

1 System Model

2 Cramer-rao Bound

Consider the geometric channel for the frequency selective massive multiple-input multiple-output (MIMO) composed by a set of L scattering clusters. The n th delay tap of the u th user equipment (UE) is expressed as

$$H_u[n] = \sum_{l=1}^L \beta_l p(nT_s - \tau_l) \mathbf{a}_R(\phi_{R,l}, \theta_{R,l}) \mathbf{a}_T(\phi_{T,l}, \theta_{T,l}), \quad (1)$$

where $p(t)$ defines the signal pulse shaping at t , T_s is the symbol period, $\alpha_l \in \mathcal{C}$ is the complex gain of the l th cluster, $\tau_l \in \mathcal{R}$ is the delay associated to the l th cluster, and $\mathbf{a}_R(\phi_{R,l}, \theta_{R,l}) \in \mathcal{C}^{N \times 1}$ and $\mathbf{a}_T(\phi_{T,l}, \theta_{T,l}) \in \mathcal{C}^{M \times 1}$ is the antenna array response vector of the receiver and transmitter sides.