Yangming LOU, Liang JIN, Wenyu JIANG, Shuaifang XIAO, 2023. Joint radio frequency front-end and digital back-end antijamming scheme based on a metasurface antenna array. *Frontiers of Information Technology & Electronic Engineering*, 24(12):1739-1751. https://doi.org/10.1631/FITEE.2300113

Joint radio frequency front-end and digital back-end antijamming scheme based on a metasurface antenna array

Key words: Antijamming; Multiple-input multiple-output; Metasurface antenna array; Independent component analysis

Corresponding author: Liang JIN
E-mail: liangjin@263.net
ORCID: https://orcid.org/0000-0001-6464-6263

Motivation

1. An array's degree of freedom (DoF) determines the number of jamming incidents that can be managed and the antijamming performance.
2. Conventional arrays can improve the DoF only by increasing the number of antennas.
3. When the received signal is digitized, high-power jamming will reduce the number of bits used to represent the desired signal, further increasing the difficulty of back-end antijamming based on digital signal processing.

Method

The metasurface antennas can rapidly switch patterns when receiving signals, so that a single channel can be equivalent to multiple channels and increase the DoF.

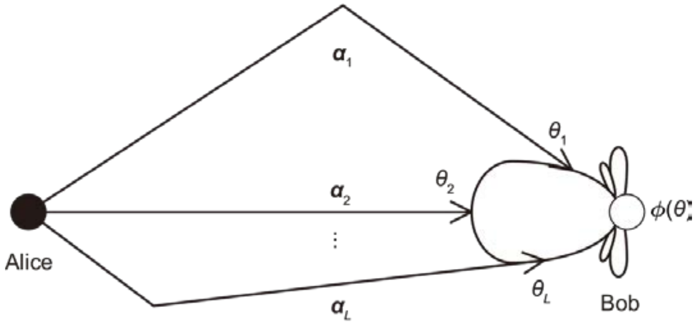

Fig. 1 Paths superposed at the receiving antenna

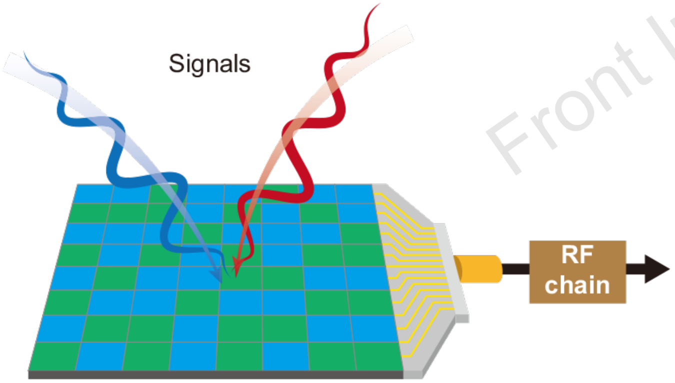

Fig. 2 Structure of a metasurface antenna

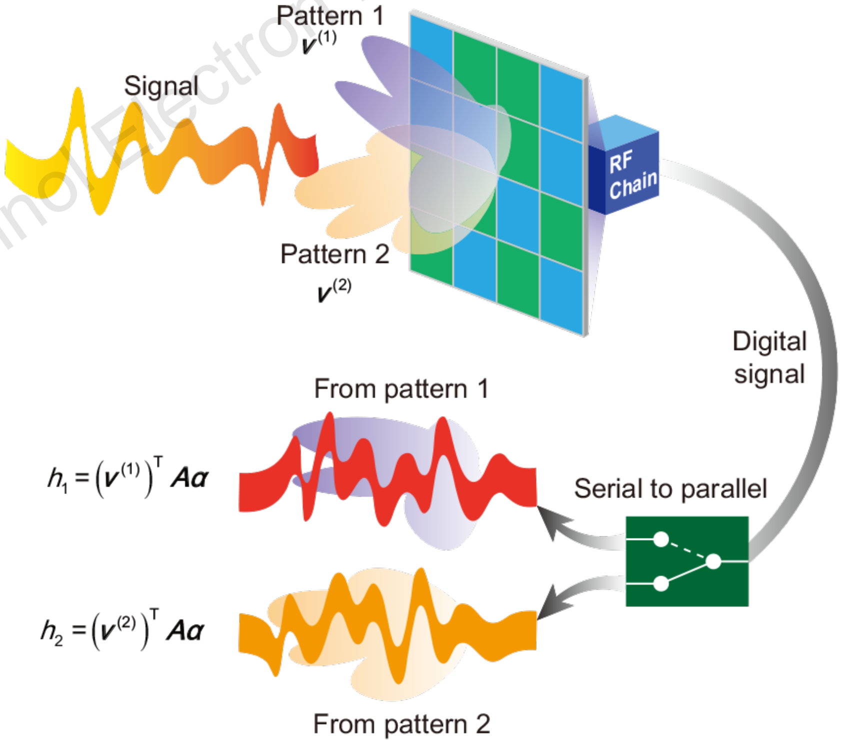

Fig. 4 Signals and jamming signals received by rapidly switching antenna patterns

Method

Independent component analysis (ICA) is used to blindly estimate the channel of the desired signals and the jammings.

Algorithm 1 Iterative algorithm for CNM-ICA

1: Obtain the whitening matrix $\boldsymbol{F}$ according to Eq. (S4) and complete the whitening pre-processing

2: Initialize the separation matrix $\boldsymbol{W} = \boldsymbol{I}$, the number of iterations $i = 1$, and the difference threshold ϵ

3: **repeat**

4:     Update each column of $\boldsymbol{W}$ using Eq. (S11)

5:     Orthogonalize $\boldsymbol{W}$ using Eq. (S12)

6:     $i = i + 1$

