Channel Estimation Techniques for Multicarrier OFDM 5G Wireless Communication Systems

Jeevan

IITH
CS20BTECH11047

Authors

- Tipparti Anil Kumar, CMR Hyderabad
- Lokam Anjaneyulu , NIT Warangal

Abstract

- We will discuss about 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.
- We will compare the proposed technique over LS and LMMSE through simulations .

System Model

- OFDM is one of the efficient modulation formats used in present 5G wireless communication systems.

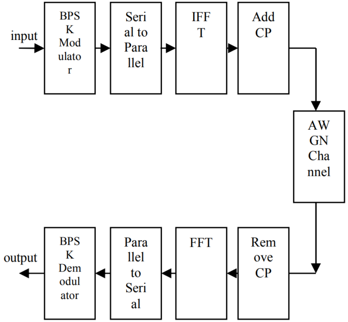


Figure: Block diagram of OFDM system with FFT

System Model

The received signal (at the receiver) may be described by

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

where

$$\mathrm{H} = [H[0], H[1], ..., H[N-1]]^T \tag{2}$$

$$\mathrm{W} = [W[0], W[1], ..., W[N-1]]^T \tag{3}$$

$$\mathrm{X} = \begin{bmatrix} X[0] & 0 & \cdots & 0 \\ 0 & X[1] & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & X(N-1) \end{bmatrix} \tag{4}$$

M-Estimator

consider a signal model

$$r_j = \sum_{k=1}^{K} s_j^k \theta_k + n_j, \quad j = 1, 2, ..., N \tag{5}$$

or in matrix notation

$$\underline{r} = \underline{S\theta} + \underline{n} \tag{6}$$

where

$$\underline{S} \triangleq \left[\underline{s_1}, \underline{s_2}, \cdots \underline{s_K}\right] \tag{7}$$

$$\underline{\theta} \triangleq \left[\theta_1, \theta_2, \cdots \theta_K\right]^T \tag{8}$$

M-Estimator

Huber proposed to minimize a sum of a less rapidly increasing function ρ of the residuals

$$\underline{\hat{\theta}} = \arg\min_{\theta \in \mathcal{R}^K} \sum_{j=1}^{N} \rho \left(r_j - \sum_{k=1}^{K} s_j^k \theta_k \right) \tag{9}$$

suppose that ρ has a derivative $\psi = \rho'$; then , the solution to (9) satisfies the equation

$$\sum_{j=1}^{N} \psi \left(r_j - \sum_{l=1}^{K} s_j^l \theta_l \right) s_j^k = 0, \quad k = 1, 2, ..., K \tag{10}$$

or in vector form

$$S^T \psi \left(\underline{r} - \underline{S\theta} \right) = \underline{0}_K \tag{11}$$

$$\text{where} \quad \psi(\underline{x}) \triangleq \left[\psi(x_1), ..., \psi(x_K) \right]^T \text{ for any } \underline{x} \in \mathcal{R}^K \tag{12}$$

M-Estimator

Assume that the penalty function $\rho(x)$ in (9) has a bounded second-order derivative i.e., $|\rho''(x)| = |\psi'(x)| \le \mu$ for some $\mu > 0$. Then (10) can be solved iteratively by the following modified residual method . Let $\underline{\theta}^t$ be the estimated at the tth step;then it is updated according to

$$\underline{z}^t \triangleq \psi\left(\underline{r} - \underline{S}\underline{\theta}^t\right) \tag{13}$$

$$\underline{\theta}^{t+1} = \underline{\theta}^t + \frac{1}{\mu}\left(\underline{S}^T\underline{S}\right)^{-1}\underline{S}^T\underline{z}^t \tag{14}$$

where μ is a step-size parameter .$\left(\mu = \dfrac{1}{N}\sum_{j=1}^{N}\psi'\left(r_j - \sum_{k=1}^{K}s_j^k\theta_k^t\right)\right)$

For initial estimate $\underline{\theta}^0$, we can take

$$\underline{\theta}^0 = \frac{1}{\mu}\left(\underline{S}^T\underline{S}\right)^{-1}\underline{S}^T\underline{r}. \tag{15}$$

The iteration is stopped if $\|\underline{\theta}^t - \underline{\theta}^{t-1}\| \le \epsilon$ for some small number ϵ .

