# TRANSMISSION DESIGN FOR A JOINT MIMO RADAR AND MU-MIMO DOWNLINK COMMUNICATION SYSTEM

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## RESEARCH HIGHLIGHTS

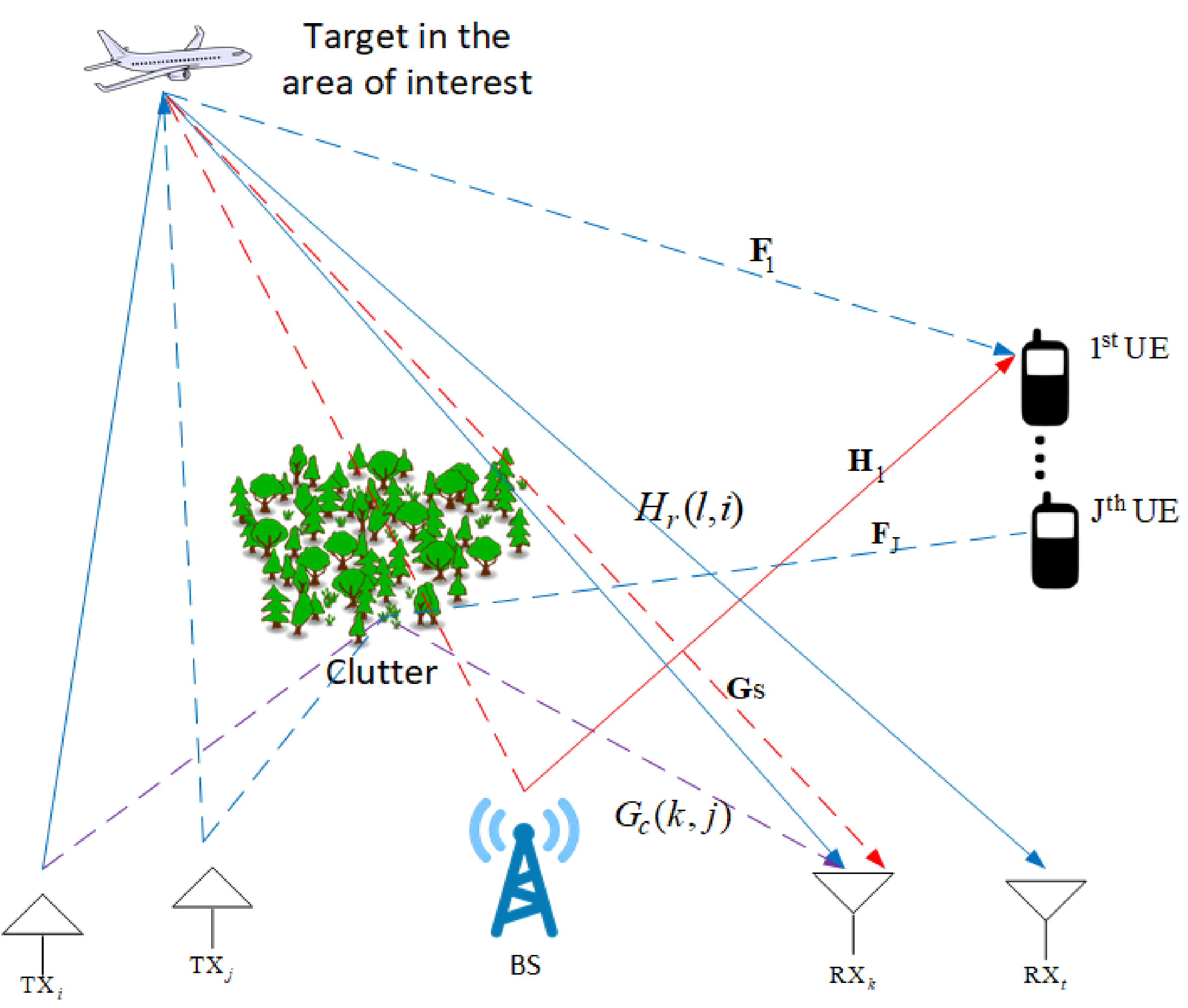
❖Propose a spectrum sharing scheme for the coexistence of a statistical MIMO radar and multi-user MIMO communication system

