



Joint Resource Allocation for Movable-Antenna-Assisted Secure Integrated Data and Energy Transfer

Xiang Pengrong¹, Li Zhiguang², Zhao Yizhe²

(1. Yangtze Delta Region Institute, University of Electronic Science and Technology of China, Huzhou 313001, China;

2. School of Information and Communication Engineering, University of Electronic Science and Technology of China, Chengdu 611731, China)

DOI: 10.12142/ZTECOM.202603005

<https://kns.cnki.net/kcms/detail/34.1294.TN.20260828.1535.002.html>,
published online August 28, 2026

Manuscript received: 2026-07-03

Abstract: This paper investigates joint resource allocation for movable-antenna (MA)-assisted secure integrated data and energy transfer (IDET) systems with passive eavesdroppers. A field-response-based MA channel model is adopted to capture the impact of antenna positions on legitimate, energy-transfer, and eavesdropping links, while energy signals are reused as artificial noise for simultaneous wireless power transfer and secrecy enhancement. A max-min secrecy-rate problem is formulated by jointly optimizing information beamformers, energy beamformers, and MA positions under energy-harvesting, power, movable-region, and antenna-spacing constraints. To address the resulting nonconvexity, an iterative algorithm based on semidefinite relaxation, successive convex approximation, and alternating optimization is developed. Simulation results demonstrate that the proposed scheme improves the minimum secrecy rate compared with fixed-position antenna benchmarks while satisfying the energy requirements of energy receivers.

Keywords: integrated data and energy transfer; movable antenna; physical-layer security; resource allocation

Citation (Format 1): Xiang P R, Li Z G, Zhao Y Z. Joint resource allocation for movable-antenna-assisted secure integrated data and energy transfer [J]. *ZTE Communications*, 2026, 24(3): 31 – 39. DOI: 10.12142/ZTECOM.202603005

Citation (Format 2): P. R. Xiang, Z. G. Li, and Y. Z. Zhao, “Joint resource allocation for movable-antenna-assisted secure integrated data and energy transfer,” *ZTE Communications*, vol. 24, no. 3, pp. 31 – 39, Sept. 2026. doi: 10.12142/ZTECOM.202603005.

1 Introduction

Beyond-fifth-generation/sixth-generation (B5G/6G) networks are expected to support massive low-power Internet of Things (IoT) devices and ubiquitous sensing nodes, for which both reliable data transmission and continuous energy supply are essential. Integrated data and energy transfer (IDET) enables wireless information and power delivery over the same radio-frequency (RF) link, thereby extending device lifetime and reducing maintenance costs^[1–3]. However, conventional fixed-position antenna systems have limited capability to adapt the array geometry to user distribution and multipath propagation.

Security is another key challenge in IDET systems because high-power energy beams may also strengthen eavesdropping links. Physical-layer security (PLS) enhances confidentiality by exploiting channel disparities, beamforming, and artificial noise (AN)^[4–5]. In secure IDET, energy signals can be reused as AN: they are harvested by energy receivers (ERs) while in-

terfering with eavesdroppers, which enables energy transfer and secrecy protection to be jointly coordinated^[6].

Movable antenna (MA) technology provides an additional spatial-control dimension for secure IDET systems^[7–9]. By adjusting antenna positions within a finite wavelength-scale region, MAs can reconfigure multipath phase superposition, enhance legitimate links, and weaken eavesdropping links or strengthen AN leakage toward eavesdroppers^[10]. Therefore, MA position optimization can complement beamforming in improving the minimum secrecy rate.

Existing MA studies have mainly focused on channel modeling, capacity analysis, channel estimation, and position optimization^[11–13], whereas most IDET resource-allocation works rely on fixed arrays or reconfigurable intelligent surfaces^[14–15]. Although MA-assisted IDET throughput optimization was studied in Ref. [16], secure IDET with joint information transmission, energy transfer, and eavesdropping suppression remains insufficiently investigated. The resulting design is challenging because secrecy-rate constraints, position-dependent channels, and antenna-spacing constraints are all nonconvex. Recent studies have also explored practical measurement- and

This work was supported in part by the Natural Science Foundation of China (NSFC) under Grant Nos. 62571091 and 62531008.

environment-aware methods for wireless coverage enhancement. Power-measurement-based channel estimation was developed to support Intelligent Reflecting Surface (IRS) reflection design with reduced training and signaling overhead^[17]. A three-dimensional virtual-scatterer model was further proposed to reconstruct channel-gain maps from limited measurements^[18]. In addition, a Reference Signal Received Power (RSRP)-based quasi-static IRS reflection framework was investigated for low-overhead network coverage enhancement^[19]. These studies demonstrate the benefits of exploiting spatial channel information and slowly varying reconfiguration. However, they focus on IRS-assisted coverage and do not address the joint optimization of MA positions, information and energy beamforming, and secrecy performance in IDET systems.

Existing secure IDET studies such as Ref. [6] optimize information and energy beamformers for fixed array responses, whereas the MA-assisted IDET design in Ref. [16] does not consider eavesdroppers or secrecy-rate constraints. In the considered system in this paper, the continuous MA coordinates determine the data receiver (DR), ER, and eavesdropper (Eve) channel responses through multipath phase shifts and are jointly coupled with the information and energy beamformers. Consequently, the max-min secrecy-rate design involves the simultaneous handling of secrecy, energy-transfer, transmit-power, movable-region, and inter-antenna spacing constraints.

Motivated by these observations, this paper studies MA-assisted secure IDET systems and makes the following contributions.

- An MA-assisted secure IDET network model is developed, where a base station serves multiple DRs and ERs in the presence of passive eavesdroppers. A field-response channel model is used to characterize the effect of MA positions, and energy signals are reused as AN.

- A max-min secrecy-rate resource-allocation problem is formulated by jointly optimizing information beamformers, energy beamformers, and MA positions subject to energy-harvesting, transmit-power, movable-region, and minimum-distance constraints.

- An algorithm combining semidefinite relaxation (SDR), successive convex approximation (SCA), and alternating optimization (AO) is proposed, termed the SDR-SCA-AO algorithm. The beamforming subproblem is handled by semidefinite relaxation and successive convex approximation, while the MA-position subproblem is updated through iterative convex approximation of the position-dependent constraints.

- Numerical results verify the convergence of the proposed method and demonstrate the effects of transmit power, the number of MAs, ER energy thresholds, movable-region size, and minimum antenna distance on secrecy performance.

2 System Model

2.1 Movable-Antenna Channel Model

Consider the downlink MA-assisted secure IDET network

shown in Fig. 1. The base station is equipped with M movable antennas. The position of the m -th antenna is denoted by $\mathbf{r}_m = [x_m, y_m]^T$, which is confined to a two-dimensional region $\mathcal{C} = [-A/2, A/2] \times [-A/2, A/2]$, where A denotes the side length of the movable region. The entire antenna position set is represented as $\tilde{\mathbf{r}} = \{\mathbf{r}_m\}_{m=1}^M$. To avoid antenna collision and strong mutual coupling, the antenna positions are subject to the following constraints:

$$\begin{aligned} \mathbf{r}_m &\in \mathcal{C}, \quad \forall m, \\ \|\mathbf{r}_m - \mathbf{r}_i\|_2 &\geq D, \quad m \neq i \end{aligned} \quad (1)$$

where D is the minimum distance between any two antennas.

