Anti-interference of Wireless Communication Signals Based on Integrated Sensing and Communication

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Abstract. Wireless communication for UAVs is becoming increasingly important with its development. However, because wireless communication relies too much on the openness of wireless channels and environments, there is a problem of low anti-interference. Therefore, this article aims to analyze previous research on using integrated sensing and communication methods to eliminate self-interference and to improve the anti-interference ability of UAV wireless communications. Combining integrated sensing and communication technology and combining it with orthogonal frequency division multiplexing technology can suppress self-interference signals, thereby improving the UAV signal quality and the UAV's anti-interference capability. The research results show that after obtaining the three-dimensional radar simulation, it is concluded that when the distance between the perceived targets is large, the influence of self-interference signals can be effectively eliminated; however, when the distance between the perceived targets is small, only part of the self-interference signals can be eliminated. Applying Integrated Sensing and Communication to wireless communication between drones in the air can effectively alleviate the limitations of Integrated Sensing and Communication on the ground; combining Integrated Sensing and Communication with orthogonal frequency division multiplexing can be more effective in eliminating inter-symbol interference and inter-carrier interference.

Keywords: Wireless communication, UAV,Anti-interference.

1. Introduction

In recent years, drone technology has developed rapidly and been widely used. The market size of drones has expanded, and the technology has improved. It is also more widely used in various application fields, such as aerial photography, agriculture and disaster detection. However, UAVs still have many problems, such as the variety of interference sources faced by UAVs, insufficient accuracy of interference detection, complexity of interference estimation and elimination, over-reliance on wireless channels and the openness of wireless channels. Wait [1]. Therefore, in order to enhance the anti-interference ability of UAV wireless communication, it is necessary to improve the quality of UAV wireless communication [2] .

Compared with wired communication, wireless communication is more flexible and convenient, makes it easy to cross various physical obstacles, and has mobility. Compared with traditional ground wireless communications, aerial drone wireless communications have higher mobility, flexibility, invulnerability, and wider communication coverage. Although wireless communication of drones has many advantages, there are also some shortcomings, such as communication bandwidth limitations, low security, and vulnerability to external interference and attacks. Research by Yao Changhua and others proposed improving the stability of the channel by strengthening the channel selection strategy. Still, this issue requires further discussion on how to divide the channels [3]. The research by Li Boyang and others proposed a hill-climbing algorithm based on the win or fast learning strategy. This algorithm effectively reduces the interference-to-signal ratio, but the method is relatively complex and there is room for simplification [4]. The research by Wu Zhijuan and others proposed to combine the deep double Q learning method and use distributed training to complete distributed decision-making for anti-interference communication, but its performance in an environment with simple interference environment is relatively ordinary [5].

This article aims to analyze the anti-interference process of UAV's wireless communication, with the purpose of improving the anti-interference performance of UAV when the anti-interference performance of UAV's wireless communication is known to be low. This time, integrated sensing and communication technology will be used to suppress self-interference signals at a lower level, thereby enhancing the drone's anti-interference ability. If there is malicious signal interference in the original wireless communication mode of the drone, the drone will be severely interfered. However, according to the self-interference signal echo model based on OFDM-based ISAC, the wireless communication of UAVs can be optimized to suppress self-interference. For this purpose, this article uses the least squares algorithm. The results were obtained after conducting simulations and discussed in this article. It eliminates the self-interference component of signal interruption, enhancing the anti-interference ability of UAV wireless communication.

2. Introduction to enhancing anti-interference performance

2.1. Introduction to theoretical methods

At present, integrated sensing and communication (ISAC) technology, as one of the key technologies of 6G signals, has received widespread attention from the academic community [6].Integrated Sensing and Communication refers to integrating communication and perception functions so that the communication system can perceive and understand the information of the surrounding environment and adjust communication parameters and behaviors based on the perception results. This integrated design can improve the intelligence and adaptability of the communication system, thereby enhancing communication's reliability, security and efficiency. At present, integrated communication and sensing systems are mostly used in ground scenarios, which still have many limitations, such as obstruction by obstacles and high requirements for transmission signal power. To alleviate the above limitations, UAVs can be used as ISAC platforms in the air to achieve mutual benefit between communication systems and sensing performance.

In the field of traditional communications, Orthogonal Frequency Division Multiplexing (OFDM) is widely used [7] In terms of perception, the large bandwidth characteristics of orthogonal frequency division multiplexing can improve the distance resolution of perception detection. Therefore, combining OFDM and ISAC can more effectively achieve Integrated Sensing and Communication [8]. The OFDM-based ISAC platform can fully use spectrum resources, expand the sensing range and improve the sensing effect. The specific method is to eliminate the influence of communication data on the waveform at the receiving end, then perform discrete Fourier transform on the symbol, and perform inverse discrete Fourier transform on the carrier to obtain the speed and distance information of the detection target [9].

In actual communications, self-interference signals with short transmission distance and high power will strongly interfere with useful signals, thereby affecting the performance of the ISAC system. Therefore, self-interference cancellation is crucial for perception [10].

2.2. Build the model

This paper constructs an echo model containing self-interference signals and proposes a digital domain self-interference elimination solution on this basis. This method uses the least squares method to estimate the amplitude of the self-interference signal, and subtracts the self-interference signal from the received signal after reconstructing the self-interference signal to achieve suppression of the self-interference signal. However, it is still difficult to effectively suppress multipath channels using the least squares method to suppress self-interference [11].

