PHYSICAL LAYER SECURITY GAME WITH FULL-DUPLEX PROACTIVE EAVESDROPPER

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I. Motivation

- Wireless link broadcast characteristic
  — Physical layer security
- Recent advances on signal processing
  — Full-duplex operation on transceiver
- Most works assume that eavesdroppers operate in either passive or half-duplex mode
  — The more powerful eavesdropper operates in full-duplex mode

II. System Model

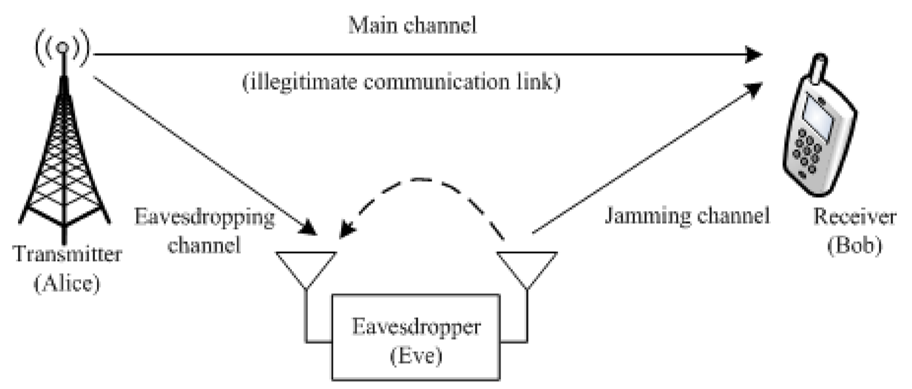

Fig. 1. Physical layer security game with a full-duplex eavesdropper

- Eve can eavesdrop and jam simultaneously
- Self-interference coefficient β ($0<\beta\leq 1$)
- Received data rates of Bob and Eve

$$\begin{cases} R_B = \log_2\left(1+\dfrac{|h_{AB}|^2 P_A}{|h_{EB}|^2 P_E + \sigma_B{}^2}\right) \\ R_E = \log_2\left(1+\dfrac{|h_{AE}|^2 P_A}{\beta P_E + \sigma_E{}^2}\right) \end{cases}$$

- Achievable secrecy rate

$$R_S = \max\{R_B - R_E, 0\}$$

- Pricing model for power consumption

$$c_i(P_i) = C_i P_i, \forall i \in \{A, E\}$$

III. Game Theoretic Approach

Two-player Noncooperative Game

- Players: Alice and Eve
- Strategies: the set of power strategy for player i

$$\mathbf{P}_i = \{0, \Delta P_i, \ldots, j\Delta P_i, \ldots, K_i \Delta P_i\}, \text{ where } \Delta P_i = \frac{P_i{}^{max}}{K_i}$$

- Utilities: the utility functions of Alice and Eve

$$U_A(P_A, P_E) = \begin{cases} GR_S - c_A(P_A), & GR_S > c_A(P_A) \\ 0, & GR_S \leq c_A(P_A) \end{cases}$$

$$U_E(P_A, P_E) = \begin{cases} -GR_S - c_E(P_E), & GR_S > c_A(P_A) \\ 0, & GR_S \leq c_A(P_A) \end{cases}$$

Power Selection Equilibrium

- Mixed-strategy of player i

$$\mathbf{p}_i(t) = \{p_i{}^0(t), \ldots, p_i{}^j(t), \ldots, p_i{}^{K_i}(t)\}$$

- Expected utility of player i

$$\bar{U}_i(\mathbf{p}_i(t), \mathbf{p}_{-i}(t)) = E_{\mathbf{p}_i, \mathbf{p}_{-i}}[U_i(P_i, P_{-i})]$$

- Fictitious play-based learning algorithm

$$P_i(t) \in \arg\max \bar{U}_i(P_i, \mathbf{p}_{-i}(t))$$

$$p_i{}^j(t) = \left(1 - \frac{1}{t}\right) \cdot p_i{}^j(t-1) + \frac{1}{t} \cdot 1_{\{P_i(t) = j\Delta P_i\}}$$

V. Conclusion

- The proposed full-duplex eavesdropper outperforms the half-duplex scheme within a certain self-interference coefficient and distance regions (e.g., d_{AE} = 200 m, β = 90 dB).
- A switch strategy is provided for the eavesdropper to determine the optimal operation mode between the full-duplex and half-duplex, depending on its location and self-interference.

