Supplement Material

Abstract

This document is the supplement material for article “Reconfigurable Massive MIMO: Harnessing the Power of the Electromagnetic Domain for Enhanced Information Transfer”. Two parts of content are exhibited in a more detailed form. First, the channel modeling of reconfigurable massive MIMO (R-mMIMO) system. Second, the pseudocode of the proposed EMR domain precoding algorithm.

I. Channel Model for R-mMIMO systems

A general channel model in the time-delay domain for a point-to-point R-mMIMO system is provided in Table I. Furthermore, by assuming each UE is equipped with a single omnidirectional antenna, the degraded channel model between each UE and the BS in the time-frequency domain is obtained in Table I.

TABLE I
CHANNEL MODEL FOR R-MMIMO SYSTEM

General channel model	$H_{n_r,n_t}(t,\tau;\nu_{n_r},\mu_{n_t}) = \sum_{l=1}^{L} \alpha_l \boldsymbol{f}_{\mathrm{rx},n_r}^{\mathrm{T}}(\theta_{r,l},\phi_{r,l};\nu_{n_r}) \boldsymbol{T}_l \boldsymbol{f}_{\mathrm{tx},n_t}(\theta_{t,l},\phi_{t,l};\mu_{n_t}) \exp\left(\frac{\mathrm{j}2\pi\left(\boldsymbol{r}_{\mathrm{rx},l}^{\mathrm{T}}\boldsymbol{d}_{\mathrm{rx},n_r}\right)}{\lambda}\right)$ $\times \exp\left(\frac{\mathrm{j}2\pi\left(\boldsymbol{r}_{\mathrm{tx},l}^{\mathrm{T}}\boldsymbol{d}_{\mathrm{tx},n_t}\right)}{\lambda}\right) \exp\left(\frac{\mathrm{j}2\pi\left(\boldsymbol{r}_{\mathrm{rx},l}^{\mathrm{T}}\boldsymbol{v}\right)}{\lambda}t\right) \delta\left(\tau-\tau_l\right)$
Degraded channel model	$h_{n_t}(t,k;\mu_{n_t}) = \sum_{l=1}^{L} \alpha_l \boldsymbol{f}_{\mathrm{rx}}^{\mathrm{T}}(\theta_{r,l},\phi_{r,l}) \boldsymbol{T}_l \boldsymbol{f}_{\mathrm{tx},n_t}(\theta_{t,l},\phi_{t,l};\mu_{n_t}) \exp\left(\frac{\mathrm{j}2\pi\left(\boldsymbol{r}_{\mathrm{rx},l}^{\mathrm{T}}\boldsymbol{d}_{\mathrm{rx}}\right)}{\lambda}\right)$ $\times \exp\left(\frac{\mathrm{j}2\pi\left(\boldsymbol{r}_{\mathrm{tx},l}^{\mathrm{T}}\boldsymbol{d}_{\mathrm{tx},n_t}\right)}{\lambda}\right) \exp\left(\frac{\mathrm{j}2\pi\left(\boldsymbol{r}_{\mathrm{rx},l}^{\mathrm{T}}\boldsymbol{v}\right)}{\lambda}t\right) \exp\left(\mathrm{j}2\pi\tau_l\left(-\frac{B_w}{2}+\frac{B_w k}{K}\right)\right)$

Parameter	Definition	Parameter	Definition
α_l	Channel gain for l-th path	λ	Wavelength
L	Total number of paths	τ_l	Channel delay for l-th path
$\boldsymbol{T}_l$	Polarization coupling matrix for l-th path	$\boldsymbol{v}$	UE velocity vector
$(\theta_{r.l}, \phi_{r,l})$	Elevation/azimuth angle for l-th arrival path	$(\theta_{t,l}, \phi_{t,l})$	Elevation/azimuth angle for l-th departure path
ν_{n_r}	Pattern type for n_r-th receive antenna	μ_{n_t}	Pattern type for n_t-th transmit antenna
$\boldsymbol{f}_{\mathrm{rx},n_r}(\theta_{r,l},\phi_{r,l};\nu_{n_r})$	Radiation pattern of n_r-th receive antenna	$\boldsymbol{f}_{\mathrm{tx},n_t}(\theta_{t,l},\phi_{t,l};\mu_{n_t})$	Radiation pattern of n_t-th transmit antenna
$\boldsymbol{r}_{\mathrm{rx},l}$	Spherical unit vector for l-th arrival path	$\boldsymbol{r}_{\mathrm{tx},l}$	Spherical unit vector for l-th departure path
$\boldsymbol{d}_{\mathrm{rx},n_r}$	Location vector of n_r-th receive antenna	$\boldsymbol{d}_{\mathrm{tx},n_t}$	Location vector of n_t-th transmit antenna
B_w	System bandwidth	K	Total number of subcarriers

II. EMR domain precoding algorithm

The pseudocode of the proposed EMR domain precoding algorithm.

Algorithm 1: EMR domain precoding algorithm

Input: CSI $\boldsymbol{h}_u\left[k;\boldsymbol{\mu}\right], \forall u, k, \boldsymbol{\mu}$;

Output: EMR domain precoding vector $\boldsymbol{\mu}^{\star}$;

Initialization: $\boldsymbol{\mu}^0 = \mathbf{0}_{N_t}$;

for $i = 1 : T_{iter}$ **do**

  for $n_t = 1 : N_t$ **do**

    for $p = 0 : P-1$ **do**

      $\widetilde{\boldsymbol{\mu}} = \left\{\mu_l = \mu_l^i, l < n_t, \mu_{n_t} = \bar{\mu}_p, \quad \mu_m = \mu_m^{i-1}, m > n_t\right\}$;

      Apply HP to CSI $\boldsymbol{h}_u\left[k;\widetilde{\boldsymbol{\mu}}\right], \forall u, k$, and calculate SE value $R_p = R\left(\boldsymbol{h}_u\left[k;\widetilde{\boldsymbol{\mu}}\right], \forall u, k\right)$;

    end

    $p^{\star} = \arg \max\limits_{0 \le p \le P-1} R_p$;

    $\mu_{n_t}^i = \bar{\mu}_{p^{\star}}$;

  end

end

return $\boldsymbol{\mu}^{\star} = \boldsymbol{\mu}^{T_{iter}}$.

REFERENCES

[1] S. Jaeckel, *et al.*, “QuaDRiGa-quasi deterministic radio channel generator, user manual and documentation,” Heinrich Hertz Institute, Tech. Rep. v2.6.1, 2021.