Space Power Synthesis-based Cooperative Jamming for Unknown Channel State Information

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CONTENTS

Motivation

Cryptographic approaches VS Physical layer(PHY) security schemes

- **Defects in the cryptographic approaches:**
  - the PHY provides a reliable communication
  - the threat of increasingly powerful computing capacity
- **PHY security schemes:**
  - a complement technology
  - reduce the decoding ability of eavesdroppers

Motivation (cont'd)

- **The existing works:**

  artificial noise

  beamforming

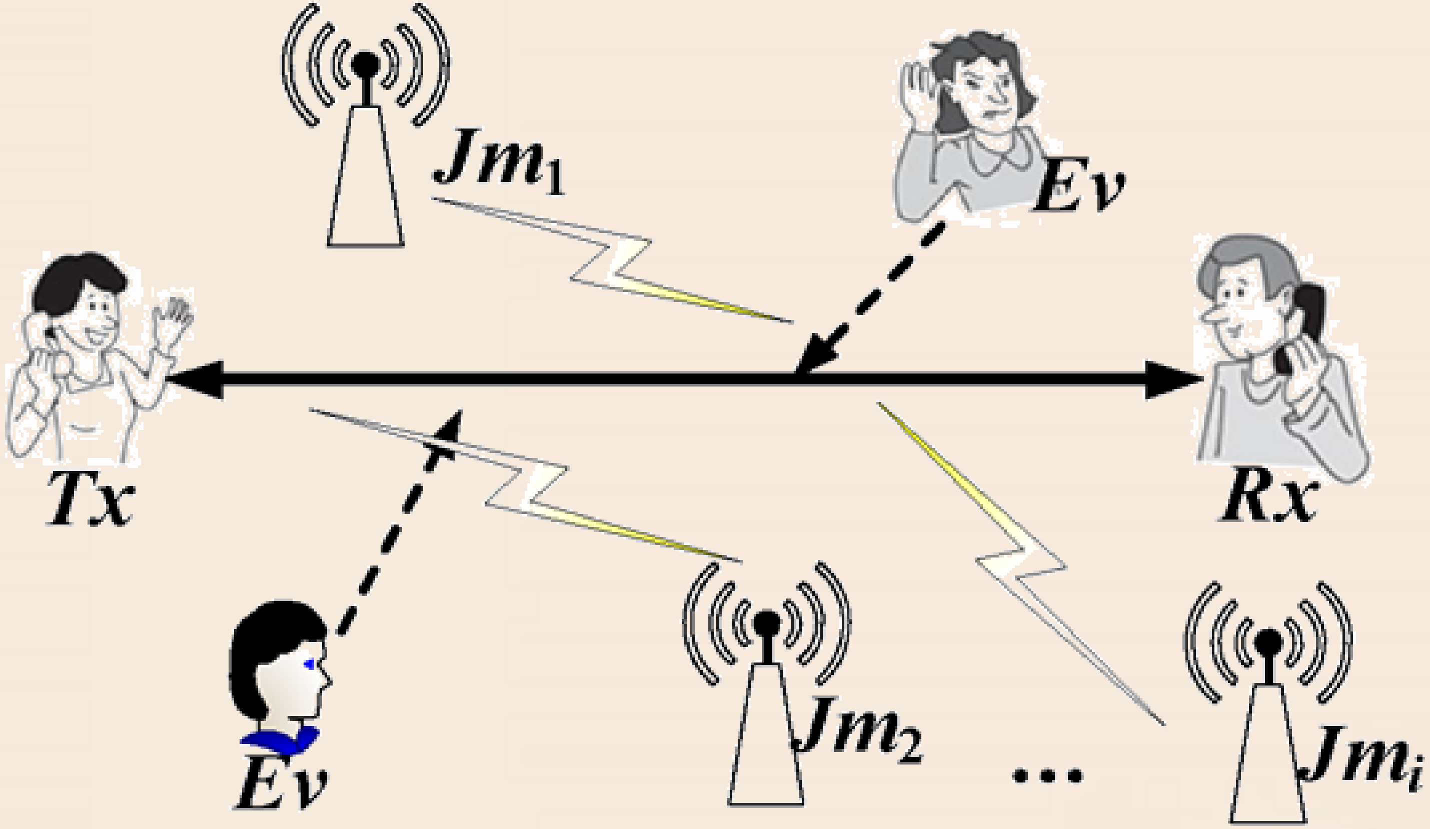
- **Most of them based on kown Channel State Information (CSI)**

- **Our work focus on:**

  Cooperative Jamming for **Unknown CSI**

System Model and Problem Formulation (cont'd)