❖Utilize the same criteria, i.e., the mutual information (MI), to jointly design the transmit covariance matrices for both radar and communication signals

❖Develop an alternating optimization based algorithm to solve the covariance matrices with the constraint of power allocation within the joint system

## SYSTEM & SIGNAL MODEL

**A statistical MIMO Radar with widely separated antennas coexists with a base station (BS) that serves $J$ downlink UEs with the presence of a stationary target or a moving target with known Doppler shift as well as environmental clutter**



$\mathbf{H}_\mathrm{r}$: MIMO radar TX → Target → MIMO radar RX
$\mathbf{G}_\mathrm{c}$ : MIMO radar TX → Clutter → MIMO radar RX
$\mathbf{G}_\mathrm{s}$ : BS TX → Target → MIMO radar RX
$\mathbf{H}_\mathrm{j}, (j = 1, \dots, J)$ : BS TX → the $j^{\text{th}}$ UE
$\mathbf{F}_\mathrm{j}, (j = 1, \dots, J)$ : BS TX → Target/Clutter → the $j^{\text{th}}$ UE

❖Received signal at MIMO Radar RX

$$\mathbf{y}_\mathrm{r} = \mathbf{H}_\mathrm{r}\mathbf{s} + \mathbf{G}_\mathrm{c}\mathbf{s} + \sum_{k=1}^{K} \mathbf{G}_\mathrm{s}\mathbf{x}_k + \mathbf{z}_\mathrm{r}$$

❖Received signal at the $j^{\text{th}}$ UE

$$\mathbf{u}_j = \mathbf{H}_j\mathbf{x}_j + \mathbf{H}_j \sum_{k \neq j} \mathbf{x}_k + \mathbf{F}_j\mathbf{s} + \mathbf{z}_j, \quad j = 1, \cdots, K,$$

❖Interference-plus-noise covariance matrix for UE j

$$\mathbf{R}_{\mathrm{in},j} \triangleq \mathbf{H}_j(\textstyle\sum_{i=j+1}^{K} \mathbf{R}_i)\mathbf{H}_j^\dagger + \mathbf{F}_j\mathbf{R}_\mathrm{s}\mathbf{F}_j^\dagger + \mathcal{N}_\mathrm{c}\mathbf{I}_{N_j}$$

## PROPOSED JOINT TRANSMISSION DESIGN ALGORITHM

❖The MI between the target response matrix $\mathbf{H}_\mathrm{r}$ and the target reflected signal $\boldsymbol{y}_\mathrm{r}$

$$I(\mathbf{y}_\mathrm{r}; \mathbf{H}_\mathrm{r}) = \log \frac{\det(\mathbf{H}_\mathrm{r}\mathbf{R}_\mathrm{s}\mathbf{H}_\mathrm{r}^\dagger + \mathbf{G}_\mathrm{s}\mathbf{R}_\mathrm{c}\mathbf{G}_\mathrm{s}^\dagger + \mathbf{R}_{\mathrm{in,r}})}{\det(\mathbf{R}_{\mathrm{in,r}})}$$

❖The achievable rate for the $j^{\text{th}}$ UE

$$R(j) = \log \frac{\det(\mathcal{N}_\mathrm{c}\mathbf{I} + \mathbf{H}_j(\sum_{i=j}^{K} \mathbf{R}_i)\mathbf{H}_j^\dagger + \mathbf{F}_j\mathbf{R}_\mathrm{s}\mathbf{F}_j^\dagger)}{\det(\mathcal{N}_\mathrm{c}\mathbf{I} + \mathbf{H}_j(\sum_{i=j+1}^{K} \mathbf{R}_i)\mathbf{H}_j^\dagger + \mathbf{F}_j\mathbf{R}_\mathrm{s}\mathbf{F}_j^\dagger)}$$
$$= \log\det(\mathbf{I} + \mathbf{R}_{\mathrm{in},j}^{-1}\mathbf{H}_j\mathbf{R}_j\mathbf{H}_j^\dagger), \quad \forall j = 1, \cdots, K,$$