For any receiving node u , including a DR, an ER, or an Eve, let L_u denote the number of propagation paths. Since this paper optimizes the transmit-side MA positions at the base station, all angular parameters are defined at the transmit-array side. Specifically, $\theta_{u,l}$ denotes the azimuth angle of departure of the l -th path from the base station to node u , while $\phi_{u,l}$ denotes the corresponding elevation angle of departure. Because each receiving node is equipped with a single antenna, no receive-array response is considered. The phase difference of the l -th path relative to the reference point of the base station is written as

$$\rho_{u,l}(\mathbf{r}_m) = \frac{2\pi}{\lambda} (x_m \sin\theta_{u,l} \cos\phi_{u,l} + y_m \cos\phi_{u,l}) \quad (2),$$

where λ denotes the carrier wavelength. The field-response vector at the m -th MA is given by

$$\mathbf{f}_u(\mathbf{r}_m) = [e^{j\rho_{u,1}(\mathbf{r}_m)}, \dots, e^{j\rho_{u,L_u}(\mathbf{r}_m)}]^T \quad (3).$$

By stacking the field-response vectors of all M antennas, we obtain:

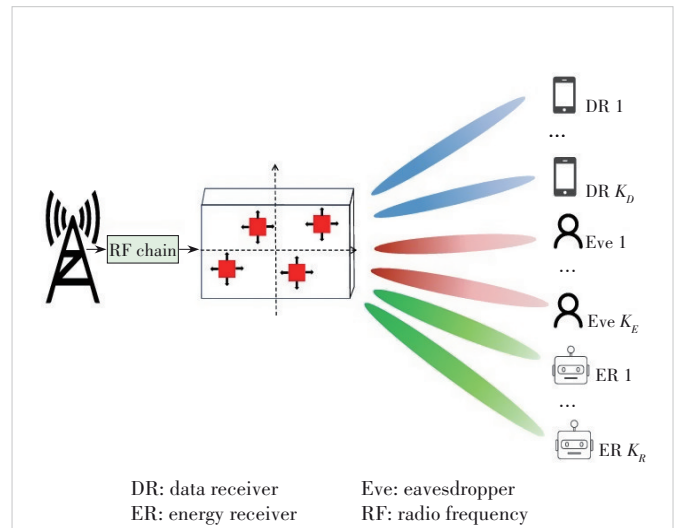


Figure 1. Illustration of an MA-assisted secure IDET network

$$\mathbf{F}_u(\tilde{\mathbf{r}}) = [\mathbf{f}_u(\mathbf{r}_1), \dots, \mathbf{f}_u(\mathbf{r}_M)] \in \mathbb{C}^{L_u \times M} \quad (4).$$

Let $\mathbf{a}_u \in \mathbb{C}^{L_u \times 1}$ denote the complex path-gain vector of node u . The equivalent channel vector from the base station to node u is then expressed as

$$\begin{aligned} \mathbf{h}_u(\tilde{\mathbf{r}}) &= \mathbf{F}_u^H(\tilde{\mathbf{r}}) \mathbf{a}_u, \\ a_{u,l} &\sim \mathcal{CN}\left(0, \frac{\beta_0 d_u^{-\alpha}}{L_u}\right), \quad l = 1, \dots, L_u \end{aligned} \quad (5),$$

where d_u denotes the propagation distance, α is the path-loss exponent, and β_0 is the path loss at the reference distance. It follows from Eq. (5) that the MA positions affect the channel through exponential phase terms, and position changes on the wavelength scale can alter the coherent superposition of multipath signals.

The channels are assumed to remain quasi-static within each transmission block. The BS acquires the CSI of the DRs, ERs, and Eves through pilot-assisted channel estimation. Under time-division duplexing, mutually orthogonal uplink pilot sequences are assigned to the terminals, and the corresponding downlink CSI is obtained using channel reciprocity after radio-frequency-chain calibration. The resulting channel estimates are treated as perfectly known during each resource-allocation interval.

2.2 Secure IDET Signal Model

Consider the DR set $\mathcal{K}_D = \{1, \dots, K_D\}$, the ER set $\mathcal{K}_R = \{1, \dots, K_R\}$, and the Eve set $\mathcal{K}_E = \{1, \dots, K_E\}$. For simplicity, $\mathbf{h}_{k_D}$, $\mathbf{g}_{k_R}$, and $\mathbf{q}_{k_E}$ denote the channel vectors from the base station to the k_D -th DR, the k_R -th ER, and the k_E -th Eve, respectively. They are all given by Eq. (5) and depend on $\tilde{\mathbf{r}}$. The base station simultaneously transmits information streams and energy streams over the same time-frequency resource:

$$\mathbf{x} = \sum_{k_D \in \mathcal{K}_D} \mathbf{w}_{k_D} s_{k_D}^D + \sum_{k_R \in \mathcal{K}_R} \mathbf{v}_{k_R} s_{k_R}^R \quad (6),$$

where $\mathbf{w}_{k_D}$ is the information beamformer, $\mathbf{v}_{k_R}$ is the energy beamformer, and $s_{k_D}^D$ and $s_{k_R}^R$ have unit power and are mutually independent. The energy streams act as power-carrying signals at ERs, as AN at Eves, and as controllable interference at DRs.

The received signal-to-interference-plus-noise ratio (SINR) at the k_D -th DR is

$$\gamma_{k_D}^D = \frac{|\mathbf{h}_{k_D}^H \mathbf{w}_{k_D}|^2}{\sum_{i_D \neq k_D} |\mathbf{h}_{k_D}^H \mathbf{w}_{i_D}|^2 + \sum_{i_R} |\mathbf{h}_{k_D}^H \mathbf{v}_{i_R}|^2 + \sigma_{k_D}^2} \quad (7).$$

The SINR at the k_E -th Eve when it eavesdrops on the information stream intended for DR k_D is

$$\gamma_{k_D, k_E}^E = \frac{|\mathbf{q}_{k_E}^H \mathbf{w}_{k_D}|^2}{\sum_{i_D \neq k_D} |\mathbf{q}_{k_E}^H \mathbf{w}_{i_D}|^2 + \sum_{i_R} |\mathbf{q}_{k_E}^H \mathbf{v}_{i_R}|^2 + \sigma_{k_E}^2} \quad (8).$$

The corresponding legitimate and eavesdropping rates are

$$\begin{aligned} R_{k_D}^D &= \log_2(1 + \gamma_{k_D}^D), \\ R_{k_D, k_E}^E &= \log_2(1 + \gamma_{k_D, k_E}^E) \end{aligned} \quad (9).$$

Considering the worst-case Eve, the secrecy rate of the k_D -th DR is defined as

$$R_{k_D}^{\text{sec}} = \max \left\{ R_{k_D}^D - \max_{k_E \in \mathcal{K}_E} R_{k_D, k_E}^E, 0 \right\} \quad (10),$$

where the maximum with zero ensures a nonnegative secrecy rate.