IV. Simulation Results

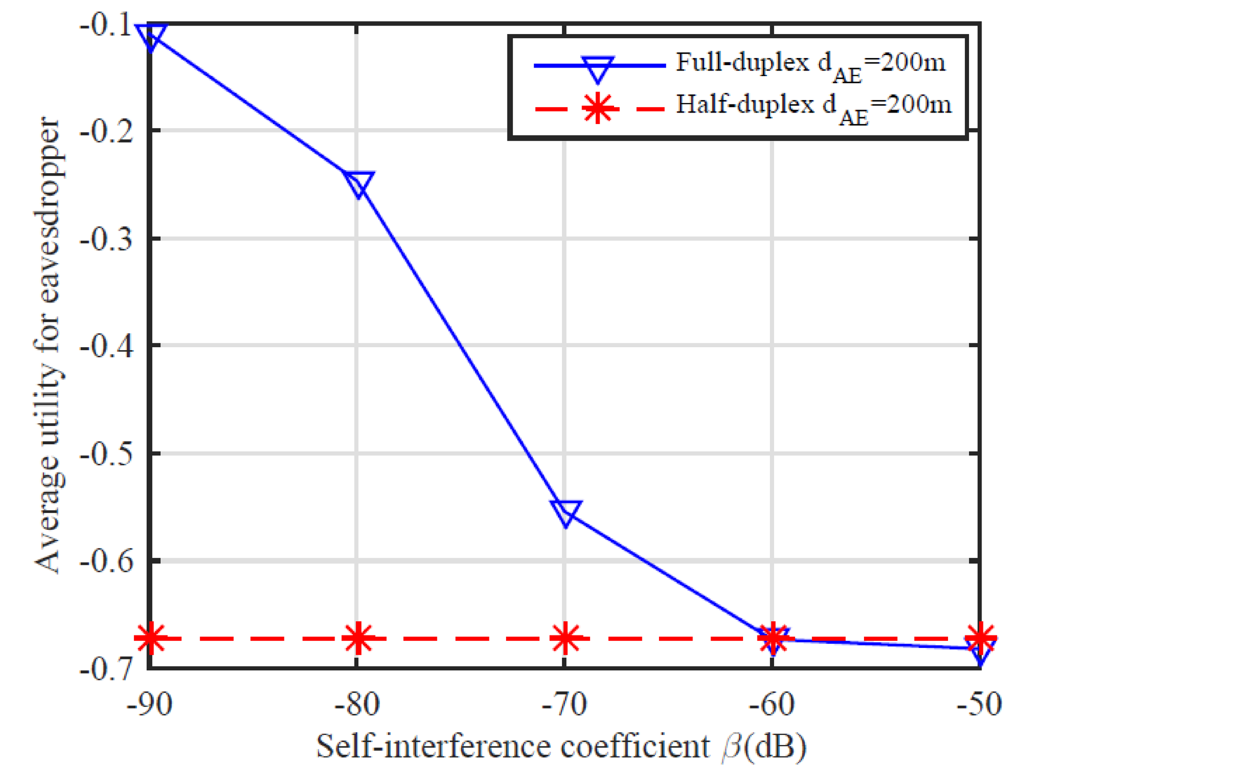

Fig. 2 Average utility for eavesdropper versus self-interference coefficient β

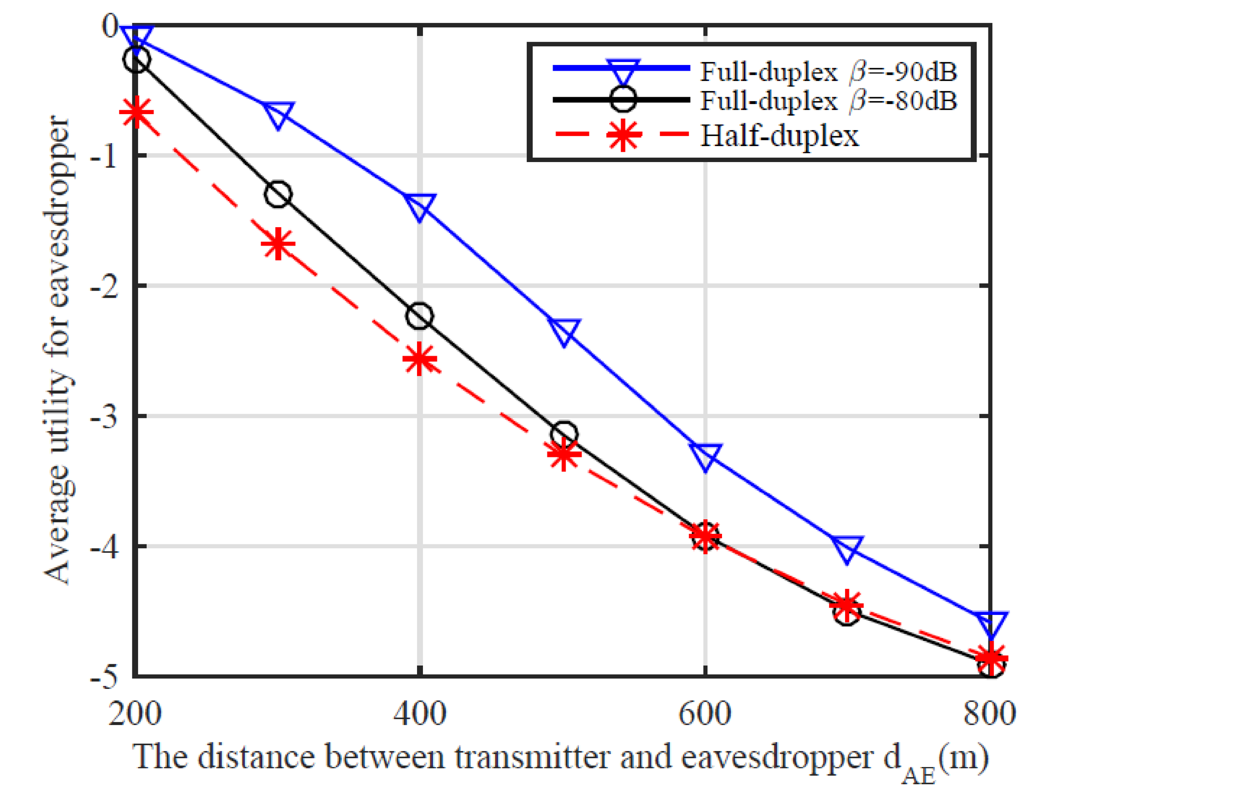