❖The Overall Joint Radar-Comm Optimization Problem

$$\begin{aligned}(\mathcal{P}1) \quad \max_{\{\mathbf{R}_j \succeq \mathbf{0}\}_{j=1}^{K}, \mathbf{R}_\mathrm{s} \succeq \mathbf{0}} \quad & I_{\mathrm{total}} = \sum_{j=1}^{K} \omega_j R(j) + \omega_{K+1} I(\mathbf{y}_\mathrm{r}; \mathbf{H}_\mathrm{r}) \\ \text{subject to} \quad & P_{\mathrm{c,min}} \leq \sum_{i=1}^{K} \mathrm{tr}\{\mathbf{R}_i\} \leq P_{\mathrm{c,max}}, \\ & P_{\mathrm{r,min}} \leq \mathrm{tr}\{\mathbf{R}_\mathrm{s}\} \leq P_{\mathrm{r,max}},\end{aligned}$$

❖The $j^{\text{th}}$ Sub-Problem to solve $\boldsymbol{R}_j$ w.r.t. $\boldsymbol{R}_s$

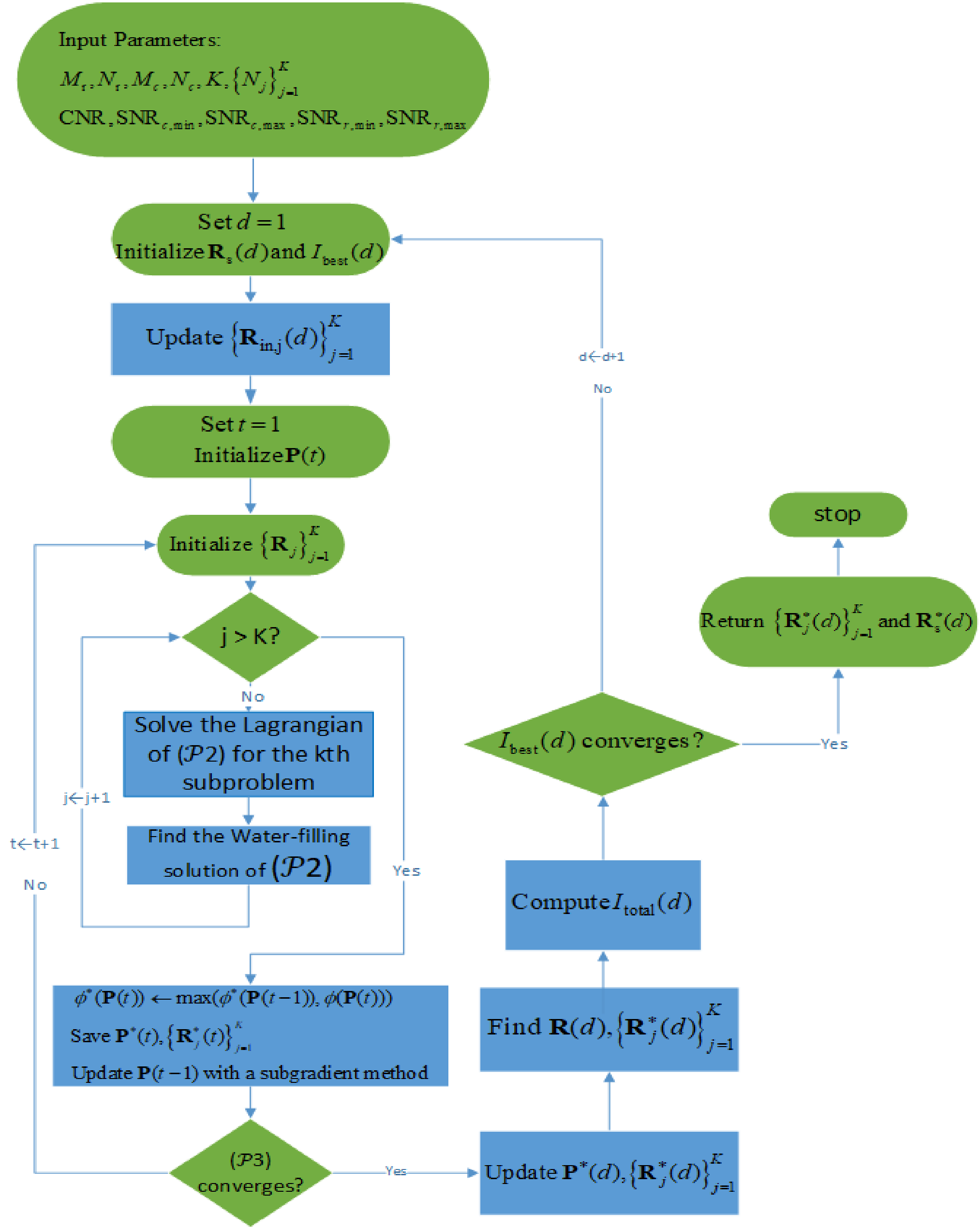
$$\begin{aligned}(\mathcal{P}2) \quad \phi_j(P_j) = \max_{\mathbf{R}_j \succeq \mathbf{0}} \quad & w_j \log\left[\det(\mathbf{I} + \mathbf{R}_{\mathrm{in},j}^{-1}\mathbf{H}_\mathrm{j}\mathbf{R}_j\mathbf{H}_j^\dagger)\right] \\ \text{subject to} \quad & \mathrm{tr}\{\mathbf{R}_j\} \leq P_j,\end{aligned}$$