2.3 IDET Receiver Structure and Energy Harvesting Model

A separate IDET receiver architecture is adopted, in which DRs perform only information decoding and ERs perform only energy harvesting. For any ER $j \in \mathcal{K}_R$, let $P_{\text{in},j}$ denote the total RF power received at the input of its rectifier. This power is contributed by both information beams and energy beams. From Eq. (6), the RF input power of the k_R -th ER can be written as

$$P_{\text{in},k_R} = \sum_{i_D \in \mathcal{K}_D} |\mathbf{g}_{k_R}^H \mathbf{w}_{i_D}|^2 + \sum_{i_R \in \mathcal{K}_R} |\mathbf{g}_{k_R}^H \mathbf{v}_{i_R}|^2 \quad (11).$$

A practical rectifier circuit exhibits a saturation effect. Its energy output can be described by the nonlinear model

$$\Psi_j(P_{\text{in},j}) = \frac{\Omega_j}{1 + \exp[-a_j(P_{\text{in},j} - b_j)]} - \frac{\Omega_j}{1 + \exp(a_j b_j)} \quad (12),$$

where Ω_j is the saturation power, and a_j and b_j are determined by the rectifier circuit. Since $\Psi_j(\cdot)$ is monotonically increasing with respect to $P_{\text{in},j}$, the constraint $\Psi_j(P_{\text{in},j}) \geq E_{\text{th},j}$ can be equivalently rewritten as

$$P_{\text{in},j} \geq P_{\text{th},j}, \quad j \in \mathcal{K}_R \quad (13),$$

where $P_{\text{th},j}$ is the equivalent radio-frequency input-power threshold obtained by inverting $E_{\text{th},j}$. In the subsequent optimization, Eq. (13) is used to represent the energy-harvesting constraint, thereby reducing computational complexity while preserving the physical meaning of nonlinear energy harvesting.

3 Joint Resource Allocation for Secure IDET

3.1 Problem Formulation

The objective is to maximize the minimum secrecy rate among all DRs while satisfying the ER energy constraints, the total transmit-power constraint, and the physical constraints of MAs. The original problem is formulated as

$$\begin{aligned}
 (\text{P0}): \quad & \max_{\{\mathbf{w}_{k_D}, \{\mathbf{v}_{k_R}\}, \tilde{\mathbf{r}}, k_D \in \mathcal{K}_D} \min R_{k_D}^{\text{sec}} \\
 \text{s.t.} \quad & P_{\text{in}, k_R} \geq P_{\text{th}, k_R}, \quad \forall k_R \in \mathcal{K}_R, \\
 & \sum_{k_D} \|\mathbf{w}_{k_D}\|^2 + \sum_{k_R} \|\mathbf{v}_{k_R}\|^2 \leq P, \\
 & \mathbf{r}_m \in \mathcal{C}, \quad \forall m, \\
 & \|\mathbf{r}_m - \mathbf{r}_i\|_2 \geq D, \quad \forall m \neq i
 \end{aligned} \quad (14).$$

By introducing an auxiliary variable τ and expanding the worst-case eavesdropping constraint, (P0) can be reformulated as

$$\begin{aligned}
 (\text{P1}): \quad & \max_{\{\mathbf{w}_{k_D}, \{\mathbf{v}_{k_R}\}, \tilde{\mathbf{r}}, \tau} \tau \\
 \text{s.t.} \quad & R_{k_D}^D - R_{k_D, k_E}^E \geq \tau, \quad \forall k_D, k_E, \\
 & P_{\text{in}, k_R} \geq P_{\text{th}, k_R}, \quad \forall k_R, \\
 & \sum_{k_D} \|\mathbf{w}_{k_D}\|^2 + \sum_{k_R} \|\mathbf{v}_{k_R}\|^2 \leq P, \\
 & \mathbf{r}_m \in \mathcal{C}, \quad \forall m, \\
 & \|\mathbf{r}_m - \mathbf{r}_i\|_2 \geq D, \quad \forall m \neq i
 \end{aligned} \quad (15).$$

Problem (P1) is nonconvex for the following reasons. First, the secrecy-rate constraint contains a difference between two logarithmic rates, and each rate further includes a fractional SINR. Second, the beamforming variables and MA-position variables are coupled through the channel vectors. Third, the minimum antenna-distance constraint $\|\mathbf{r}_m - \mathbf{r}_i\|_2 \geq D$ defines a nonconvex feasible set. Therefore, an AO framework is adopted, in which the variables are divided into the beamforming-matrix block and the MA-position block, and SDR and SCA are used to handle the corresponding subproblems.

3.2 Beamforming Optimization with Fixed MA Positions

Given $\tilde{\mathbf{r}}$, all channel vectors are fixed. First, define the information and energy beamforming matrices as

$$\begin{aligned}
 \mathbf{W}_{k_D} &= \mathbf{w}_{k_D} \mathbf{w}_{k_D}^H, \quad \mathbf{W}_{k_D} \geq 0, \text{rank}(\mathbf{W}_{k_D}) = 1, \\
 \mathbf{V}_{k_R} &= \mathbf{v}_{k_R} \mathbf{v}_{k_R}^H, \quad \mathbf{V}_{k_R} \geq 0, \text{rank}(\mathbf{V}_{k_R}) = 1
 \end{aligned} \quad (16).$$

Define the channel matrices as

$$\begin{aligned}
 \mathbf{H}_{k_D} &= \mathbf{h}_{k_D} \mathbf{h}_{k_D}^H, \\
 \mathbf{G}_{k_R} &= \mathbf{g}_{k_R} \mathbf{g}_{k_R}^H, \\
 \mathbf{Q}_{k_E} &= \mathbf{q}_{k_E} \mathbf{q}_{k_E}^H
 \end{aligned} \quad (17).$$

Then $|\mathbf{h}^H \mathbf{w}|^2 = \text{Tr}(\mathbf{h} \mathbf{h}^H \mathbf{W})$, and the corresponding beamforming power is $\text{Tr}(\mathbf{W})$. The legitimate-link rate can be written in the following difference-of-concave form:

$$R_{k_D}^D = \log_2 A_{k_D}(\mathbf{W}, \mathbf{V}) - \log_2 B_{k_D}(\mathbf{W}, \mathbf{V}) \quad (18),$$

where

$$\begin{aligned}
 A_{k_D} &= \sum_{i_D} \text{Tr}(\mathbf{H}_{k_D} \mathbf{W}_{i_D}) + \sum_{i_R} \text{Tr}(\mathbf{H}_{k_D} \mathbf{V}_{i_R}) + \sigma_{k_D}^2, \\
 B_{k_D} &= \sum_{i_D \neq k_D} \text{Tr}(\mathbf{H}_{k_D} \mathbf{W}_{i_D}) + \sum_{i_R} \text{Tr}(\mathbf{H}_{k_D} \mathbf{V}_{i_R}) + \sigma_{k_D}^2
 \end{aligned} \quad (19).$$

Similarly, the Eve rate can be written as

$$R_{k_D, k_E}^E = \log_2 C_{k_D, k_E}(\mathbf{W}, \mathbf{V}) - \log_2 D_{k_D, k_E}(\mathbf{W}, \mathbf{V}) \quad (20),$$

where

$$\begin{aligned}
 C_{k_D, k_E} &= \sum_{i_D} \text{Tr}(\mathbf{Q}_{k_E} \mathbf{W}_{i_D}) + \sum_{i_R} \text{Tr}(\mathbf{Q}_{k_E} \mathbf{V}_{i_R}) + \sigma_{k_E}^2, \\
 D_{k_D, k_E} &= \sum_{i_D \neq k_D} \text{Tr}(\mathbf{Q}_{k_E} \mathbf{W}_{i_D}) + \sum_{i_R} \text{Tr}(\mathbf{Q}_{k_E} \mathbf{V}_{i_R}) + \sigma_{k_E}^2
 \end{aligned} \quad (21).$$

