

$$\begin{array}{l} x \\ M \\ x \\ \tilde{x}^{dl} = [\tilde{x}_1^{dl}; ...; \tilde{x}_{N_R}^{dl}] = As \end{array}$$

$$(1) \begin{array}{l} A \\ s \\ A = \\ [A_1,...,A_{N_U}] \\ s = \\ [s_1;...;s_{N_U}] \\ x^{dl} = \tilde{x}^{dl} + Q, \end{array}$$

$$(2) \begin{array}{l} Q = \\ [q_1,\ldots,q_{N_u}]^T \\ q_i\mathcal{N}(0,\sigma_{q^2}) \\ \tilde{x}^{dl} = WP^{\frac{1}{2}}s, \end{array}$$

$$\begin{array}{l} A \\ P \\ W \\ N_r \\ y_j = H_jx + z_j \end{array}$$

$$(3) \begin{array}{l} y_j \\ j \\ H_j \\ 1 \times \\ N_r \\ z_j \\ z_j \mathcal{N}(0,1) \\ i \end{array}$$

$$P_i(W,\sigma)=\frac{1}{T}E[||x_i||^2]=trace(w_iP^{\frac{1}{2}}P^{H\frac{1}{2}}w_i^H+\sigma_{q_i}^2(I))$$

$$(4) \begin{array}{l} W = \\ [w_1,...,w_{N_U}] \\ \sigma_{q_i}^2 \\ i \end{array}$$

$$C_i(W,\sigma_q)=\log det(w_iP^{\frac{1}{2}}P^{H\frac{1}{2}}w_i^H+\sigma_{q_i}^2(I))-N_r\log(\sigma_{q_i}^2)$$

$$(5) \begin{array}{l} j \end{array}$$

$$R(W,\sigma_q)_j=I_H(s_j,y_j)=\log det(I+H_j(W_jW_j^H+\sigma_x\times I)H_j^H)-\log det(I+H_j(\sum_{k\in N_u,k\neq j}W_kW_k^H+\sigma_x\times I)H_j^H)$$

$$(6) \begin{array}{l} I_H \\ \max_{W,\sigma} \sum R(W,\sigma_q) subject to \bar{P}_i(W,\sigma_q) \leq P_{max} \forall i C_i(W,\sigma_q) \leq C^{th} \forall i \end{array}$$

$$(7) \begin{array}{l} \bar{P}_i(W,\sigma_q) \\ i \\ C_i(W,\sigma_q) \end{array}$$

$$\begin{array}{l} b_q \\ W \\ S \\ v \\ R_v \\ D_v \\ r_{(s,n)} \\ y \\ d_{(s,k)} \\ k \\ s \end{array}$$

$$y_{\mathcal{D}_s} = \sum_{v=1}^S H_{\mathcal{R}_v,\mathcal{D}_s}^H W_{R_v,D_v} P_{D_v}^{\frac{1}{2}} x_{\mathcal{R}_v} + z_{\mathcal{D}_s},$$

$$(8) \begin{array}{l} x_{\mathcal{D}_v} = \\ [x_{d_{(v,1)}},...,x_{d_{(v,D_v)}}]^T \in \\ C^{\mathcal{D} \times T} \\ t \\ T \\ W_{R_v,D_v} = \\ [w_{R_v,d_{(v,1)}},...,w_{R_v,d_{(v,D_v)}}]^T \in \\ C^{R_v \times D_v} \\ q \\ z_{\mathcal{D}_s} \mathcal{N}(0,N_0I_{D_s}) \\ N_0 \\ H_{R_v,D_s} \\ R_v \\ D_s \\ H_{\mathcal{R}_v,\mathcal{D}_s} = \\ [\end{array}$$