Effect of Imperfect Channel Estimation on Spectrum Sharing Between the Massive MIMO System and MIMO Radar

TURE PEKEN, MOHAMMED HIRZALLAH, TAMAL BOSE

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

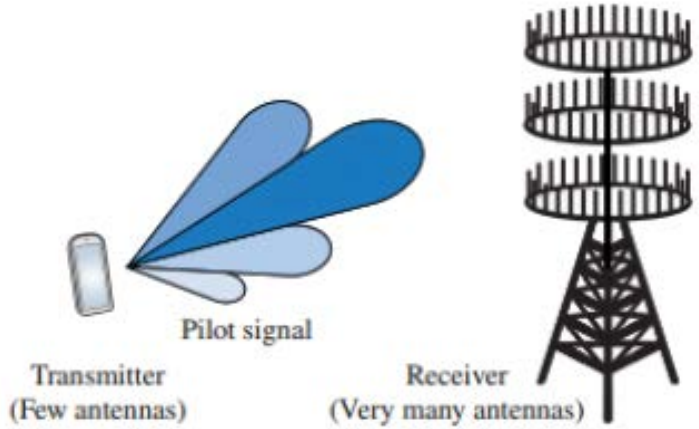
THE UNIVERSITY OF ARIZONA.

Outline

- Introduction to Massive MIMO
- Advantages of Massive MIMO
- Challenges in Massive MIMO
- Motivation
- Channel Estimation for Massive MIMO
- Massive MIMO System Model
- MIMO Radar Model
- Channel Model
- Spectrum Sharing Between Massive MIMO System and MIMO Radar
- Simulation Results
- Conclusion

Introduction to Massive MIMO

- The system having a much larger number of antennas than conventional Multiple Input Multiple Output (MIMO) system is called massive MIMO system.
- Massive MIMO has several benefits which makes this technology an active research area for next generation wireless systems such as 5G.



THE UNIVERSITY OF ARIZONA.

Advantages of Massive MIMO

- Increases the capacity.
- Improves the radiated energy efficiency.
- It can be built with inexpensive, low-power components.
- The energy consumption of the cellular base units can be decreased significantly.
- It can be built very robust compared with conventional MIMO.

Challenges in Massive MIMO

- Pilot contamination
- Hardware cost
- Fast and distributed coherent signal processing
- Hardware impairments
- Channel modelling
- Channel estimation

Motivation

- Spectrum sharing between MIMO communication systems and MIMO radar has been studied so far.
- However, spectrum sharing between massive MIMO and MIMO radar is an open problem.
- Our motivation is to show how massive MIMO system would have been affected when channel between massive MIMO and MIMO radar is not known perfectly.

THE UNIVERSITY OF ARIZONA.

Channel Estimation for Massive MIMO

- Channel estimation is an important challenge in massive MIMO
- Clever channel estimation algorithms may mitigate or eliminate the effects of the pilot contamination.
- Pilot symbols based, semi-blind and blind channel estimation methods have been proposed.
- We study the well known pilot symbols based channel estimation methods linear squares (LS) and linear minimum mean squared error (LMMSE).

THE UNIVERSITY OF ARIZONA.

Linear Squares (LS) Channel Estimation

- The goal of the LS channel estimator is to minimize the squared distance between the received signal and the original signal.
- The received pilot signal can be written as,

$$Y_p = X_p H_p + W_p$$

- The LS estimates of the channel at the pilot subcarriers can be obtained by the following equation,

$$H_p^{LS} = (X_p)^{-1} Y_p$$

THE UNIVERSITY OF ARIZONA.

Linear Minimum Mean Squared Error (LMMSE) Channel Estimation

- The LMMSE based channel estimator utilizes the second-order statistics of the channel conditions to minimize the mean-square error of the channel estimates.

- LMMSE estimate of the channel at the pilot subcarriers is given as,

$$H_p^{LMMSE} = R_{HH_p}(R_{H_pH_p} + \sigma_W^2((X_pX_p^H)^{-1})H_p^{LS}$$

Massive MIMO System Model

- The massive MIMO system consists of K transmitter and receiver pairs. The jth transmitter and receiver pair has N_j and M_j antennas where $N_j >> M_j$ respectively.

