A Novel Wireless Channel Confusion Technique with Intelligent Reflecting Surface

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***Abstract*—In this paper, we propose a novel intelligent reflecting surface (IRS) based wireless channel confusion technique for energy efficient jamming. Since IRS consists of passive reflecting elements, its amplitude and phase can be changed rapidly. Due to its rapid alternation of passive elements, IRS makes legitimate receiver to acquire wrong channel state information (CSI) by changing effective channel of legitimate network so that the channel at pilot signal slot and at data signal slots are different. As a result, channel confusion technique can effectively degrade the communication performance of legitimate network even legitimate transmitter uses much higher transmit power. The jamming performance of proposed IRS based channel confusion technique is evaluated by extensive computer simulation. Moreover, it is shown that proposed IRS based channel confusion technique is better jamming technique than Gaussian jamming technique.**

***Index Terms*—Intelligent reflecting surface (IRS), Energy efficient jamming, Channel acquisition, Channel confusion.**

I. Introduction

In recent years, intelligent reflecting surface (IRS) has been considered as a technique that enables significant spectrum and energy efficiency improvements for future communication system [1], [2]. More specifically, IRS is a reconfigurable metasurface consists of low-cost passive reflecting elements which reflects signal with changing amplitude adjustment and phase shift. As a result, IRS can control the effective communication channel and helps conventional communication network.

Due to its huge potential that can change the fundamental design method of wireless communication, the main target of IRS is to improve the performance of wireless communication. For example, in [3], total transmit power of access point (AP) is minimized by IRS subject to the signal to interference plus noise ratio (SINR) constraints of users. To minimize transmit power, the active beamforming and passive phase shifts at the IRS are jointly optimized. In [4], IRS was deployed to increase system energy efficiency, where the phase shift of IRS is discrete value for actual implementation. In addition, [5] proposed IRS assisted non-orthogonal multiple access (NOMA) technique for the downlink transmission rate optimization. Based on iterative optimizing algorithm, phase shift element of IRS is designed. Furthermore, for the secure communication, [6] considers achievable secrecy rate as a target performance. For the achievable secrecy rate optimization, both active beamforming of AP and IRS reflection matrix is iteratively optimized.

As [3]–[6], most of literature considers how to enhance the communication performance by exploiting IRS. However, there might be a possibility that take IRS into account as a totally opposite device on wireless communication. If IRS is deployed and its reflection matrix is designed for minimizing received signal to noise ratio (SNR) of legitimate network, it may act as a jammer that can effectively and energy efficiently jam the communication. In [7], as mentioned above, IRS is designed as a *green jammer* that degrades received SNR of legitimate network communication on purpose without any transmit power. However, IRS in [7] need to know channel state information (CSI) between itself and legitimate transmitter (LT) and between itself and legitimate receiver (LR). To know CSI at IRS, IRS need to obtain additional radio frequency (RF) chains and micro-controller need to operate channel acquisition [8]. Furthermore, if RF chains are equipped with IRS, the low-cost advantage vanishes as the number of passive reflecting elements increases.

Therefore, in this paper, we propose an IRS based channel confusion technique for energy efficient jamming. Owing to the fact that passive elements can be change its component rapidly compare to active elements, IRS in channel confusion technique rapidly alternates its reflecting amplitude and phase shift faster than the communication slot time of legitimate network. If IRS changes its reflection matrix faster than slot time, reflection matrix at pilot signal slot and at data signal slot of legitimate network will be different. Eventually, since LR use acquired CSI at pilot signal slot to decode data signal, the difference of effective channel at pilot signal slot and at data signal slot might cause communication error. As a result, that intended communication error by channel confusion of IRS behave as a jammer without transmit power.

Rest of this paper is composed as follows. In section II, the considered system model in this paper and effect of the channel confusion are described with two subsection, respectively. After description, we will show the jamming performance of the proposed IRS based channel confusion by extensive simulation in III. Finally, the conclusion of this paper will be described in IV.

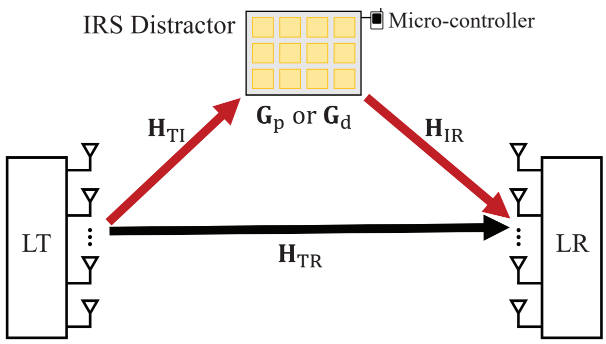

Fig. 1. Considered system model.