Tx: Legitimate sender
Rx: Legitimate receiver
Jm_i: Cooperative Jammers
Ev: Eavesdroppers



System Model and Problem Formulation(cont'd)

According to the Poynting theorem, Maxwell equation, and the principle of antenna and electromagnetic wave:

synthetic electric field strength:

$$E = \sum_{i=1}^{n} \frac{15\pi I_i}{r_i} e^{j(\beta r_i + \varphi_i)} e^{j\omega t}$$

synthetic power density:

$$P_r = \frac{1}{2}\mathrm{Re}(E \times H^*) = \frac{E^2}{2\eta}$$

$$\Rightarrow \quad P_r \propto |E|^2$$

Symbol	Meaning
n	The number of the jammers
I_i	The current of the antenna of the Jm_i
r_i	The distance from the Jm_i to the target
φ_i	The initial phase of transmitted signal
β	The parameter for the phase constant
η	The parameter for the wave impedance of the medium
ω	The frequency of transmitted signal
t	The parameter for the time

System Model and Problem Formulation(cont'd)

- **The secrecy rate is defined as:**
- $C_s=\max(C_{Rx}-C_{Ev},0)$
- $=\max(\log(1+SINR_{Rx})-\log(1+SINR_{Ev}),0)$
- **Thus, our objective:**
- **optimize** n, l_i , r_i , φ_i ,
- to minimize synthetic power of jamming signals at Rx

The Existence of Fundamental Solution

- **Lemma 1.** Considering a cooperative jamming system with two friendly jammers, the synthetic power density is proportional to the square of two signal superimposed amplitude, i.e.

$$P_r \propto A_2 = A_1^2 + A_2^2 + 2A_1A_2\cos(\Delta\phi)$$

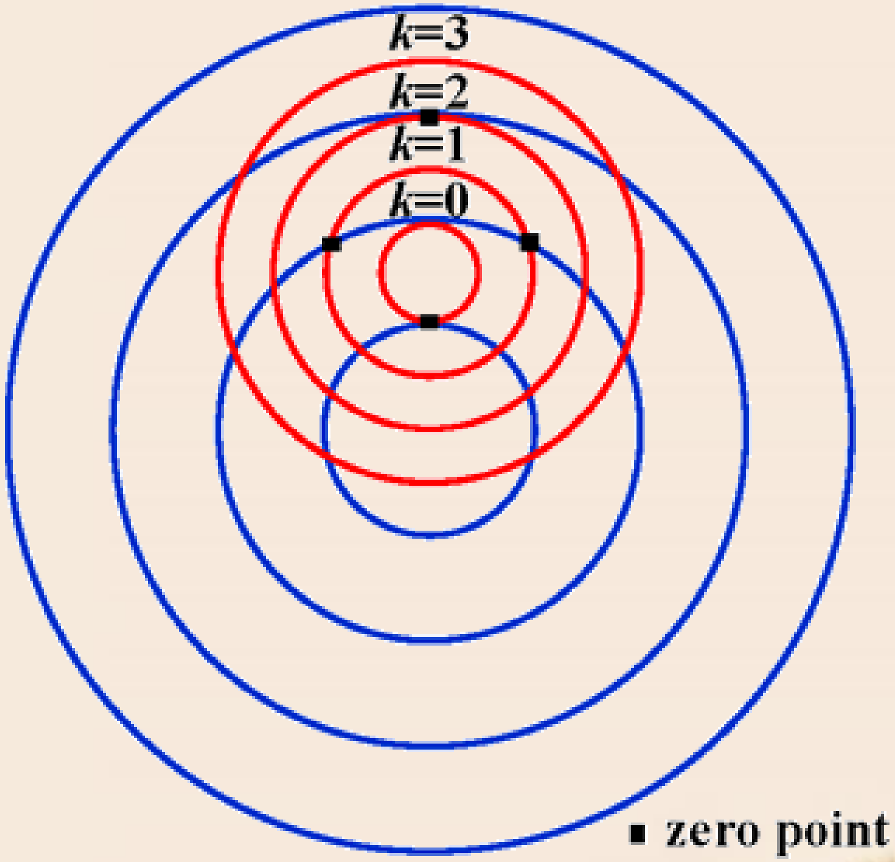
- where $A_i = \frac{15\pi I_i}{r_i}$, and $\Delta\phi = \varphi_2 - \varphi_1 + \beta(r_2 - r_1)$ is the corresponding phase difference.