Fig. 3 Average utility for eavesdropper versus distance d_{AE}

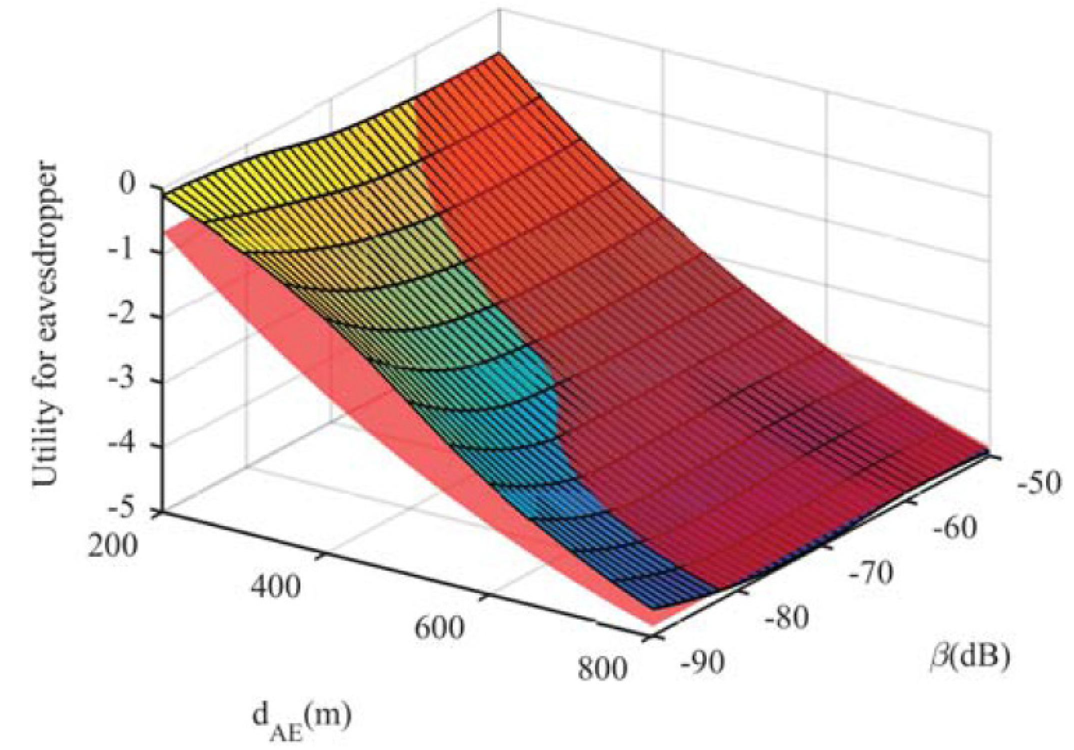

Fig. 4 Average utility for eavesdropper versus β and d_{AE}