- The signal transmitted from jth transmitter to jth receiver is given by,

$$Y_j = X_j H_{jj} + W_j$$

MIMO Radar Model

- The MIMO radar has R_t transmit and R_r receive antennas.
- Let's consider a single target at direction θ. The received signal by kth receive element is,

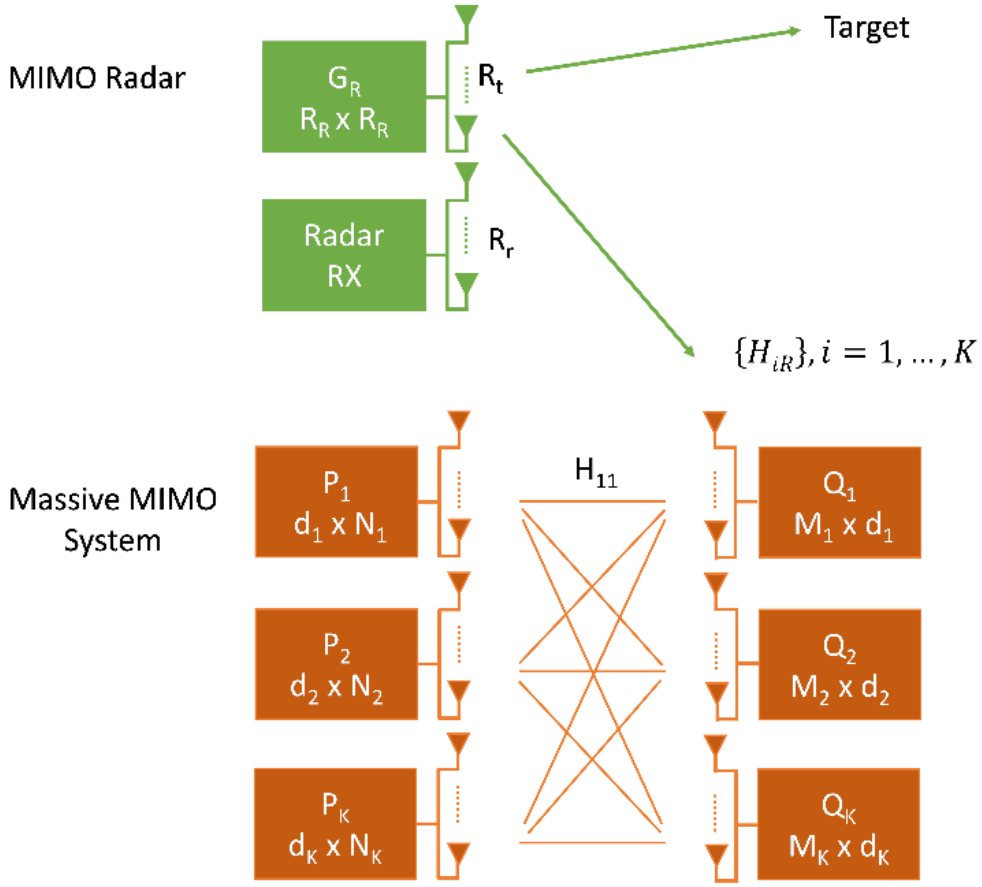
$$y_k(n) = \delta \sum_{i=1}^{R_r} G_{ik} x_i(n) + w_k(n), \qquad k = 1, \dots, R_r$$

Channel Model

- Massive MIMO can have antenna arrays that span tens to hundreds of wavelengths in space.
- It should be modelled in delay and directional domains through the geometric distribution of scatterers.
- The COST 2100 MIMO channel model is a geometry based stochastic channel model (GSCM) which characterizes this behavior.
- Hence, channel between massive MIMO system and MIMO radar is modeled with COST 2100 channel model in our paper.

Spectrum Sharing Between Massive MIMO System and MIMO Radar

- We consider a communication system with massive MIMO capability which operates in the geographical neighborhood of a collocated MIMO radar.



THE UNIVERSITY OF ARIZONA.