- **Phase condition**: $\Delta\phi = (2k+1)\pi\,, \quad k \in Z$

- **Amplitude condition**: $\frac{I_1}{r_1} = \frac{I_2}{r_2}$

The Uniqueness of Solution

$$\begin{cases} r_1 = \dfrac{(2k+1)\pi + \varphi_1 - \varphi_2}{\beta(I_2 - I_1)} I_1 \\ r_2 = \dfrac{(2k+1)\pi + \varphi_1 - \varphi_2}{\beta(I_2 - I_1)} I_2 \end{cases}, (k \in Z)$$



The Uniqueness of Solution (cont'd)

Rx is collinear with two jammers

- **Lemma 2.** When there exists a externally-tangent point of two jammers with r1 and r2 based on Phase condition, we cannot find other intersection points along with the increase of k, if and only if

$$\lambda > \lambda_{ext} = d_{Jm1,Jm2} + d_{Rx,Jm1} - d_{Rx,Jm2}$$

- where $d_{Rx,Jm2} > d_{Rx,Jm1}$.

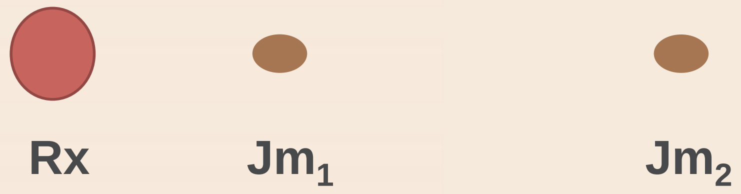
The Uniqueness of Solution (cont'd)

Rx is collinear with two jammers

- **Lemma 3.** When there exists a internally-tangent point of two jammers with r1 and r2 based on Phase condition, we cannot find other intersection points along with the decrease of k, if and only if

$$\lambda > \lambda_{int} = d_{Rx,Jm2} - d_{Rx,Jm1} - \frac{I_2 - I_1}{I_1 + I_2} d_{Jm1,Jm2}$$

- where $d_{Rx,Jm2} > d_{Rx,Jm1}$.

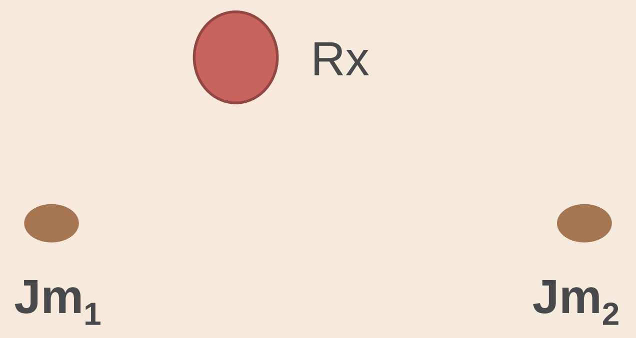


The Uniqueness of Solution (cont'd)

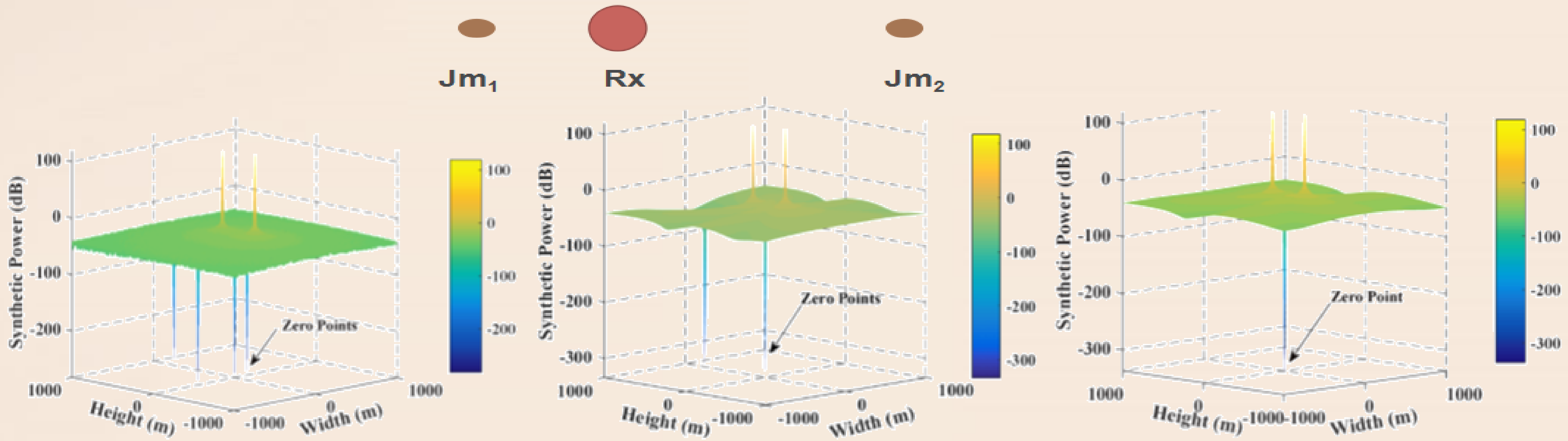
Rx is not collinear with two jammers

- **Lemma 4.** Under the premise of satisfying *Phase condition* and *Amplitude condition*, we can find two intersection points at most along with the changing k, if and only if