7: **until** the difference between $\boldsymbol{W}(i + 1)$ and $\boldsymbol{W}(i)$ is less than ϵ, or the maximum number of iterations is reached

Method

A joint design of the antenna parameters in the space-time domain is performed. By adding a minimum SJR constraint at each antenna, we guarantee sufficient ADC effective bits.

$$\max_{\boldsymbol{u}_{(m)}} \frac{\boldsymbol{u}_{(m)}^{\mathrm{H}} \hat{\boldsymbol{h}}_{(m)} \hat{\boldsymbol{h}}_{(m)}^{\mathrm{H}} \boldsymbol{u}_{(m)}}{\boldsymbol{u}_{(m)}^{\mathrm{H}} \hat{\boldsymbol{H}}_{(m')} \hat{\boldsymbol{H}}_{(m')}^{\mathrm{H}} \boldsymbol{u}_{(m)} + N\sigma^2}$$

$$\text{s.t.} \quad \frac{\left(\boldsymbol{u}_n^{(m)}\right)^{\mathrm{H}} \hat{\boldsymbol{H}}_{\boldsymbol{S}_n} \hat{\boldsymbol{H}}_{\boldsymbol{S}_n}^{\mathrm{H}} \boldsymbol{u}_n^{(m)}}{\left(\boldsymbol{u}_n^{(m)}\right)^{\mathrm{H}} \hat{\boldsymbol{H}}_{\boldsymbol{J}_n} \hat{\boldsymbol{H}}_{\boldsymbol{J}_n}^{\mathrm{H}} \boldsymbol{u}_n^{(m)}} \geq \gamma, \ n=1,2,\cdots,N,$$

$$\left|\boldsymbol{v}_{(m)}\right|^2 \leq 1.$$

Maximum array SJNR

SJR constraint for each antenna

Algorithm 2 Optimization algorithm for metasurface antenna array antijamming

1: Randomly initialize the parameters of the metasurface antenna array $\check{\boldsymbol{V}}$ and receive the desired signals and jammings
2: Separate the desired signals from the jamming using Algorithm 1 and estimate the channel $\hat{\boldsymbol{H}}$
3: Perform the correlation analysis of the separated signals using the reference sequence of the desired signals
4: **if** clear correlation peaks appear and the desired signals can be distinguished from the jammings **then**
5: Go to line 9
6: **else**
7: Back to line 1
8: **end if**
9: Solve the optimization problem (25) for each signal to obtain the array antijamming parameters
10: Use the antijamming parameters to configure the array and received signals, and then separate the desired signals from the jammings using Algorithm 1 again

Method

Simulation results show that the proposed scheme could effectively improve the antijamming performance.