Thus, the secrecy-rate difference of any DR-Eve pair is

$$\begin{aligned}
 R_{k_D}^D - R_{k_D, k_E}^E &= \log_2 A_{k_D} - \log_2 B_{k_D} - \\
 & \log_2 C_{k_D, k_E} + \log_2 D_{k_D, k_E}
 \end{aligned} \quad (22).$$

In Eq. (22), $\log_2 A_{k_D}$ and $\log_2 D_{k_D, k_E}$ are concave functions, whereas $-\log_2 B_{k_D}$ and $-\log_2 C_{k_D, k_E}$ are convex functions. This structure leads to nonconvex constraints. Since $\log_2(x)$ is concave, its first-order upper bound at the n -th SCA iteration point is

$$\log_2 x \leq \log_2 x^{(n)} + \frac{x - x^{(n)}}{x^{(n)} \ln 2}, \quad x > 0 \quad (23).$$

By replacing $\log_2 B_{k_D}$ and $\log_2 C_{k_D, k_E}$ with their upper bounds, a concave lower bound of the secrecy-rate difference can be obtained as

$$\begin{aligned}
 \hat{R}_{k_D, k_E}^{(n)} &= \log_2 A_{k_D} + \log_2 D_{k_D, k_E} - \\
 & \left[\log_2 B_{k_D}^{(n)} + \frac{B_{k_D} - B_{k_D}^{(n)}}{B_{k_D}^{(n)} \ln 2} \right] - \\
 & \left[\log_2 C_{k_D, k_E}^{(n)} + \frac{C_{k_D, k_E} - C_{k_D, k_E}^{(n)}}{C_{k_D, k_E}^{(n)} \ln 2} \right]
 \end{aligned} \quad (24).$$

Here, $B_{k_D}^{(n)}$ and $C_{k_D, k_E}^{(n)}$ are computed using the solution of the previous SCA iteration. Since $\hat{R}_{k_D, k_E}^{(n)} \leq R_{k_D}^D - R_{k_D, k_E}^E$ and equality holds at the current point, $\hat{R}_{k_D, k_E}^{(n)} \geq \tau$ is used to guarantee conservative feasibility.

The energy and power constraints can be expressed in terms of the matrix variables as

$$\begin{aligned}
 \sum_{i_D} \text{Tr}(\mathbf{G}_{k_R} \mathbf{W}_{i_D}) + \sum_{i_R} \text{Tr}(\mathbf{G}_{k_R} \mathbf{V}_{i_R}) &\geq P_{\text{th}, k_R}, \quad \forall k_R, \\
 \sum_{k_D} \text{Tr}(\mathbf{W}_{k_D}) + \sum_{k_R} \text{Tr}(\mathbf{V}_{k_R}) &\leq P
 \end{aligned} \quad (25).$$

After removing the nonconvex rank-one constraints, the beamforming subproblem in the n -th SCA iteration becomes

$$\begin{aligned}
 (\text{P2}): \quad & \max_{\{\mathbf{W}_{k_D}, \{\mathbf{V}_{k_E}\}, \tau} \tau \\
 \text{s.t.} \quad & \hat{R}_{k_D, k_E}^{(n)} \geq \tau, \quad \forall k_D, k_E, \\
 & \mathbf{W}_{k_D} \geq 0, \quad \forall k_D, \\
 & \mathbf{V}_{k_E} \geq 0, \quad \forall k_E
 \end{aligned} \quad (26)$$

The objective function is linear, the constraint $\hat{R}_{k_D, k_E}^{(n)} \geq \tau$ is a superlevel-set constraint of a concave function, and the remaining constraints are linear matrix inequalities or linear constraints. Hence, (P2) is a convex semidefinite programming (SDP) problem. If the obtained $\mathbf{W}_{k_D}$ and $\mathbf{V}_{k_E}$ are all rank-one matrices, the beamformers can be recovered directly through the principal eigenvectors. If high-rank solutions are obtained, Gaussian randomization is used to generate candidate beamformers, and the candidate satisfying the power and energy constraints while achieving the highest secrecy rate is selected.

For each high-rank SDR matrix, eigenvalue decomposition is first performed. In each trial, an independent complex Gaussian vector is generated and mapped through the eigenvector matrix and the square root of the eigenvalue matrix to construct candidate information and energy beamformers. The candidates are then power-scaled and evaluated under the original constraints. Among N_{CR} trials, the feasible candidate set yielding the largest original minimum secrecy rate is selected^[20–21].

3.3 MA Position Optimization with Fixed Beamformers

Given the information and energy beamformers, the MA positions are optimized to reconfigure the legitimate, energy-transfer, and eavesdropping links. Define the useful signal power and the interference-plus-noise power of any node u with respect to the target information stream k_D as

$$\begin{aligned}
 S_{u, k_D}(\tilde{\mathbf{r}}) &= \left| \mathbf{h}_u^H(\tilde{\mathbf{r}}) \mathbf{w}_{k_D} \right|^2, \\
 I_{u, k_D}(\tilde{\mathbf{r}}) &= \sum_{i_D \neq k_D} \left| \mathbf{h}_u^H(\tilde{\mathbf{r}}) \mathbf{w}_{i_D} \right|^2 + \\
 &\quad \sum_{i_R} \left| \mathbf{h}_u^H(\tilde{\mathbf{r}}) \mathbf{v}_{i_R} \right|^2 + \sigma_u^2
 \end{aligned} \quad (27)$$

When u is a DR, $\mathbf{h}_u$ denotes a legitimate channel; when u is an Eve, $\mathbf{h}_u$ denotes an eavesdropping channel. Let

$$\begin{aligned}
 A_{u, k_D}(\tilde{\mathbf{r}}) &= S_{u, k_D}(\tilde{\mathbf{r}}) + I_{u, k_D}(\tilde{\mathbf{r}}), \\
 B_{u, k_D}(\tilde{\mathbf{r}}) &= I_{u, k_D}(\tilde{\mathbf{r}})
 \end{aligned} \quad (28)$$

The unified rate expression is therefore

$$R_{u, k_D}(\tilde{\mathbf{r}}) = \log_2 A_{u, k_D}(\tilde{\mathbf{r}}) - \log_2 B_{u, k_D}(\tilde{\mathbf{r}}) \quad (29)$$

The secrecy-rate difference between the k_D -th DR and the

k_E -th Eve is

$$\begin{aligned}
 R_{k_D, k_E}^{\text{sec}}(\tilde{\mathbf{r}}) &= \log_2 A_{k_D, k_D}(\tilde{\mathbf{r}}) - \log_2 B_{k_D, k_D}(\tilde{\mathbf{r}}) - \\
 &\quad \log_2 A_{k_E, k_D}(\tilde{\mathbf{r}}) + \log_2 B_{k_E, k_D}(\tilde{\mathbf{r}})
 \end{aligned} \quad (30)$$

