Int. J. Electron. Commun. (AEÜ) 72 (2017) 225–233

Contents lists available at ScienceDirect

International Journal of Electronics and Communications (AEÜ)

journal homepage: www.elsevier.com/locate/aeue

Regular paper

A novel anti-intercepting wireless communication scheme

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ARTICLE INFO

Article history:
Received 16 August 2016
Accepted 10 December 2016

Keywords:
Anti-intercepting
Mixed signal
Frequency efficiency
Gibbs sample

ABSTRACT

In this paper, a novel wireless communication scheme is proposed, which has high anti-intercepting ability without the frequency efficiency loss. In this scheme, we use the baseband mixed signal to construct the transmission signal, which is consisted of two independent and useful baseband signals. According to our analysis, we find that the baseband mixed signal transmission scheme can achieve higher anti-intercepting ability than the existing mixed signal schemes, and it can achieve high frequency efficiency since the mixed signals carry useful information simultaneously. We also provide a low-complexity reception algorithm based Gibbs sampling for the proposed scheme. According to simulation results, we demonstrate that the proposed scheme is effective, and validate its anti-intercepting ability.

1. Introduction

In traditional wireless communication, the transmission signals are allocated in the orthogonal resource in time domain, frequency domain, code domain or spatial domain, and the signal characteristics are perfectly reserved to recover the initial information at the receiver. Due to the broadcast nature of wireless channel, a passive eavesdropper can intercept the transmission signals without risk when it locates in the "earshot" of the wireless transmission, which will give rise to information leakage.

At present, the analysis of physical layer security has been widely developed [1,2], and many auxiliary schemes have been proposed to improve the anti-intercepting ability, which can be divided into two branches: resource domain and signal domain processing. The former adjusts different communication resources to increase the difficulty of acquiring signals for the eavesdropper in different scenarios, including power allocation [3–5], time allocation [5], antenna selection [5,6], beamforming [7,8] and relaying protocol switch [9,10]. The latter mixes the expected signal with the other signal (artificial noise or useful signal) to deteriorate the quality of the receiving signals for the eavesdropper. The signal-domain processing is independent of the resource domain processing, and they can be applied at the same time [8,9]. This paper mainly focuses on the signal domain processing, several mixed signal based communication schemes have been proposed [11–16]. In [11,12], the artificial noise based methods are studied, which generate artificial noise to impair the channel between the transmitter and intruder. In respect that the artificial noise does not carrier any useful information, these schemes essentially sacrifice the frequency efficiency to obtain the anti-intercepting ability. To achieve the similar frequency efficiency with traditional wireless communication in the anti-intercepting applications, the physical-layer network coding and paired carrier multiple access technologies are proposed [13–16]. In these schemes, the transmitter and receiver simultaneously transmit the useful signals in the same frequency, which are mixed in the air. The air mixed signal is difficult to be intercepted for non-cooperative receiver, especially in single-channel receiving scenario. While it is proved that the air mixed signal is separable for any receiver when the number of receiving antennas is large enough and the distance between antennas is far enough. That is, the air mixed schemes cannot prevent from multi-channel intercepting algorithms. Besides, the air mixed schemes require the cooperation between the transmitter and the receiver, which will cause additional information transmission in the non-symmetry communication system.

To overcome the shortages of the existing mixed signal schemes, we propose a novel wireless communication scheme, which uses two independent data flows to generate the baseband mixed signal at the transmitter, and the mixed signal is transmitted to the destination through single common wireless channel. Different from the artificial noise schemes, we use two parallel information flows to construct the mixed signal. Thus, our method can achieve the same frequency efficiency with traditional communication system. Different from the air mixed schemes, the rank of the receiving matrix is always equal to 1 for the baseband mixed signals in all scenarios. Thus, the multi-channel intercepting algorithms are invalid for the proposed scheme. Compared with the air

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http://dx.doi.org/10.1016/j.aeue.2016.12.010
1434-8411/

mixed signal, the difference between the mixed signals is smaller in the proposed scheme, so our scheme can better prevent from the single-channel intercepting algorithms. For the proposed scheme, we provide a low-complexity reception algorithm with Gibbs sampling and QRD-M decomposition. According to analysis and simulation results, our method can provide excellent anti-intercepting ability with acceptable complexity for practical applications.

The rest of the paper is organized as follows. Section 2 describes the system model of the baseband mixed signal and analyzes its performance. Section 3 introduces a reception algorithm and analyses its complexity. Simulation results and conclusion are discussed in Sections 4 and 5, respectively.

2. The system model and performance analysis

2.1. System model

The generation process of the baseband mixed signal is shown in Fig. 1.

In Fig. 1, $a_{1,n}$ and $a_{2,n}$ are two independent and useful binary data streams, which are mapped to the modulation data $s_{1,n}$ and $s_{2,n}$ by the constellation mapping, including MPSK and MQAM. The discrete data $s_{1,n}$ and $s_{2,n}$ are transformed into the continuous signals, $s_1(t)$ and $s_2(t)$, by the pulse shaping filter. After $s_2(t)$ is delayed by τ, $s_1(t)$ and $s_2(t-\tau)$ are mixed to generate the baseband mixed signal $s(t)$. Finally, the baseband mixed signal is upconverted and transmitted. $s_f(t)$ can be expressed as

$$s_f(t) = e^{j(2\pi f_c t+\varphi)}[s_1(t) + s_2(t-\tau)] = e^{j(2\pi f_c t+\varphi)}\left(\sum_n s_{1,n}g_1(t-nT) + \sum_n s_{2,n}g_2(t-nT-\tau)\right) \quad (1)$$

where f_c is the carrier frequency, φ is the initial phase, $s_{i,n}$ is the nth symbol of the ith signal, $g_i(t)$ is the pulse shaping filter.