II. IRS BASED CHANNEL CONFUSION

In this section, we describe our considered system model and the effect of the IRS distractor on the legitimate network communication where reflection matrix of IRS distractor is alternated with sufficiently fast speed.

A. System Model

First of all, we consider legitimate network (i.e. target network of jamming) consists of a LT and a LR, and jamming network does of a IRS distractor that tries to confuse the communication channel of legitimate network, and a micro-controller to change reflecting matrix of IRS distractor as Fig.1. Each LT and LR are respectively equipped with K transmit and L receive antenna, and IRS distractor is equipped with N passive reflecting elements. Each passive reflecting element can adjust reflecting amplitude and phase shifts of the reflected signal from LT by micro-controller. However, since IRS is not equipped with RF chains, we assume that IRS is not able to acquire CSI between itself and LT or LR. Hence, IRS only can perform controlling operations such as changing the amplitude and the phase of passive reflecting elements without any CSI.

$\mathbf{H}_{\mathsf{TI}} \in \mathbb{C}^{N\times K}$, $\mathbf{H}_{\mathsf{IR}} \in \mathbb{C}^{L\times N}$, and $\mathbf{H}_{\mathsf{TR}} \in \mathbb{C}^{L\times K}$ represent channel coefficients from LT to IRS, from IRS to LR, and from LT to LR, respectively. Moreover, we assume that all elements of $\mathbf{H}_{\mathsf{TI}}, \mathbf{H}_{\mathsf{IR}}, \mathbf{H}_{\mathsf{TR}}$ respectively follows $\mathcal{CN}(0,1)$. In addition, IRS will change the amplitude and the phase of each passive reflecting element rapidly to ensure that the reflection matrix of IRS is different at each pilot signal slot and data signal slot of legitimate communication. Hence, reflection matrix at pilot signal slot and reflection matrix at data signal slot are respectively denoted by $\mathbf{G}_{\mathsf{p}}$, and $\mathbf{G}_{\mathsf{d}}$ which is defined as follows:

$$\mathbf{G}_{\mathsf{p}} = \begin{bmatrix} \alpha_1 e^{j\theta_1} & 0 & \cdots & 0 \\ 0 & \alpha_2 e^{j\theta_2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \alpha_N e^{j\theta_N} \end{bmatrix},$$

$$\mathbf{G}_{\mathsf{d}} = \begin{bmatrix} \beta_1 e^{j\phi_1} & 0 & \cdots & 0 \\ 0 & \beta_2 e^{j\phi_2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \beta_N e^{j\phi_N} \end{bmatrix}, \quad (1)$$

where α_n and β_n represent reflecting amplitude of n-th passive reflecting element at pilot signal slot and at data signal slot. Similarly, θ_n and ϕ_n is phase shift amount of n-th passive reflecting element at pilot signal slot and at data signal slot. Note that all IRS elements (i.e. α_n, β_n, θ_n, and ϕ_n) are generated with completely random manner for fast alternation of reflection matrix. α_n and β_n follow uniform distribution within the range $[0, 1]$ and θ_n and ϕ_n also follow uniform distribution within the range $[0, 2\pi]$.

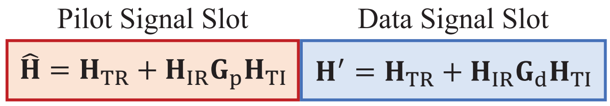

Fig. 2. Acquired communication channel and actual communication channel

B. Effect of Channel Confusion

In the pilot signal slot, received signal of LR can be written as follows:

$$\mathbf{y}_{\mathsf{p}} = \hat{\mathbf{H}}\mathbf{x}_{\mathsf{p}} + \mathbf{n}_{\mathsf{p}} = \left(\mathbf{H}_{\mathsf{TR}} + \mathbf{H}_{\mathsf{IR}}\mathbf{G}_{\mathsf{p}}\mathbf{H}_{\mathsf{TI}}\right)\mathbf{x}_{\mathsf{p}} + \mathbf{n}_{\mathsf{p}}, \quad (2)$$

where $\mathbf{x}_{\mathsf{p}}$, $\mathbf{n}_{\mathsf{p}}$ represent a pilot signal vector from LT, and additive Gaussian noise vector in which all elements follows $\mathcal{CN}(0, N_0)$. Here, since LR does not know the presence of IRS distractor, LR acquire $\hat{\mathbf{H}}$ as a actual communication channel. We assume that perfect CSI can be acquired at legitimate network, so that LT and LR can perform beamforming for communication with perfect CSI, even the CSI possesses distracted channel by IRS.