❖The master problem of $(\mathcal{P}2)$

$$\begin{aligned}(\mathcal{P}3) \quad \max_{\{\mathbf{R}_\mathrm{s} \succeq \mathbf{0}\}} \quad & \log\det\left(\mathbf{H}_\mathrm{r}\mathbf{R}_\mathrm{s}\mathbf{H}_\mathrm{r}^\dagger + \mathbf{G}_\mathrm{s}\mathbf{R}_\mathrm{c}\mathbf{G}_\mathrm{s}^\dagger\right) \\ \text{subject to} \quad & P_{\mathrm{r,min}} \leq \mathrm{tr}\{\mathbf{R}_\mathrm{s}\} \leq P_{\mathrm{r,max}}.\end{aligned}$$

❖Solve $\boldsymbol{R}_s$ through $(\mathcal{P}4)$ w.r.t $\{\boldsymbol{R}_j\}_{j=1}^{K}$

$$\begin{aligned}(\mathcal{P}4) \quad \max_{\{\mathbf{R}_\mathrm{s} \succeq \mathbf{0}\}} \quad & \log\det\left(\mathbf{H}_\mathrm{r}\mathbf{R}_\mathrm{s}\mathbf{H}_\mathrm{r}^\dagger + \mathbf{G}_\mathrm{s}\mathbf{R}_\mathrm{c}\mathbf{G}_\mathrm{s}^\dagger\right) \\ \text{subject to} \quad & P_{\mathrm{r,min}} \leq \mathrm{tr}\{\mathbf{R}_\mathrm{s}\} \leq P_{\mathrm{r,max}}.\end{aligned}$$