Through the wireless channel, the receiving signal is written as

$$y_b(t) = s_f(t) \otimes h(t) \quad (2)$$

Without loss of generality, the channel response is considered be invariable in a short time. Thus, (2) can be rewritten as

$$y_b(t) = h_b e^{j2\pi\Delta f_b t}[e^{j(2\pi f_c t+\varphi)}(s_1(t-d) + s_2(t-\tau-d))] + \upsilon(t) = h_b e^{j(2\pi(f_c+\Delta f_b)t+\varphi)}\left(\sum_n s_{1,n}g_1(t-nT-d) + \sum_n s_{2,n}g_2(t-nT-\tau-d)\right) \quad (3)$$

where Δf_b is the frequency offset, d is the transmission delay.

2.2. The performance analysis

At present, the anti-intercepting communication schemes are based on the mixed signal, including the artificial noise based schemes [11,12], physical-layer network coding based schemes [13,14] and paired carrier multiple access based schemes [15,16]. In this paper, we will analyze the advantages of the proposed scheme compared with the existing schemes.

2.2.1. The frequency efficiency analysis and comparison

In the artificial noise based schemes, the expected signal is mixed with the artificial noise. The receiving signal can be written as

$$y_a(t) \approx h_{1,a}e^{j2\pi\Delta f_{1,a}t}[e^{j(2\pi f_c t+\varphi_1)}s_{1,a}(t-d_1)] + h_{2,a}e^{j2\pi\Delta f_{2,a}t}[e^{j(2\pi f_c t+\varphi_2)}n(t-d_2)] + \upsilon(t) \quad (4)$$

where $s_{1,a}$ is the expected signal, $n(t)$ is the artificial noise, $\upsilon(t)$ is the channel noise, $\Delta f_{i,a}$ is the frequency offset, $h_{i,a}$ is the channel gain, and d_i is the transmission delay. In (4), $n(t)$ does not carry any useful information. Therefore, the frequency efficiency can be expressed as

$$\eta_a = \frac{h_{1,a}s_{1,a}(t)}{h_{1,a}s_{1,a}(t) + h_{2,a}n(t) + \upsilon(t)} \approx \frac{h_{1,a}s_{1,a}(t)}{h_{1,a}s_{1,a}(t) + h_{2,a}n(t)} \quad (5)$$

In (5), η_a is always smaller than 1. That is, the artificial noise based schemes sacrifice the frequency efficiency to improve the anti-intercepting ability.

Reviewing (3), both $s_1(t)$ and $s_2(t)$ carry useful information, then the frequency efficiency of the proposed scheme may be expressed as

$$\eta_b = \frac{h_b[s_1(t) + s_2(t)]}{h_b[s_1(t) + s_2(t)] + \upsilon(t)} \approx \frac{h_b[s_1(t) + s_2(t)]}{h_b[s_1(t) + s_2(t)]} = 1 \quad (6)$$

We can conclude that show that the proposed scheme can achieve higher frequency efficiency than the artificial noise based schemes from (5) and (6).

In the physical-layer network coding based schemes and paired carrier multiple access based schemes, the transmitter and receiver simultaneously transmit the useful signals in the same frequency, which are mixed in the air. The schemes are called for the air mixed schemes. Then, the receiving signal can be written as

$$y_{air}(t) \approx h_{1,air}e^{j2\pi\Delta f_{1,air}t}[e^{j(2\pi f_c t+\varphi_1)}s_1(t-d_1)] + h_{2,air}e^{j2\pi\Delta f_{2,air}t}[e^{j(2\pi f_c t+\varphi_2)}s_2(t-d_2)] + \upsilon(t) \quad (7)$$

where $h_{i,air}$ is the channel gain, $\Delta f_{i,air}$ is the frequency offset, d_i is the transmission delay, $s_1(t)$ is the transmission signal by the transmitter, and $s_2(t)$ is the transmission signal by the receiver. In respect that $s_1(t)$ and $s_2(t)$ carry useful information, the frequency efficiency can be expressed as

$$\eta_{air} = \frac{h_{1,air}s_1(t) + h_{2,air}s_2(t)}{h_{1,air}s_1(t) + h_{2,air}s_2(t) + \upsilon(t)} \approx \frac{h_{1,air}s_1(t) + h_{2,air}s_2(t)}{h_{1,air}s_1(t) + h_{2,air}s_2(t)} = 1 \quad (8)$$

From (6) and (8), it is known that the frequency efficiency is the same between the proposed scheme and the air mixed schemes.

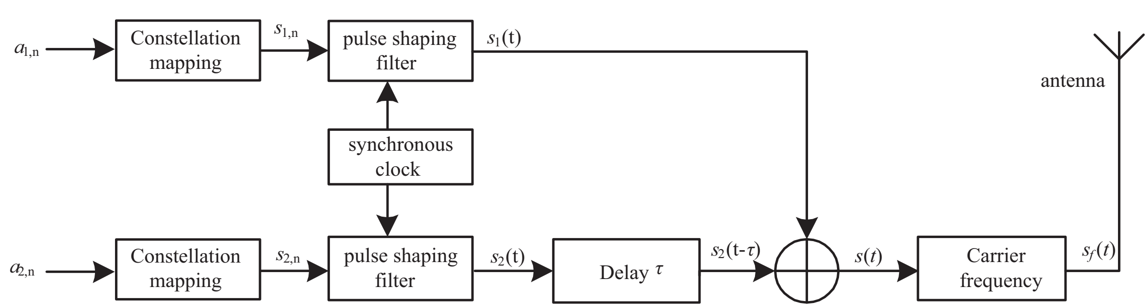

Fig. 1. The generation process of the baseband mixed signal.