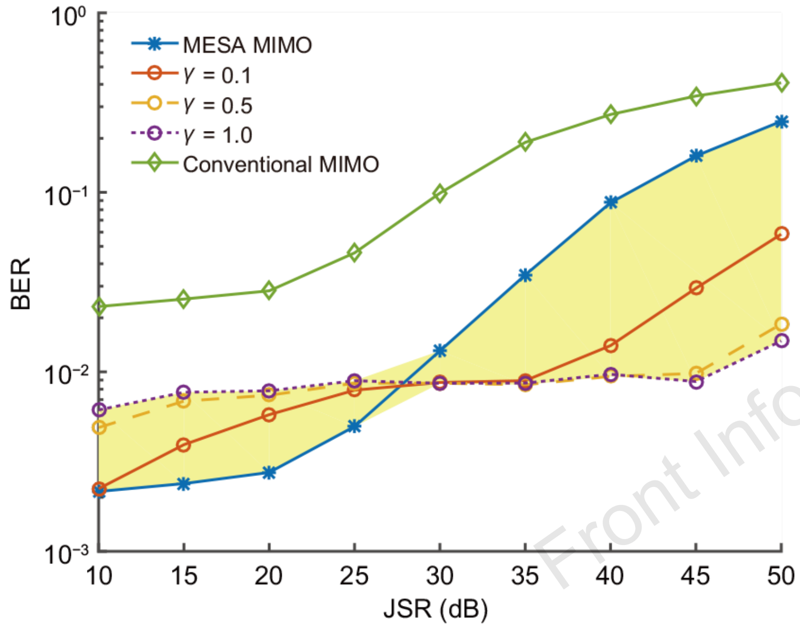

Fig. 7 Bit error rate (BER) of the desired signals vs. the jamming-to-signal ratio (JSR)

For each of the configurations, the BER of the desired signals increases with the increasing JSR. At a high JSR, the suppression of jamming at the antenna can avoid decreasing the number of ADC effective bits

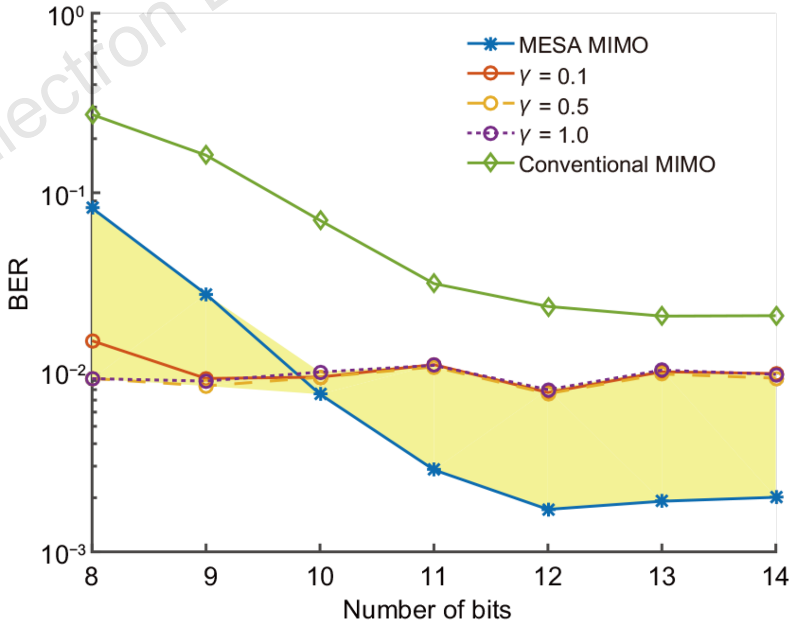

Fig. 9 Bit error rate (BER) of the desired signals vs. the number of ADC quantization bits

The antijamming performance can be effectively improved by suppressing the jamming signals at the front end when the number of ADC quantization bits is small

Conclusions

1. We used the rapidly reconfigurable capability of the metasurface antenna to solve the problem of insufficient DoF.
2. We proposed a parameter optimization method for the metasurface antenna array, which improves the number of ADC effective bits under high-power jamming.
3. Simulation results showed that the proposed scheme could effectively improve the antijamming performance compared with conventional arrays and reduce the BER of the received signals by one order of magnitude.

Yangming LOU received the M.S. degree and Ph.D. degree in information and communication engineering from PLA Strategic Support Force Information Engineering University. He is currently an assistant researcher of PLA Strategic Support Force Information Engineering University. His research interests include physical layer security and wireless communication.

Liang JIN received the Ph.D. degree from Xi’an Jiaotong University. He is currently a Professor and Ph.D. Supervisor of the PLA Strategic Support Force Information Engineering University, Zhengzhou, China. His research interests include wireless communication, physical layer security, and smart antenna.