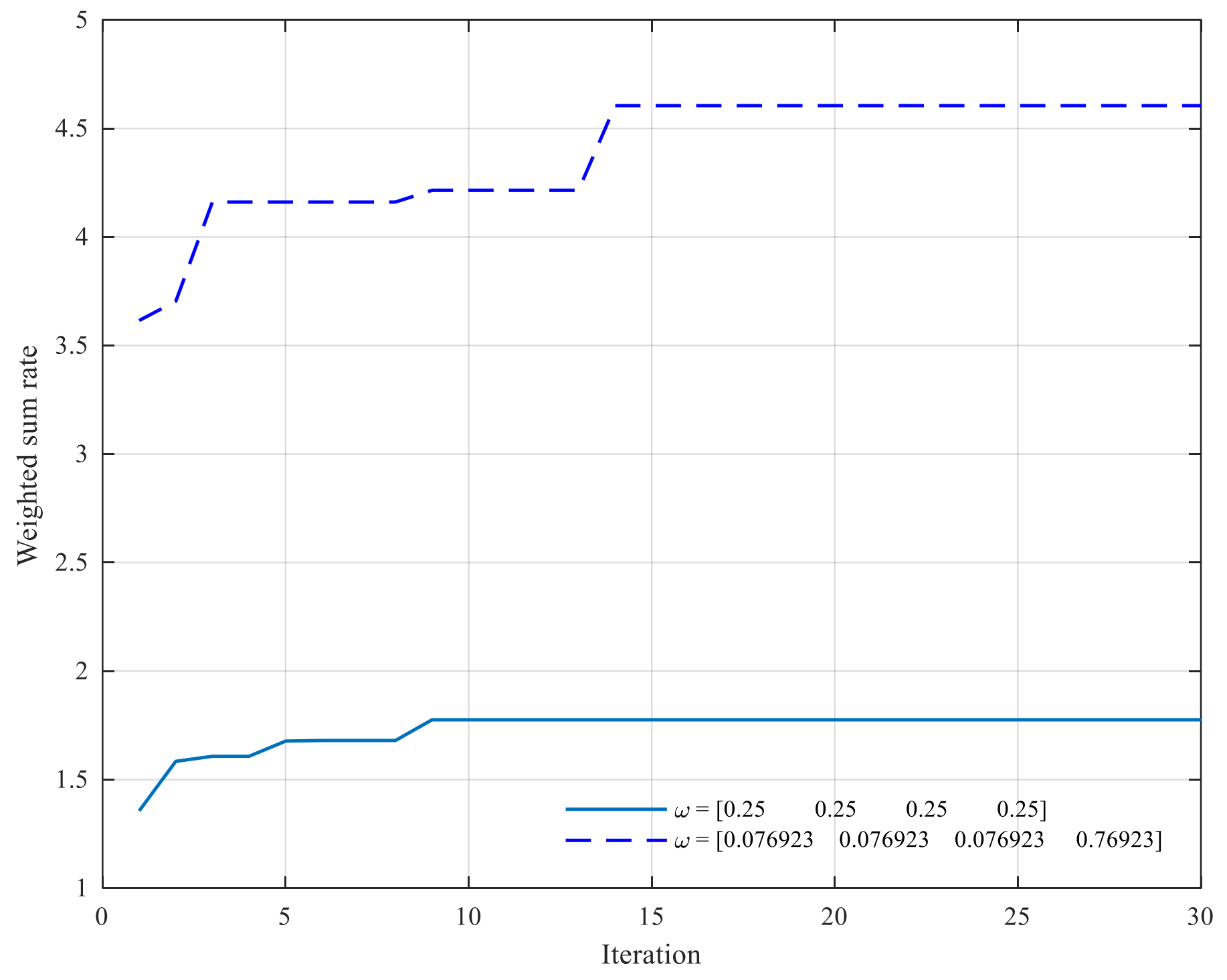


## SIMULATION RESULTS

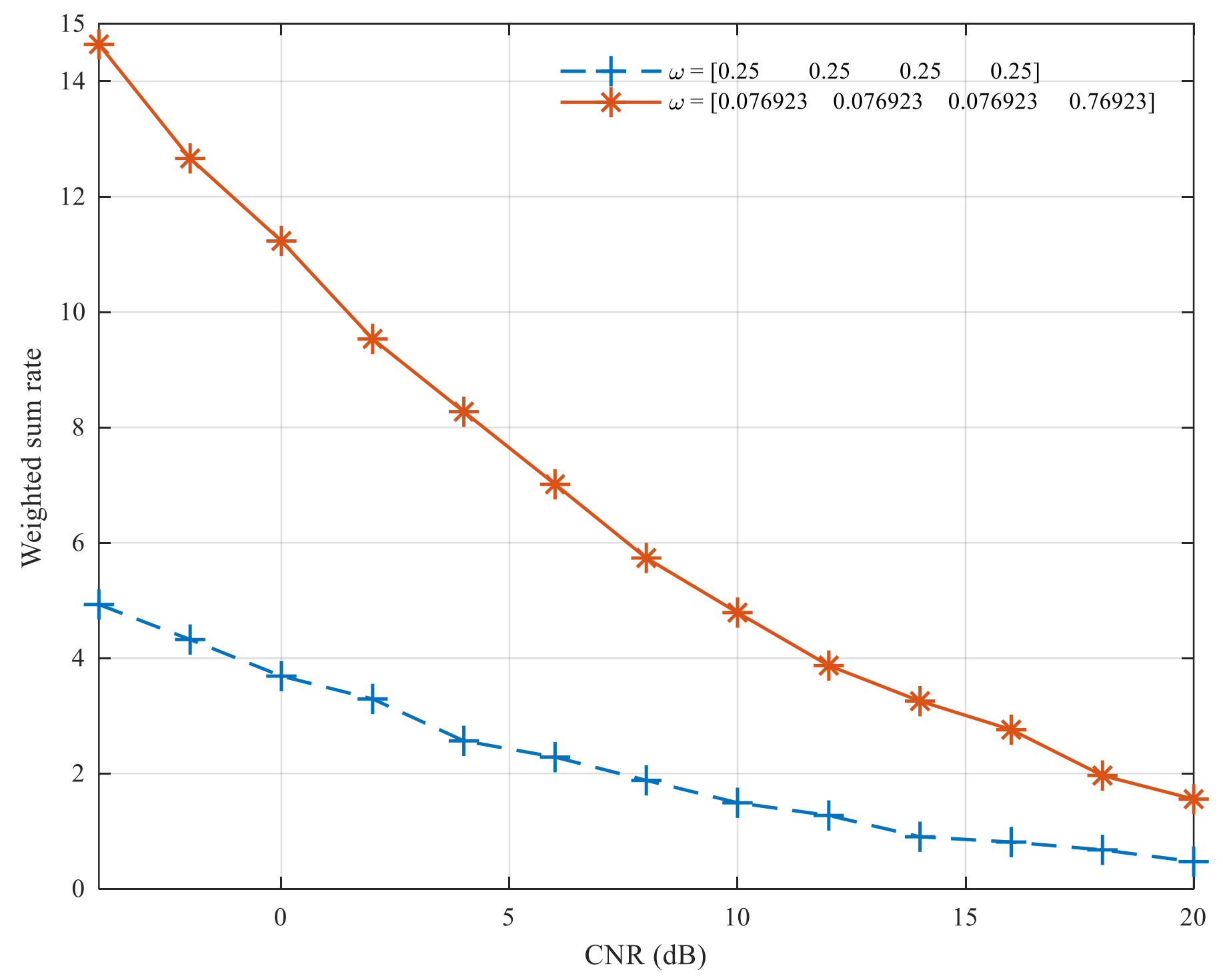
❖Simulation Parameters

- Number of MIMO Radar TX and RX $M_r = 8$ and $N_r = 8$
- Number of Base Station Antennas $M_r = 4$
- Number of UEs K= 4
- Number of Antennas the $j^{\text{th}}$ UE has $N_j = 2, \forall j = 1, \dots, K$
- $\mathrm{CNR} = 15\ \mathrm{dB}, \mathrm{SNR}_{\mathrm{c,min}} = 10\ \mathrm{dB}, \mathrm{SNR}_{\mathrm{c,max}} = 20\ \mathrm{dB}$
- $\mathrm{SNR}_{\mathrm{r,min}} = 15\ \mathrm{dB}, \mathrm{SNR}_{\mathrm{r,max}} = 30\ \mathrm{dB}$
- Weight vectors: $\omega_1 = \left[\frac{1}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{4}\right], \omega_2 = \left[\frac{1}{14}, \frac{1}{14}, \frac{1}{14}, \frac{11}{14}\right]$

❖Simulation 1: Convergence of the Alternating Algorithm for $(\mathcal{P}1)$



❖Simulation 2:
❖CNR (Clutter-to-Noise Ratio ) vs Sum Rate



## CONCLUSIONS AND FUTURE WORK

- ➢ Information theory based waveform design criteria is applied to a coexisted radar and communication system
- ➢ The (local) convergence of the proposed alternation optimization algorithm is guaranteed as shown by simulation 1
- ➢ Simulation 2 shows that the performance of the system deteriorates as the SNR increases
- ➢ The significance of each user in the joint system can be tweaked by assigning it a corresponding weight as shown in simulation 2
- ➢ Application-based analysis, such as the detection performance of the MIMO radar will be explored in the future work

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