According to Eq. (23), at the current iteration point $\tilde{\mathbf{r}}^{(n)}$, we have

$$\begin{aligned}
 \log_2 B_{k_D, k_D}(\tilde{\mathbf{r}}) &\leq \log_2 B_{k_D, k_D}^{(n)} + \frac{B_{k_D, k_D}(\tilde{\mathbf{r}}) - B_{k_D, k_D}^{(n)}}{B_{k_D, k_D}^{(n)} \ln 2}, \\
 \log_2 A_{k_E, k_D}(\tilde{\mathbf{r}}) &\leq \log_2 A_{k_E, k_D}^{(n)} + \frac{A_{k_E, k_D}(\tilde{\mathbf{r}}) - A_{k_E, k_D}^{(n)}}{A_{k_E, k_D}^{(n)} \ln 2}
 \end{aligned} \quad (31)$$

where $B_{k_D, k_D}^{(n)} = B_{k_D, k_D}(\tilde{\mathbf{r}}^{(n)})$ and $A_{k_E, k_D}^{(n)} = A_{k_E, k_D}(\tilde{\mathbf{r}}^{(n)})$. Hence, a conservative lower bound of the secrecy-rate difference is

$$\begin{aligned}
 \hat{R}_{k_D, k_E}^{\text{pos}, (n)} &= \log_2 A_{k_D, k_D}(\tilde{\mathbf{r}}) + \log_2 B_{k_E, k_D}(\tilde{\mathbf{r}}) - \\
 &\quad \left[\log_2 B_{k_D, k_D}^{(n)} + \frac{B_{k_D, k_D}(\tilde{\mathbf{r}}) - B_{k_D, k_D}^{(n)}}{B_{k_D, k_D}^{(n)} \ln 2} \right] - \\
 &\quad \left[\log_2 A_{k_E, k_D}^{(n)} + \frac{A_{k_E, k_D}(\tilde{\mathbf{r}}) - A_{k_E, k_D}^{(n)}}{A_{k_E, k_D}^{(n)} \ln 2} \right]
 \end{aligned} \quad (32)$$

The radio-frequency input power of the k_R -th ER can be written as

$$\Gamma_{k_R}(\tilde{\mathbf{r}}) = \sum_{i_D} \left| \mathbf{g}_{k_R}^H(\tilde{\mathbf{r}}) \mathbf{w}_{i_D} \right|^2 + \sum_{i_R} \left| \mathbf{g}_{k_R}^H(\tilde{\mathbf{r}}) \mathbf{v}_{i_R} \right|^2 \quad (33)$$

Let $\mathbf{z} = [x_1, y_1, \dots, x_M, y_M]^T$ denote the position vector. For any beamformer $\mathbf{b}$, define the power function as

$$p_{u, \mathbf{b}}(\mathbf{z}) = \left| \mathbf{h}_u^H(\mathbf{z}) \mathbf{b} \right|^2 \quad (34)$$

Its gradient with respect to any coordinate $\chi \in \{x_m, y_m\}$ is

$$\frac{\partial p_{u, \mathbf{b}}}{\partial \chi} = 2 \text{Re} \left(\overline{\mathbf{h}_u^H \mathbf{b}} \frac{\partial (\mathbf{h}_u^H \mathbf{b})}{\partial \chi} \right) \quad (35)$$

When $\chi = x_m$, it follows from Eqs. (2)–(5) that

$$\frac{\partial (\mathbf{h}_u^H \mathbf{b})}{\partial x_m} = j \frac{2\pi}{\lambda} b_m \sum_{l=1}^{L_u} a_{u, l}^* e^{j \frac{2\pi}{\lambda} \rho_{u, l}(r_m)} \times \sin \theta_{u, l} \cos \phi_{u, l} \quad (36)$$

where $\sin \theta_{u, l} \cos \phi_{u, l}$ is replaced with $\cos \phi_{u, l}$ when $\chi = y_m$.

Therefore, the first-order approximation of the ER input power at the n -th iteration point is

$$\begin{aligned}
 \hat{\Gamma}_{k_R}^{(n)}(\mathbf{z}) &= \Gamma_{k_R}(\mathbf{z}^{(n)}) + \nabla \Gamma_{k_R}(\mathbf{z}^{(n)})^T (\mathbf{z} - \mathbf{z}^{(n)}), \\
 \nabla \Gamma_{k_R}(\mathbf{z}^{(n)}) &= \sum_{i_D} \nabla p_{k_R, \mathbf{w}_{i_D}}(\mathbf{z}^{(n)}) + \sum_{i_R} \nabla p_{k_R, \mathbf{v}_{i_R}}(\mathbf{z}^{(n)})
 \end{aligned} \quad (37)$$

Thus, the energy constraint in the current SCA iteration becomes

$$\hat{I}_{k_R}^{(n)}(z) \geq P_{th, k_R}, \quad \forall k_R \quad (38).$$

For the minimum antenna distance, since $\|\mathbf{r}_m - \mathbf{r}_i\|_2^2$ is a convex function, its first-order lower bound is

$$\begin{aligned} & \|\mathbf{r}_m^{(n)} - \mathbf{r}_i^{(n)}\|_2^2 + 2(\mathbf{r}_m^{(n)} - \mathbf{r}_i^{(n)})^T \times \\ & \left[(\mathbf{r}_m - \mathbf{r}_i) - (\mathbf{r}_m^{(n)} - \mathbf{r}_i^{(n)}) \right] \geq D^2, \quad \forall m \neq i \end{aligned} \quad (39).$$

Accordingly, the approximate MA-position subproblem with fixed beamformers is formulated as

$$\begin{aligned} & \text{(P3): } \max_{z, \tau} \tau \\ & \text{s.t. } \hat{R}_{k_D, k_E}^{\text{pos}, (n)} \geq \tau, \quad \forall k_D, k_E, \\ & \hat{I}_{k_R}^{(n)}(z) \geq P_{th, k_R}, \quad \forall k_R \\ & \mathbf{r}_m \in \mathcal{C}, \quad \forall m \end{aligned} \quad (40).$$

Thus, (P3) is the SCA approximation problem at the current iteration point and can be solved by standard convex optimization tools. After an optimal solution is obtained, it is used as the next SCA linearization point, and the iterations continue until the objective value converges.

3.4 Overall Algorithm and Complexity Analysis

Based on the two subproblems above, an SDR-SCA-AO joint resource-allocation algorithm is proposed for secure IDET, as shown in Algorithm 1. The algorithm first initializes MA positions that satisfy the region and distance constraints and constructs feasible beamformers that satisfy the power constraint. In each outer iteration, the beamforming SDP subproblem is solved with fixed MA positions, and the position SCA subproblem is then solved with fixed beamformers. The iterations terminate when the change in the minimum secrecy rate is below a preset threshold.

Algorithm 1. SDR-SCA-AO joint resource allocation algorithm for secure IDET

Input: Initial MA positions, initial information and energy beamformers, convergence threshold ϵ , and maximum number of iterations $N_{\max}$. The number of Gaussian-randomization trials is denoted by N_{GR} .

Output: Optimized information beamformers, energy beamformers, MA positions, and objective value τ^* .

1. Initialize the iteration index $n = 0$ and compute the initial objective value $\tau^{(0)}$.
2. While $n < N_{\max}$:
 - Fix the MA positions $\tilde{\mathbf{r}}^{(n)}$.
 - Construct the corresponding channel matrices $\mathbf{H}_{k_D}$, $\mathbf{G}_{k_R}$, and $\mathbf{Q}_{k_E}$.
 - Solve the beamforming optimization subproblem using SDR and SCA, and obtain $\{\mathbf{W}_{k_D}^{(n+1)}\}$, $\{\mathbf{V}_{k_R}^{(n+1)}\}$, and the

objective value $\tau_{\text{beam}}^{(n+1)}$.