Spectrum Sharing Between Massive MIMO System and MIMO Radar

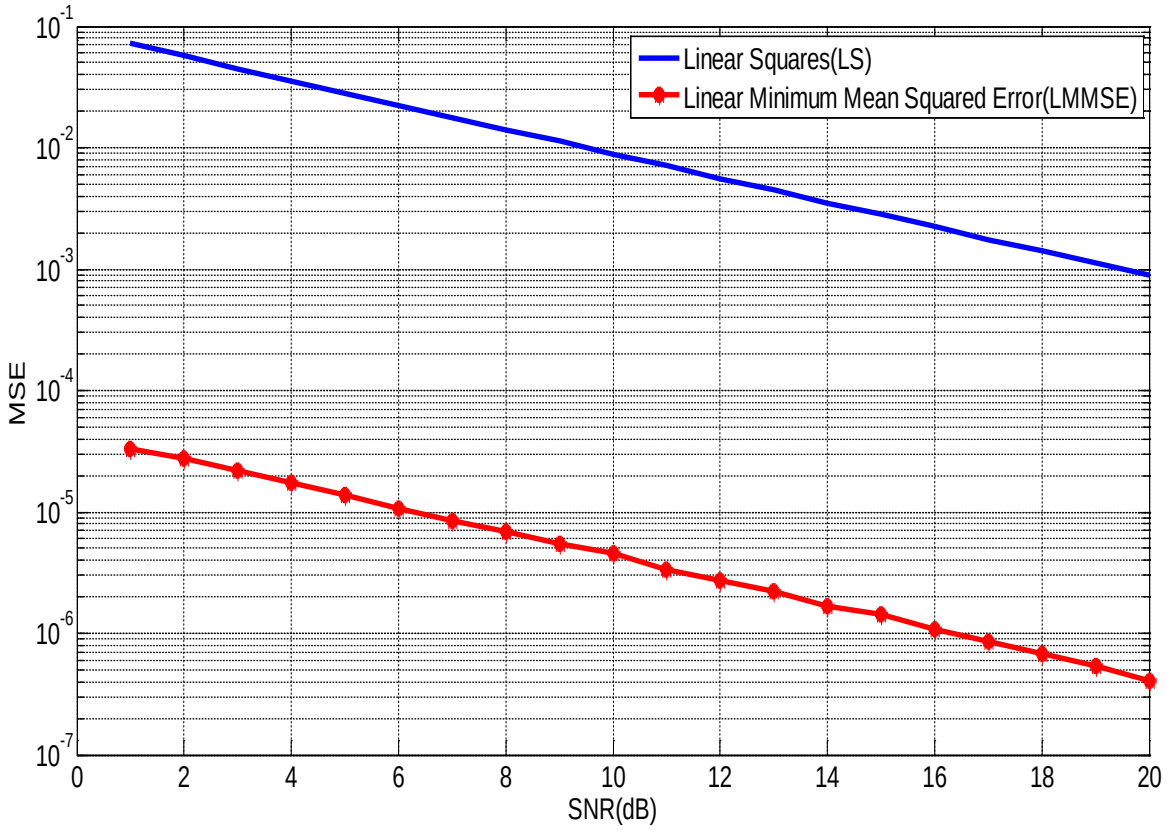
- Since high-power radio frequency (RF) pulses with low-duty cycle are sent from radar, the massive MIMO system is negatively affected by the interference.
- We consider the set *C = {1, 2, …, K}* as the set of massive MIMO transmitter-receiver pairs.
- The interference from radar to receiver *j* of massive MIMO system after post-processing is given as,

$$Q_j H_{jR} G_R \widehat{s_r}, \qquad j \in C$$

THE UNIVERSITY OF ARIZONA.

Simulation Results

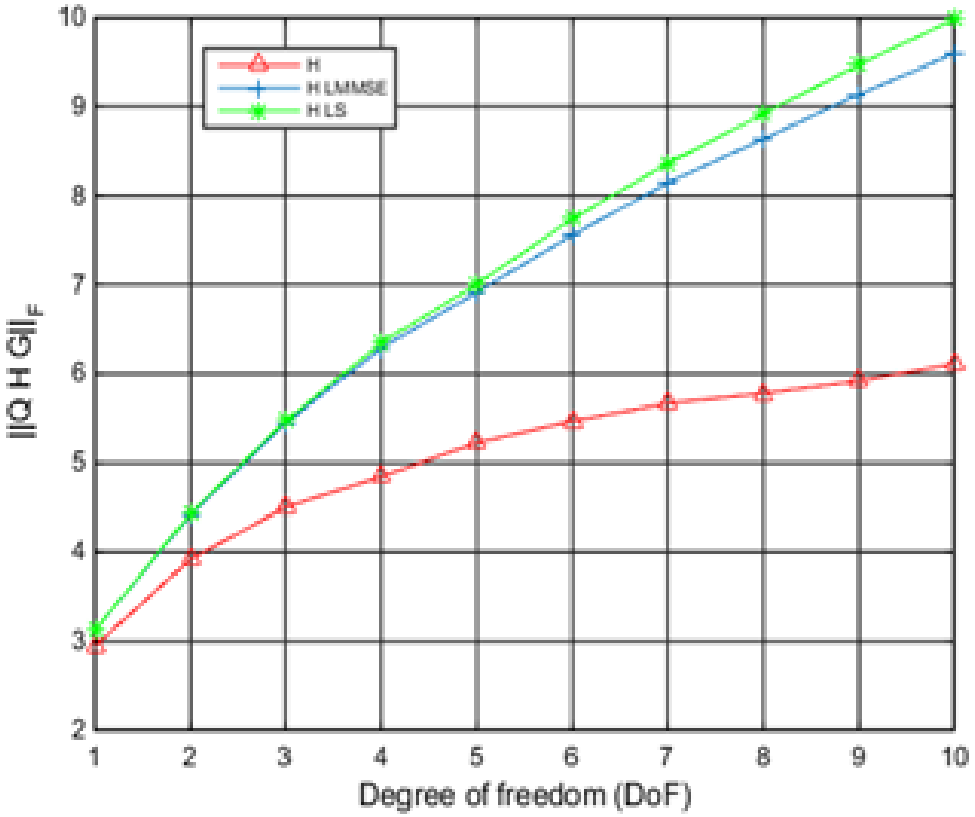
- First of all, we study the performance of LS and LMMSE channel estimation techniques on massive MIMO communication system.
- Figure on right shows Mean Squared Error (MSE) of LS and LMMSE for different SNR values when number of transmit and receive antennas 50 and 10 respectively.