Proposed M-Estimator

Penalty, influence and weight functions of the proposed M-estimator for channel estimation in 5G multicarrier wireless communications in Rayleigh and Rician fading channels are given by

$$\rho_{PROPOSED}(x) = \begin{cases} \dfrac{x^2}{2} & |x| \leq a \\ a^2 - a|x| & a < |x| \leq b \\ \dfrac{-ab}{2} \exp\left(1 - \dfrac{x^2}{b^2}\right) + d & |x| > b \end{cases} \tag{16}$$

$$\psi_{PROPOSED}(x) = \begin{cases} x & |x| \leq a \\ asgn(x) & a < |x| \leq b \\ \dfrac{a}{b} x \exp\left(1 - \dfrac{x^2}{b^2}\right) & |x| > b \end{cases} \tag{17}$$

Proposed M-Estimator

$$w_{PROPOSED}(x) = \begin{cases} 1 & |x| \leq a \\ \dfrac{asgn(x)}{x} & a < |x| \leq b \\ \dfrac{a}{b}\exp\left(1 - \dfrac{x^2}{b^2}\right) & |x| > b \end{cases} \tag{18}$$

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).

where $\rho(x)$ 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.

Proposed M-Estimator

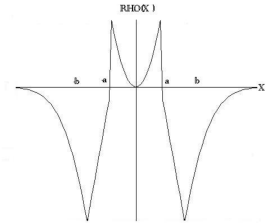


Figure: Proposed M-estimator penalty function.

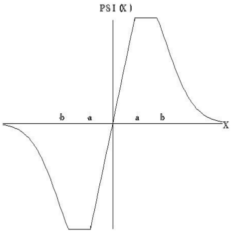


Figure: Proposed M-estimator influence function

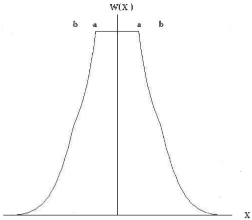


Figure: Proposed M-estimator weight function

Channel Estimation

LS channel estimation

$$\hat{H}_{LS} = \left(X^H X\right)^{-1} X^H Y = X^{-1} Y \tag{19}$$

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

MMSE channel estimation

$$\hat{H}_{MMSE} = R_{HH}\left[R_{HH} + \left(XX^H\right)^{-1} W v^2\right]^{-1} \hat{H}_{LS} \tag{20}$$

where R_{HH} is the matrix form of auto-covariance of X and v^2 is variance of noise vector.

Channel Estimation

proposed estimation

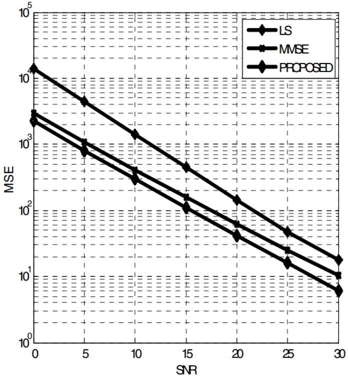
Proposed technique estimates channel parameters for 5G multicarrier wireless communications in Rayleigh and Rician fading channels using

$$H^{t+1} = H^t + \frac{1}{\mu}\left(X^H X\right)^{-1} X^H \psi\left(Y - HX\right) \tag{21}$$

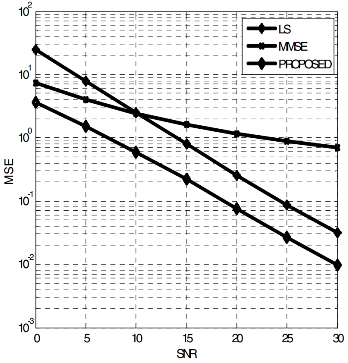
for some $\mu > 0$ where $H^0 = \frac{1}{\mu}\hat{H}_{LS}$

SIMULATION RESULTS

In this simulation , the comparison shows the performance gains achieved by the proposed technique over LS and MMSE estimation in multicarrier OFDM 5G wireless communication systems



(a)



(b)

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

CONCLUSION

- M-estimator based channel estimation technique for 5G multicarrier OFDM wireless communication systems in Rayleigh and Rician fading channels is analyzed in this paper.
- 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.