- If all $\mathbf{W}_{k_D}^{(n+1)}$ and $\mathbf{V}_{k_R}^{(n+1)}$ are rank-one matrices, recover the information beamformers $\{\mathbf{w}_{k_D}^{(n+1)}\}$ and energy beamformers $\{\mathbf{v}_{k_R}^{(n+1)}\}$ through eigenvalue decomposition; otherwise, construct an approximately feasible beamforming solution using Gaussian randomization.
- For a high-rank solution, perform N_{GR} Gaussian-randomization trials, scale the candidate beamformers, discard infeasible candidates, and retain the feasible candidate with the highest original minimum secrecy rate.
- Fix the updated information beamformers $\{\mathbf{w}_{k_D}^{(n+1)}\}$ and energy beamformers $\{\mathbf{v}_{k_R}^{(n+1)}\}$.
- Solve the antenna-positioning subproblem using SCA, and obtain the updated MA positions $\tilde{\mathbf{r}}^{(n+1)}$ and the objective value $\tau^{(n+1)}$.
- Evaluate the candidate solution using the original objective and all original constraints. Accept the update only if it is feasible and its minimum secrecy rate is no lower than that of the previous accepted iterate; otherwise, retain the previous feasible solution.
- If $|\tau^{(n+1)} - \tau^{(n)}| \leq \epsilon$, terminate the loop.
- Set $n \leftarrow n + 1$.

3. Output the final solution.

The objective-value sequence generated by Algorithm 1 is monotonically nondecreasing. Let $\tau^{(n)}$ denote the objective value at the n -th accepted iterate. The SCA surrogate functions in (P2) and (P3) are tight at the current point, and the current solution remains feasible for the corresponding approximated problem. Solving the two subproblems and applying the acceptance criterion specified in Algorithm 1 thus yields $\tau^{(n+1)} \geq \tau^{(n)}$. Moreover, under the finite total transmit-power constraint, the achievable secrecy rate is upper bounded. Hence, $\{\tau^{(n)}\}$ is a bounded nondecreasing sequence, and Algorithm 1 converges.

Let I_{AO} denote the number of outer AO iterations, and let I_{B} and I_{P} denote the numbers of inner iterations for the beamforming SCA and position SCA, respectively. The beamforming subproblem contains $(K_D + K_R)$ positive semidefinite matrices of size $M \times M$, and its dominant complexity can be approximately expressed as

$$C_{\text{B}} = \mathcal{O}\left(\left((K_D + K_R)M^2\right)^3\right) \quad (41).$$

The dimension of the position subproblem is approximately $2M$, and it contains $K_D K_E$ secrecy constraints, K_R energy constraints, and $M(M-1)/2$ distance constraints. Its complexity can be roughly characterized as

$$C_{\text{P}} = \mathcal{O}\left((2M)^3\right) = \mathcal{O}(M^3) \quad (42).$$

Therefore, the total complexity is

$$\mathcal{O}\{I_{AO}(I_B C_B + I_P C_P)\} \quad (43).$$

It can be observed from Eq. (43) that the main computational burden lies in the beamforming SDP subproblem.

4 Simulation Results

To verify the effectiveness of the proposed algorithm, we consider a downlink MA-assisted secure IDET network. The base station is located at the origin and is equipped with $M = 6$ MAs. The system contains $K_D = 2$ DRs, $K_R = 2$ ERs, and $K_E = 2$ Eves. The carrier wavelength is set to $\lambda = 0.1$ m, the side length of the MA movable region is $A = 3\lambda$, and the minimum antenna distance is $D = \lambda/2$. The path-loss exponent is $\alpha = 2.4$, the reference-distance path loss is -40 dB, the noise power is -80 dBm, and the maximum transmit power of the base station is set to 20 dBm unless otherwise specified. The equivalent energy threshold of each ER is set to 0.01 mW by default. The simulation results are averaged over multiple independent channel realizations. The main parameters are listed in Table 1.

The proposed algorithm is referred to as the MA-PLS scheme. Three benchmarks are considered for comparison.

1) Fixed-position antenna (FPA) scheme: the BS adopts a uniform planar array with fixed antenna positions, and only the information and energy beamformers are optimized.

2) Without-eavesdropper (No-Eve) scheme: Eves are absent and the PLS constraints are removed, which provides an ideal reference without security threats.

3) FPA-No-Eve scheme: fixed antenna positions and the No-Eve setting are both adopted, representing a conventional IDET baseline.

These benchmarks isolate the effects of MA position optimization, PLS constraints, and energy-signal reuse as AN.

Table 1. Main simulation parameters

Parameter	Meaning	Value
M	Number of MAs	6
K_D, K_R	Numbers of DRs and ERs	2, 2
K_E	Number of Eves	2
A	Side length of movable region	3λ
D	Minimum antenna distance	$\lambda/2$
P	Transmit power	20 dBm
σ^2	Noise power	-80 dBm
α	Path-loss exponent	2.4
P_{th}	Equivalent energy threshold	0.01 mW
λ	Carrier wavelength	0.1 m
L_u	Number of propagation paths	10
N_{CR}	Gaussian-randomization trials	1 000

DR: data receiver ER: energy receiver MA: movable antenna

Fig. 2 shows the convergence behavior of the proposed algorithm. The minimum secrecy rate increases rapidly in the first few iterations and then stabilizes, indicating that the SDR-SCA-AO framework effectively coordinates beamforming and MA-position updates. A larger number of MAs yields a higher converged value because more spatial degrees of freedom are available. This behavior occurs because the early iterations substantially improve the initial beamformers and antenna geometry, whereas the gain produced by each subsequent update becomes smaller near convergence.

Fig. 3 shows the minimum secrecy rate versus the transmit power, where P_{max} varies from 10 dBm to 30 dBm in steps of 2 dB. The proposed MA-PLS scheme consistently outperforms the FPA scheme because MA position optimization provides additional spatial degrees of freedom for enhancing legitimate links and suppressing eavesdropping links. The additional

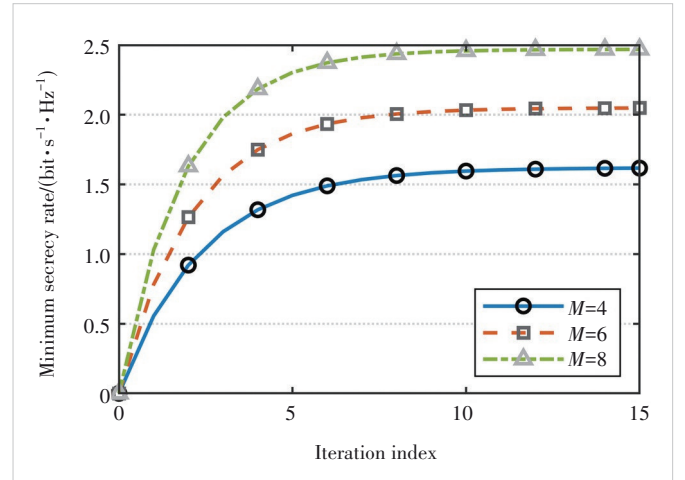


Figure 2. Convergence analysis of the SDR-SCA-AO algorithm

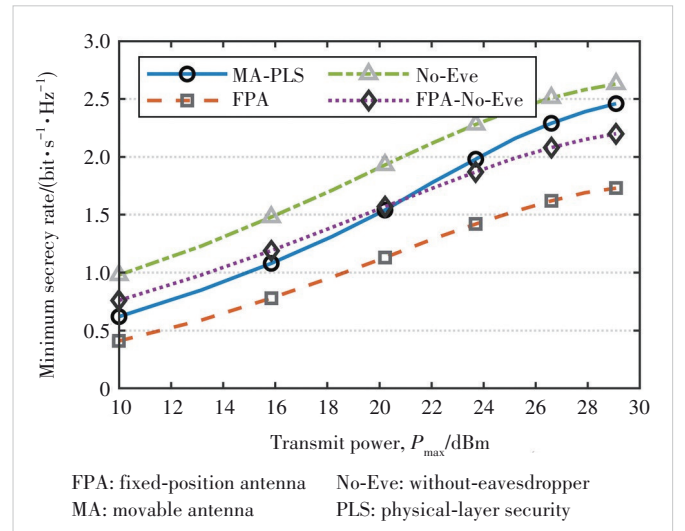


Figure 3. Minimum secrecy rate versus base-station transmit power under different schemes

transmit power benefits both desired transmission and energy-signal-based artificial noise; the MA scheme can use its reconfigurable geometry to direct these gains toward the DRs and interference toward the Eves more effectively than the fixed array.