$$\lambda > \max(\lambda_{ext},\lambda_{int})$$



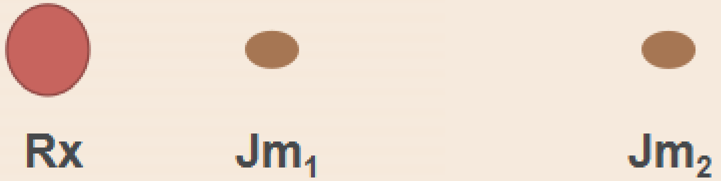
Numerical Simulation Results

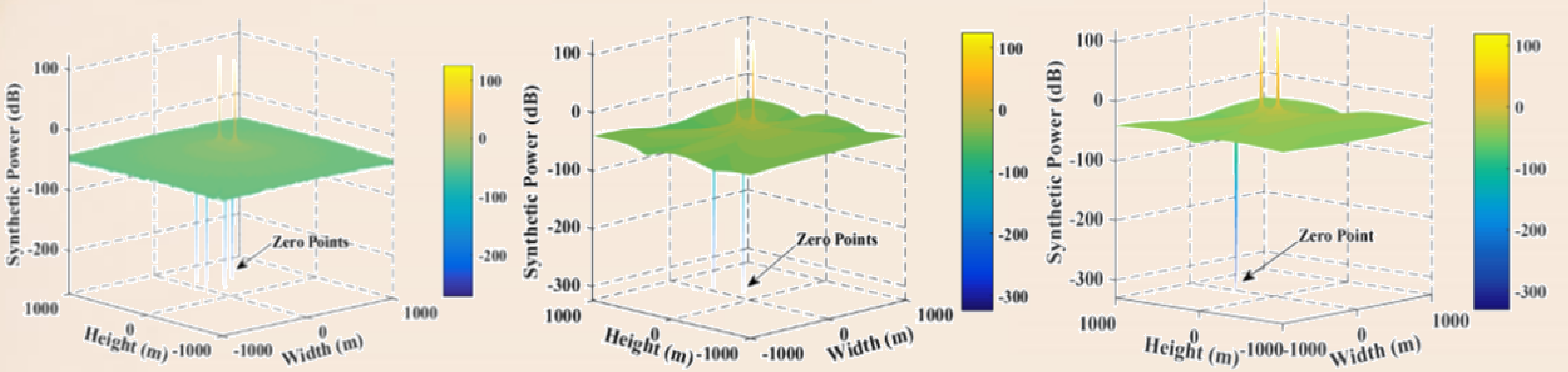


(a) $\lambda = 0.2, \varphi_1 = 999\pi, \varphi_2 = 0$ (b) $\lambda = 300, \varphi_1 = 0, \varphi_2 = \frac{\pi}{3}$ (c) $\lambda = 400, \varphi_1 = 0, \varphi_2 = \frac{\pi}{2}$

Fig. 3. The effect of different λ of jammers on the synthetic jamming power. The simulation parameters are set as follow. Rx, Jm_1, Jm_2 are located at (0,0), (0,150), (0,-250), respectively. Besides, $I_1 = 3A$, $I_2 = 5A$.

Numerical Simulation Results (cont'd)





(a) $\lambda = 0.2, \varphi_1 = 1999\pi, \varphi_2 = 0$ (b) $\lambda = 150, \varphi_1 = \frac{5\pi}{3}, \varphi_2 = 0$ (c) $\lambda = 200, \varphi_1 = \pi, \varphi_2 = 0$

Fig. 4. The effect of different λ of jammers on the synthetic jamming power. The simulation parameters are set as follow. Rx, Jm_1, Jm_2 are located at (0,450), (0,150), (0,-50), respectively. Besides, $I_1 = 3A$, $I_2 = 5A$.