After pilot signal slot is over, each LT and LR can design its beamforming based on CSI. In this paper, we assume that LT and LR adopts singular value decomposition (SVD) based eigen beamforming as follows:

$$\mathbf{U}\boldsymbol{\Sigma}\mathbf{V}^H = \hat{\mathbf{H}}, \quad (3)$$

where $\mathbf{U} = [\mathbf{u}_1, \cdots, \mathbf{u}_L]$, $\boldsymbol{\Sigma} = \mathsf{diag}\left([\sigma_1, \cdots, \sigma_S]\right)$, and $\mathbf{V} = [\mathbf{v}_1, \cdots, \mathbf{v}_K]$ is a left singular matrix of $\hat{\mathbf{H}}$, a diagonal matrix composed by singular value, and a right singular matrix of $\hat{\mathbf{H}}$, where $S = \mathsf{min}\,(L, K)$. Thus, the transmit beamforming vector of LT and receive beamforming vector of LR are $\mathbf{v}_1$ and $\mathbf{u}_1$, respectively.

After beamforming design is over, data signal will be transmitted from LT to LR. Then, the received signal in data signal slot can be explained as follows:

$$\mathbf{y}_{\mathsf{d}} = \mathbf{H}^{'}\mathbf{v}_1 x_{\mathsf{d}} + \mathbf{n}_{\mathsf{d}} = \left(\mathbf{H}_{\mathsf{TR}} + \mathbf{H}_{\mathsf{IR}}\mathbf{G}_{\mathsf{d}}\mathbf{H}_{\mathsf{TI}}\right)\mathbf{v}_1 x_{\mathsf{d}} + \mathbf{n}_{\mathsf{d}}, \quad (4)$$

where x_{d} and $\mathbf{n}_{\mathsf{d}}$ denote a unit power M-ary QAM modulated data signal and additive Gaussian noise vector at data signal slot in which all elements follows $\mathcal{CN}(0, N_0)$, respectively. Note that elements of IRS changes quicker than the communication channels (e.g. $\mathbf{H}_{\mathsf{TR}}$, $\mathbf{H}_{\mathsf{TI}}$, and $\mathbf{H}_{\mathsf{IR}}$), the difference between $\hat{\mathbf{H}}$ and $\mathbf{H}^{'}$ is only reflection matrix of IRS.

Finally, LR tries to decode data signal based on receive beamforming vector, $\mathbf{u}_1$. However, since reflection matrix of IRS is changed from $\mathbf{G}_p$ to $\mathbf{G}_d$ (i.e. from the reflection matrix at pilot signal slot to the reflection matrix at data signal slot), LR will try to decode data signal with inaccurate CSI as:

$$\hat{x}_{\mathsf{d}} = \frac{\mathbf{u}_1^H}{\sigma_1}\mathbf{y}_{\mathsf{d}} = \frac{\mathbf{u}_1^H}{\sigma_1}\left(\mathbf{H}^{'}\mathbf{v}_1 x_{\mathsf{d}} + \mathbf{n}_{\mathsf{d}}\right). \quad (5)$$

Note that, if reflection matrix of IRS distractor changes slower than communication channel, data signal might also transmitted through the same communication channel of pilot signal slot (i.e. $\hat{\mathbf{H}}$), so that $\hat{x}_{\mathsf{d}} = x_{\mathsf{d}} + \frac{\mathbf{u}_1^H}{\sigma_1}\mathbf{n}_{\mathsf{d}}$. However, in the proposed technique, reflection matrix of IRS distractor alternates quickly. Therefore, the decoded signal $\hat{x}_{\mathsf{d}}$ in (5) possesses error caused by different channel.

III. Numerical Results

In this section, we show the jamming performance of proposed IRS based channel confusion compare to a Gaussian jamming technique and non-jamming environment by showing bit error rate (BER) performance of legitimate network. The jammer with Gaussian jamming technique in this paper is equipped with N multiple antenna and transmit jamming signal which is generated fully random manner that follows $\mathcal{CN}(0, 1)$. The transmit SNR (i.e. transmit power of jammer to noise variance of LR ratio) of jammer in Gaussian jamming is fixed to 15dB for all simulation environment.

