

AO-MM:

The objective function of OP4 is given as

$$\frac{\varphi}{\beta_e^2 + \rho_e^2 \|\Theta \mathbf{H} \mathbf{f}\|^2} = R \left[\frac{\|(\rho_b \hat{\mathbf{g}}_b \Theta \mathbf{H} + \beta_b \mathbf{h}_b) \mathbf{f}\|^2}{\|\sqrt{1 - \rho_b^2 \tilde{\mathbf{g}}_b \Theta \mathbf{H} \mathbf{f}}\|^2 + \frac{\sigma_b^2}{P_A}} + \mathcal{B}_1 \right]. \quad (1)$$

where, $R = \frac{\alpha}{\beta_e^2 + \rho_e^2 \|\Theta \mathbf{H} \mathbf{f}\|^2}$. Now, let us perform optimization over Θ by fixing \mathbf{f} . With (1), OP4 can be transformed as

$$\begin{aligned} \text{P1: } \max_{\Theta} & \frac{\|(\rho_b \hat{\mathbf{g}}_b \Theta \mathbf{H} + \beta_b \mathbf{h}_b) \mathbf{f}\|^2}{\|\sqrt{1 - \rho_b^2 \tilde{\mathbf{g}}_b \Theta \mathbf{H} \mathbf{f}}\|^2 + \frac{\sigma_b^2}{P_A}}, \\ \text{s.t. } & 12. \end{aligned} \quad (2)$$

Using (37) and (38), we have

$$\text{P2: } \max_{\mathbf{v}, |v_m|=1} \frac{\mathbf{v}^H \mathbf{y}_1 \mathbf{v} + |\alpha_A|^2 + 2\rho_b \Re\{\mathbf{e}_1^H \mathbf{v}^H \alpha_A^*\}}{\mathbf{v}^H \mathbf{y}_2 \mathbf{v} + \frac{\sigma_b^2}{P_A}}, \quad (3)$$

where $\mathbf{y}_1 = \rho_b^2 \mathbf{e}_1^H \mathbf{e}_1$, $\mathbf{y}_2 = (1 - \rho_b^2) \mathbf{e}_2^H \mathbf{e}_2$, and $\alpha_A = \beta_b \mathbf{h}_b \mathbf{f}$. Rewrite (3), we have

$$\text{P3: } \min_{\mathbf{v}, |v_m|=1} \frac{\mathbf{v}^H \mathbf{y}_2 \mathbf{v} + \frac{\sigma_b^2}{P_A}}{\mathbf{v}^H \mathbf{y}_1 \mathbf{v} + |\alpha_A|^2 + 2\rho_b \Re\{\mathbf{e}_1^H \mathbf{v}^H \alpha_A^*\}}. \quad (4)$$

This problem belongs to fractional programming. Following [31], we consider the corresponding parametric program:

$$\text{P4: } \min_{\mathbf{v}, |v_m|=1} \mathbf{v}^H \boldsymbol{\theta} \mathbf{v} + \frac{\sigma_b^2}{P_A} - \mu |\alpha_A|^2 - 2\mu \rho_b \Re\{\mathbf{e}_1^H \mathbf{v}^H \alpha_A^*\}, \quad (5)$$

where $\mu > 0$ is an introduced parameter and $\boldsymbol{\theta} = \mathbf{y}_2 - \mu \rho_b^2 \mathbf{y}_1$. Here, we adopt MM algorithm to solve P4 due to its closed-form solution at each iteration [8],[10],[11]. At iteration t , for any feasible point $\mathbf{v}(t)$,

$$\begin{aligned} & \mathbf{v}^H \boldsymbol{\theta} \mathbf{v} + \frac{\sigma_b^2}{P_A} - \mu |\alpha_A|^2 - 2\Re\{\mu \rho_b \mathbf{e}_1 \mathbf{v}^H \alpha_A^*\} \\ & \leq \lambda_{\max}(\boldsymbol{\theta}) \|\mathbf{v}\|^2 - \Re\{\mathbf{v}^H \boldsymbol{\varphi}\} + q_1, \end{aligned} \quad (6)$$

where $\boldsymbol{\varphi} = (\lambda_{\max}(\boldsymbol{\theta}) \mathbf{I} - \boldsymbol{\theta}) \mathbf{v}(t) + \mu \rho_b \mathbf{e}_1 \alpha_A^*$, $q_1 = (\lambda_{\max}(\boldsymbol{\theta}) \mathbf{I} - \boldsymbol{\theta}) \mathbf{v} + \frac{\sigma_b^2}{P_A} - \mu |\alpha_A|^2$. The simplified optimization problem becomes

$$\begin{aligned} \text{P5: } \max_{\mathbf{v}} & \Re\{\mathbf{v}^H \boldsymbol{\varphi}\}, \\ \text{s.t. } & |v_m| = 1, \forall \quad m = 1, \dots, M. \end{aligned} \quad (7)$$

The optimal solution of P5 at iteration t is

$$\mathbf{v}(t+1) = \left[e^{j \arg(\varphi_1)}, \dots, e^{j \arg(\varphi_M)} \right]. \quad (8)$$