Numerical Simulation Results (cont'd)

Four jammers | **Three jammers**

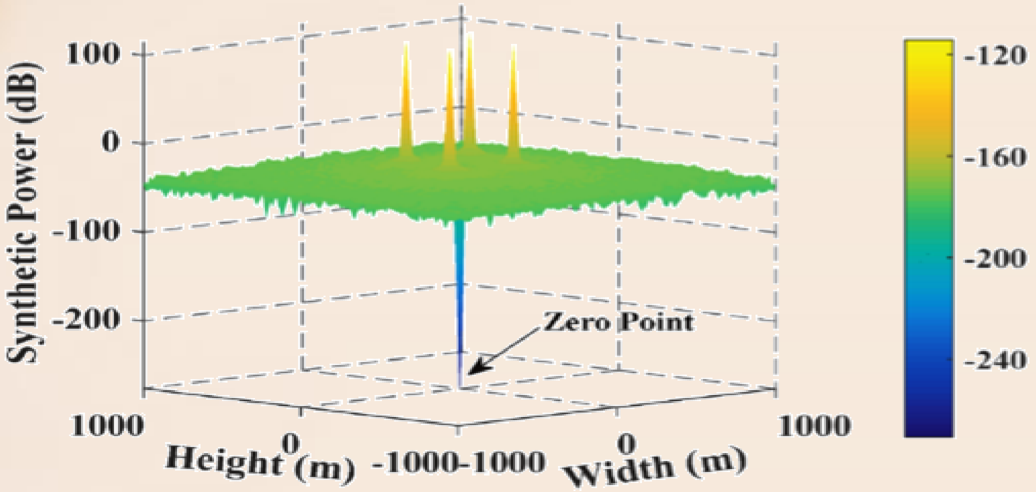


Fig. 5. Synthetic jamming power of four jammers distribution diagram. The simulation parameters are set as follow.Rx,Jm_1,Jm_2,Jm_3, and Jm_4 are located at (0,0),(144,-192),(-256,-192),(-144,192),(256,192), respectively. Besides, $\lambda = 0.4m$, $I_1 = I_3 = 3A$, $I_2 = I_4 = 4A$,$\varphi_1 = \varphi_3 = 0$,$\varphi_2 = \varphi_4 = pi$.

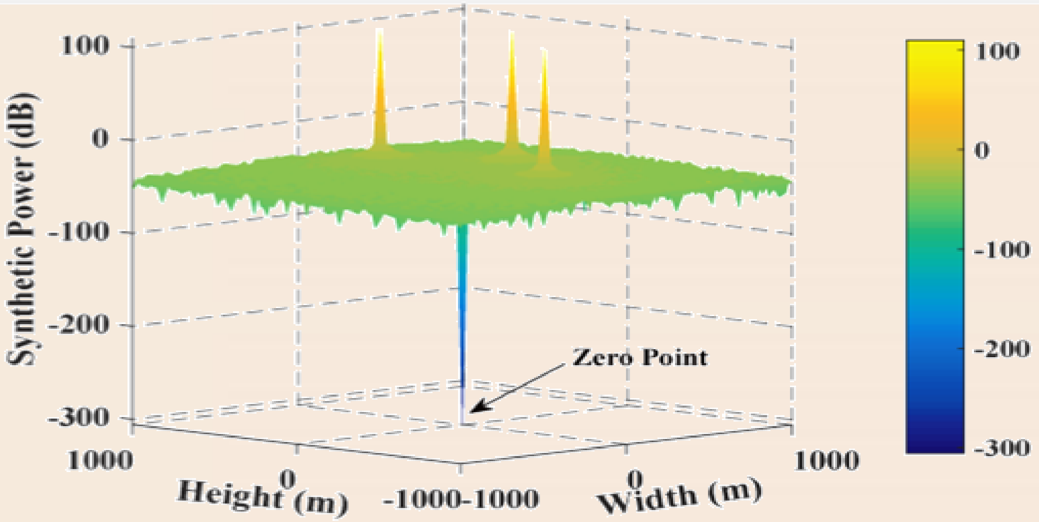


Fig. 6. Synthetic jamming power of three jammers distribution diagram. The simulation parameters are set as follow. Rx, Jm_1, Jm_2, and Jm_3 are located at (0,0), (0,500), (0,-500), (300,0), respectively. Besides,$\lambda = 0.3m$, $I_1 = I_2 = 3A$, $\varphi_1 = \varphi_2 = 0$.

Conclusion and Future Work

- **Conclusion:**
- A novel approach to study jamming
- Based on the space power synthesis
- Without knowing the CSI of the eavesdroppers

- **Future Work:**
- MIMO system
- Power allocation algorithms

THANK YOU