Fig. 4 investigates the impact of the number of MAs on the minimum secrecy rate. Increasing the number of antennas improves both beamforming flexibility and spatial reconfigurability, leading to a higher minimum secrecy rate. The proposed MA-PLS scheme maintains clear gains over fixed-position benchmarks. Each additional MA contributes not only an extra beamforming coefficient but also an optimizable spatial coordinate, which explains the increasing advantage over the fixed-position benchmarks.

Fig. 5 evaluates the effect of the ER energy threshold on system performance. A higher threshold requires more power and spatial resources for energy transfer, leaving fewer resources for information transmission and secrecy enhancement. Consequently, the minimum secrecy rate decreases, while the proposed scheme remains superior to the FPA benchmark. Although the energy signals also act as artificial noise, a stringent ER requirement reduces the remaining beamforming freedom; MA positioning mitigates this loss by strengthening the ER channels and lowering the power cost of satisfying the threshold.

Fig. 6 illustrates the influence of the normalized movable-region side length A/λ on the secrecy rate. Enlarging the movable region provides more feasible antenna positions, which improves channel reconfiguration and secrecy performance. The gain gradually saturates because of the finite transmit power and fixed network topology. A larger region allows the MAs to explore more distinct multipath phase combinations, whereas the saturation indicates that the performance eventually becomes limited by the finite power budget and the available propagation paths.

Fig. 7 shows the impact of the normalized minimum antenna distance D/λ on the achievable secrecy rate. A larger spacing requirement reduces the feasible position region and weakens the flexibility of array-geometry optimization, thereby decreasing the minimum secrecy rate. Even under this constraint, the proposed scheme outperforms the FPA benchmark. The larger spacing removes some channel-favorable antenna configurations from the feasible set, but the proposed scheme can still optimize the remaining positions jointly with the beamformers.

5 Conclusions

This paper investigated joint resource allocation for MA-assisted secure IDET systems. By exploiting a field-response MA channel model, energy signals were reused as AN, and a max-min secrecy-rate problem was formulated to jointly optimize information beamformers, energy beamformers, and MA positions under practical energy-harvesting and antenna-position constraints. An SDR-SCA-AO algorithm was developed to solve the resulting nonconvex problem. Simulation re-

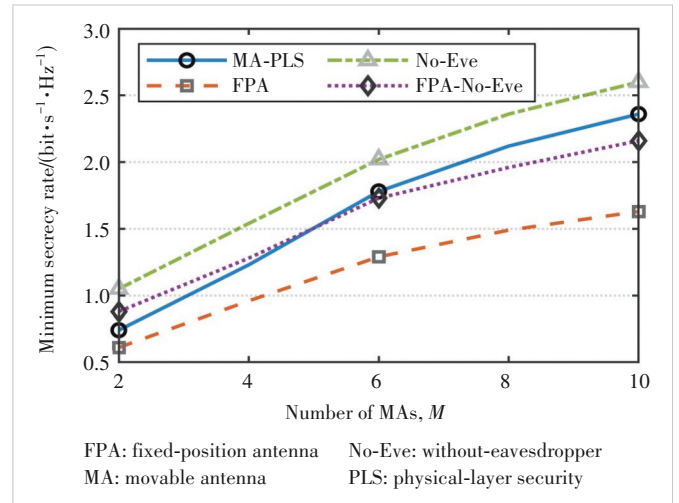


Figure 4. Minimum secrecy rate versus the number of MAs under different schemes

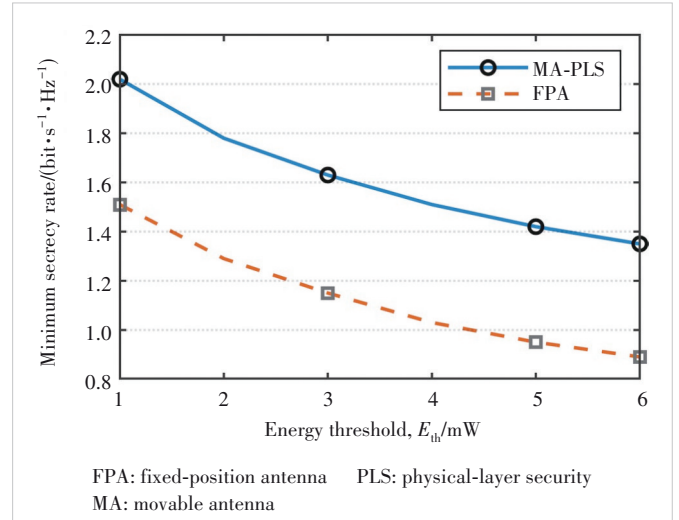


Figure 5. Minimum secrecy rate versus the minimum harvested-energy threshold of ERs

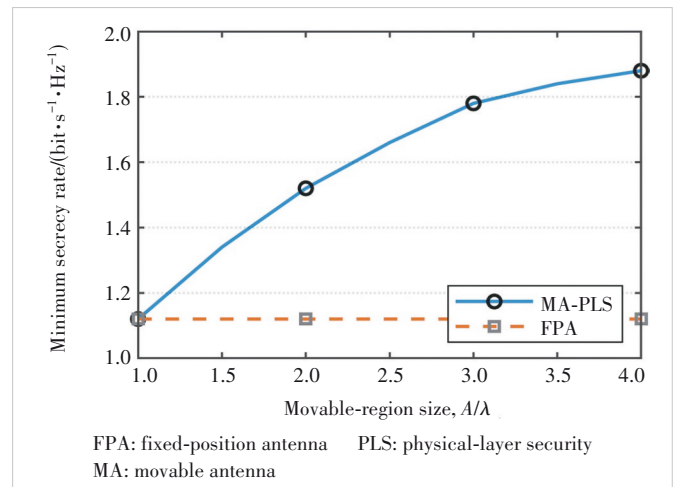


Figure 6. Minimum secrecy rate versus the normalized movable-region side length A/λ

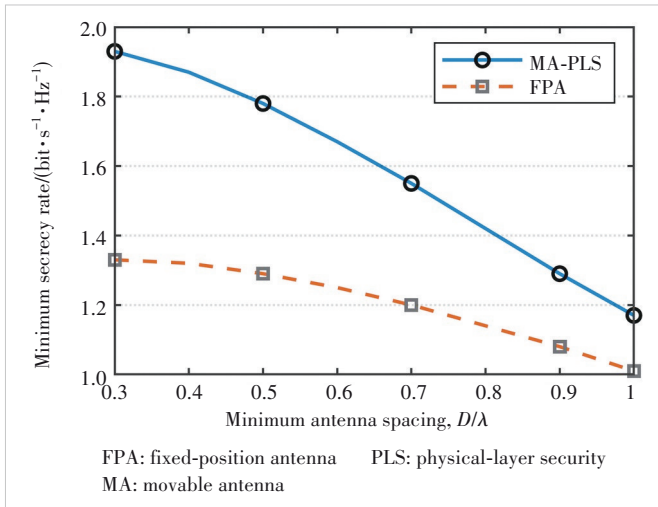


Figure 7. Minimum secrecy rate versus the normalized minimum antenna distance D/λ under different schemes

sults showed that MA position optimization and energy-signal reuse can effectively improve the minimum secrecy rate compared with fixed-position antenna benchmarks while satisfying ER energy requirements. Future work will incorporate MA movement-energy consumption and mechanical delay and develop low-complexity online resource-allocation algorithms for large-scale time-varying secure IDET networks.