Fig.3 shows the BER performance of legitimate network according to transmit SNR (i.e. transmit power of LT to noise variance of LR ratio) with different modulation order, where $N = 6$ for IRS based channel confusion technique and Gaussian jamming technique. Since transmit power of jammer is fixed to 15dB compare to noise variance of LR, jamming performance of Gaussian jamming is slightly better than proposed channel confusion when transmit SNR of legitimate network is low. However, as transmit SNR of legitimate network gets higher, Gaussian jamming technique cannot jams legitimate network enough. Besides, jamming performance of proposed IRS based channel confusion technique is not degraded by increase of transmit SNR of legitimate network. Moreover, proposed IRS based channel confusion technique does not require any power for transmission which is quite energy efficient way for jamming.

Fig.4 shows BER performance of legitimate network according to N where transmit SNR (transmit power of LT to noise variance of LR ratio) equals to 0dB. Since N is the number of passive reflecting elements in channel confusion technique and the number of transmit antennas in Gaussian jamming technique, it does not effect on performance of non-jamming environment. However, we can see that jamming performance of Gaussian jamming does not increase even though the number of transmit antennas is gets higher. Meanwhile, proposed IRS based channel confusion technique gets higher jamming performance as the number of reflecting elements increases. Therefore, from the simulation results, we can see that channel confusion technique is more appropriate technique for energy efficient jamming, if the number of reflecting elements are sufficiently large.

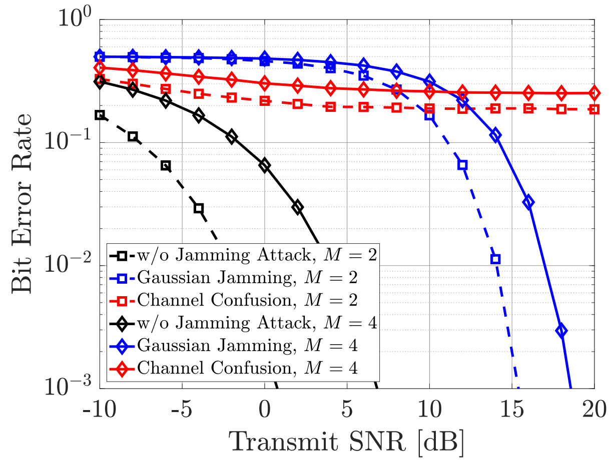

Fig. 3. BER performance of legitimate network according to transmit SNR

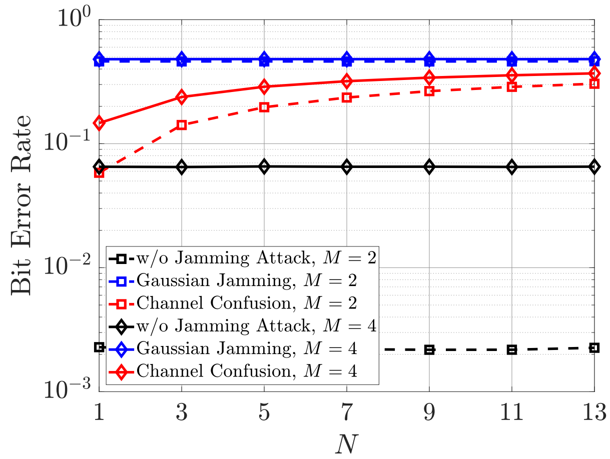

Fig. 4. BER performance of legitimate network according to N

IV. Conclusion

In this paper, we proposed intelligent reflecting surface (IRS) based channel confusion technique for energy efficient jamming. In IRS based channel confusion technique, IRS changes its reflection matrix (i.e. amplitude and phase of passive reflecting element) with fully random manner rapidly. By rapid alternation of reflection matrix, acquired channel state information (CSI) of legitimate network is no longer useful to decode data. Eventually, if legitimate receiver tries to decode data with expired CSI, bit error occurs more often. The jamming performance of proposed channel confusion is evaluated with bit error ratio (BER) of legitimate network. Even though channel confusion technique does not use any transmit power, it is shown that jamming performance of channel confusion is better than Gaussian jamming technique especially, transmit SNR of legitimate network is high.

V. ACKNOWLEDGEMENTS

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