THE UNIVERSITY OF ARIZONA.

Simulation Results

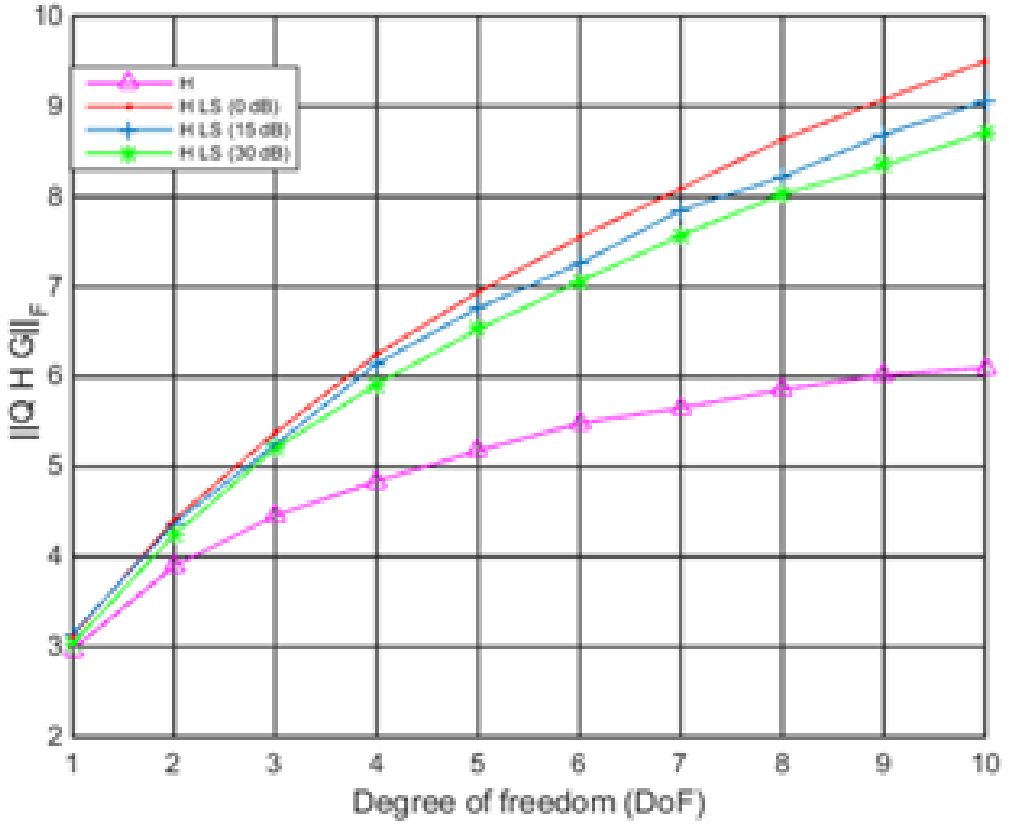
- Then, we evaluate the interference from MIMO radar to first transmitter-receiver pair of massive MIMO system.
- The interference levels from MIMO radar to massive MIMO system for perfect channel, LS and LMMSE channel estimates when SNR equals to 20 dB are obtained.



THE UNIVERSITY OF ARIZONA.

Simulation Results

- Finally, we compare the interference levels from MIMO radar to first transmitter-receiver pair of massive MIMO system for different SNR values when LS channel estimation is used.



THE UNIVERSITY OF ARIZONA.

Conclusion

- We study the effects of imperfect channel estimation on interference elimination between MIMO radar and massive MIMO system.
- We show that LMMSE has better performance than LS when it is applied to estimate the channel of a massive MIMO system.
- In terms of interference levels, we show that both LS and LMMSE channel estimation methods give worse performance than compared to the case that channel is known perfectly as expected.

THE UNIVERSITY OF ARIZONA.

Conclusion

- Moreover, we show that the interference levels are almost same when LS channel estimation and LMMSE channel estimation are used.
- We conclude that interference elimination from MIMO radar to massive MIMO system can be done with LS channel estimation since it has lower complexity than LMMSE channel estimation.
- It is also shown that interference from MIMO radar to massive MIMO system decreases with higher values of SNR.

Future Work

- In the future, we aim to study blind and semi-blind channel estimation methods to observe how the interference at the massive MIMO system would have been affected when these channel estimation methods are used.
- We will also compare their performances with LS and LMMSE channel estimation methods.

THE UNIVERSITY OF ARIZONA.

Thank you…