References

- [1] Clerckx B, Zhang R, Schober R, et al. Fundamentals of wireless information and power transfer: from RF energy harvester models to signal and system designs [J]. *IEEE journal on selected areas in communications*, 2019, 37(1): 4 – 33. DOI: 10.1109/JSAC.2018.2872615
- [2] Bi S, Ho C K, Zhang R. Wireless powered communication: opportunities and challenges [J]. *IEEE communications magazine*, 2015, 53(4): 117 – 125. DOI: 10.1109/MCOM.2015.7081084
- [3] Hu J, Yang K, Wen G J, et al. Integrated data and energy communication network: a comprehensive survey [J]. *IEEE communications surveys & tutorials*, 2018, 20(4): 3169 – 3219. DOI: 10.1109/COMST.2018.2860778
- [4] Wyner A D. The wire-tap channel [J]. *Bell system technical journal*, 1975, 54(8): 1355 – 1387. DOI: 10.1002/j.1538-7305.1975.tb02040.x
- [5] Goel S, Negi R. Guaranteeing secrecy using artificial noise [J]. *IEEE transactions on wireless communications*, 2008, 7(6): 2180 – 2189. DOI: 10.1109/TWC.2008.060848
- [6] Ng D W K, Lo E S, Schober R. Robust beamforming for secure communication in systems with wireless information and power transfer [J]. *IEEE transactions on wireless communications*, 2014, 13(8): 4599 – 4615. DOI: 10.1109/TWC.2014.2314654
- [7] Zhu L P, Ma W Y, Zhang R. Movable antennas for wireless communication: opportunities and challenges [J]. *IEEE communications magazine*, 2024, 62(6): 114 – 120. DOI: 10.1109/MCOM.001.2300212
- [8] Zhu L P, Ma W Y, Zhang R. Modeling and performance analysis for movable antenna enabled wireless communications [J]. *IEEE transactions on wireless communications*, 2024, 23(6): 6234 – 6250. DOI: 10.1109/TWC.2023.3330887
- [9] Ma W Y, Zhu L P, Zhang R. MIMO capacity characterization for movable antenna systems [J]. *IEEE transactions on wireless communications*, 2024, 23(4): 3392 – 3407. DOI: 10.1109/TWC.2023.3307696
- [10] Zhao Y Z, Zhang L, Yang H, et al. Reconfigurable antennas for next-generation mobile communication networks: a comprehensive survey and tutorial [J]. *IEEE communications surveys & tutorials*, 2026, 28: 5267 – 5306. DOI: 10.1109/COMST.2026.3673688
- [11] Zhu L P, Ma W Y, Ning B Y, et al. Movable-antenna enhanced multiuser communication via antenna position optimization [J]. *IEEE transactions on wireless communications*, 2024, 23(7): 7214 – 7229. DOI: 10.1109/TWC.2023.3338626
- [12] Ma W Y, Zhu L P, Zhang R. Compressed sensing based channel estimation for movable antenna communications [J]. *IEEE communications letters*, 2023, 27(10): 2747 – 2751. DOI: 10.1109/LCOMM.2023.3310535
- [13] Xiao Z Y, Cao S Q, Zhu L P, et al. Channel estimation for movable antenna communication systems: a framework based on compressed sensing [J]. *IEEE transactions on wireless communications*, 2024, 23(9): 11814 – 11830. DOI: 10.1109/TWC.2024.3385110
- [14] Zhao Y Z, Zhang L, Hu J, et al. Reflective index modulation for IRS assisted integrated data and energy transfer [J]. *IEEE transactions on wireless communications*, 2024, 23(9): 11508 – 11520. DOI: 10.1109/TWC.2024.3382578
- [15] Huang Q X, Hu J, Zhao Y Z, et al. Holographic integrated data and energy transfer [J]. *IEEE transactions on wireless communications*, 2024, 23(12): 18987 – 19002. DOI: 10.1109/TWC.2024.3477750
- [16] Xiang P R, Zhao Y Z, Zhao Y H, et al. Joint resource allocation for movable antenna-assisted integrated data and energy transfer [J]. *IEEE wireless communications letters*, 2026, 15: 2704 – 2708. DOI: 10.1109/LWC.2026.3684328
- [17] Sun H, Zhu L, Mei W D, et al. Power measurement-based channel estimation for IRS-enhanced wireless coverage [J]. *IEEE transactions on wireless communications*, 2024, 23(12): 19183 – 19198. DOI: 10.1109/TWC.2024.3480314
- [18] Sun H, Zhu L, Xu J, et al. Channel gain map estimation based on 3-D virtual scatterer model [J]. *IEEE transactions on wireless communications*, 2026, 25: 15741 – 15757. DOI: 10.1109/TWC.2026.3685411
- [19] Sun H, Zhu L, Yan G, et al. Quasi-static IRS reflection design for network coverage enhancement: a practical RSRP-based approach [J]. *IEEE wireless communications*, 2026, early access. DOI: 10.1109/MWC.2026.3692436
- [20] Luo Z Q, Ma W K, So A M C, et al. Semidefinite relaxation of quadratic optimization problems [J]. *IEEE signal processing magazine*, 2010, 27(3): 20 – 34. DOI: 10.1109/MSP.2010.936019
- [21] Sidiropoulos N D, Davidson T N, Luo Z Q. Transmit beamforming for physical-layer multicasting [J]. *IEEE transactions on signal processing*, 2006, 54(6): 2239 – 2251. DOI: 10.1109/TSP.2006.872578

Biographies

Xiang Pengrong received her MS degree from the School of Information and Communication Engineering, University of Electronic Science and Technology of China (UESTC) in 2026. Her research interests include movable-antenna-assisted wireless communications and integrated data energy transfer.

Li Zhiguang is pursuing his MS degree at the School of Information and Communication Engineering, University of Electronic Science and Technology of China (UESTC). His research interests include movable-antenna-assisted wireless communications and integrated data energy transfer.

Zhao Yizhe (yzzhao@uestc.edu.cn) is currently an associate professor at University of Electronic Science and Technology of China (UESTC), where he received his PhD in information and communication engineering in 2021. He has been a visiting researcher with the Department of Electrical and Computer Engineering, University of California, Davis, USA. He is a member of IEEE and a senior member of China Institute of Communications. He is selected in Young Elite Scientists Sponsorship Program by China Association for Science and Technology (CAST). He serves for *China Communications* and *Journal of Communications and Information Networks (JCIN)* as the Guest Editor, and is also a TPC member of several prestigious IEEE conferences, such as IEEE ICC and Globecom. He was the recipient of IEEE CSE Best Paper Award in 2023. His research interests include modulation and coding design, integrated data and energy transfer, and fluid antenna systems.