If each OFDM symbol has N subcarriers and the subcarrier spacing is △f, then the band signal of the mth OFDM symbol at the transmitter can be expressed as

$$x_m(t) = \sum_{n=0}^{N-1} a_m(n) e^{j2\pi n \triangle f t} \eta(t - mT) \tag{1}$$

If M consecutive OFDM symbols form a transmitted signal, it is the carrier frequency. After up-conversion, the above equation can be expressed as

$$\sum_{m=0}^{M-1} x_m(t)e^{j2\pi f_c t} \tag{2}$$

Assume that K targets reflect the transmitted OFDM signal to the receiving end, where the distance and relative speed of the i-th target are Ri and vi, respectively. Assuming that the antenna distance between the transmitter and the receiver is known and less than Ri, then the receiver signal can be expressed as

$$y(t) = \sum_{i=1}^{k} \beta_i\, x(t-\tau_i)e^{j2\pi f_i t} + \beta_o x(t-\tau_0) + w(t) \tag{3}$$

$\beta_o x(t-\tau_0)$ is the self-interference signal, w(t) is the complex Gaussian white noise.

The phase rotation within an OFDM symbol period can be approximated as a constant, where y(t) is approximately

$$y(t) = \sum_{i=1}^{k}\sum_{m=0}^{M-1} \quad \beta_i x(t-\tau_i)e^{j2\pi \bar{\mathrm{f}}_i T} + \beta_o x(t-\tau_0) + w(t) \tag{4}$$

Use the sampling frequency Ts=T/N to sample the callback, and after removing the CP, the sampled signal can be obtained, and the discrete Fourier transform of the sampled signal can be obtained

$$r_m(n) = \sum_{i=1}^{k} \beta_i\, a_m(n)e^{-2\pi\triangle f\tau_i}e^{i2\pi m \bar{\mathrm{f}}_i T} + \beta_0 a_m(n)e^{-j2\pi n\triangle f\tau_0} + w_m(n) \tag{5}$$

$\beta_0 a_m(n)e^{-j2\pi n\triangle f\tau_0}$ is the self-interference signal.

The signal contains distance and speed information of K targets, but there are also self-interference signals, and the strength of the self-interference signal is large, which will cause the received distance and speed to be false.

2.3. Introduction to solutions and algorithms

In order to eliminate the impact of self-interference on target perception, this paper proposes a self-interference elimination method based on the least squares method. After reconstructing the self-interference signal, the reconstructed digital domain self-interference signal is subtracted from the received signal.

First, put the received signal in Ctrip matrix form, let R define the vectors β, vi, di, then we get

$$R = A \odot \left(\sum_{i=1}^{K} \beta_i\, v_i \otimes d_i^T\right) + A \odot \left(\beta_0 v_0 \otimes d_0^T\right) + W \tag{6}$$

$A \odot (\beta_0 v_0 \otimes d_0^T)$ is the self-interference signal.

By performing element-level division on R in the above formula to eliminate the modulated signal, Z can be further expressed as

$$Z = \sum_{i=1}^{K} \beta_i\, v_i \otimes d_i^T + \beta_0 v_0 \otimes d_0^T + N \tag{7}$$

Then, vectorize Z, we can get

$$z \triangleq ve\,c(Z) = \sum_{i=1}^{K} \beta_i\, d_i \otimes v_i + \beta_0 d_0 \otimes v_0 + ve\,c(N) \tag{8}$$

At this time, only the amplitude β0 of the self-interference signal needs to be obtained to reconstruct the self-interference signal, that is, to suppress the influence of the self-interference signal.

The complex amplitude β0 of the self-interference signal can be obtained as follows.

$$\hat{\beta}_0 = arg \min_{\beta} \parallel z - \beta a_0 \parallel^2 \tag{9}$$

Self-interference cancellation is completed by subtracting the reconstructed digital domain self-interference signal from the received signal z.

$$\tilde{z} \triangleq z - z_{SI} \tag{10}$$

In order to obtain three-dimensional radar images, a two-bit discrete Fourier transform algorithm based on frequency domain element-level division is used to process the received signals before and after self-interference elimination.

Assume that the distance Rsr between the transmitting antenna of the airborne Integrated Sensing and Communication system and the radar receiving antenna is 1m, there are two sensing targets in front, and the distances are the same. RT target 1 has a relative speed of 0m/s, target 2 has a relative speed of 10m/s, and the target callback power Calculate using the radar equation:

$$P_{Rx} = \frac{P_{Tx} G \sigma_{RCS} \lambda^2}{(4\pi)^3 R_T{}^4} \tag{11}$$

The signal-to-interference-to-noise ratios of the callbacks of the two targets are equal. It is inferred that when the equivalent distance of the delay difference is small, the degree of coupling is low.

3. Prediction and analysis of simulation results

If RT is large, there is no coupling in the radar image, and the influence of the self-interference signal in the radar image can be removed entirely through SIC processing; if the RT size is moderate, there is a particular coupling in the radar image, and the influence of the self-interference signal in the radar image can be completely removed through SIC processing. The influence in the graphics; if RT is too small, it has strong coupling, and the influence of the self-interference signal in the radar graphics can be initially removed through SIC processing, but some self-interference signals still remain.

According to the experimental results of Ye Qibin, Xiao Hongyu, Tian Chen and others, the following figure can be obtained [9].

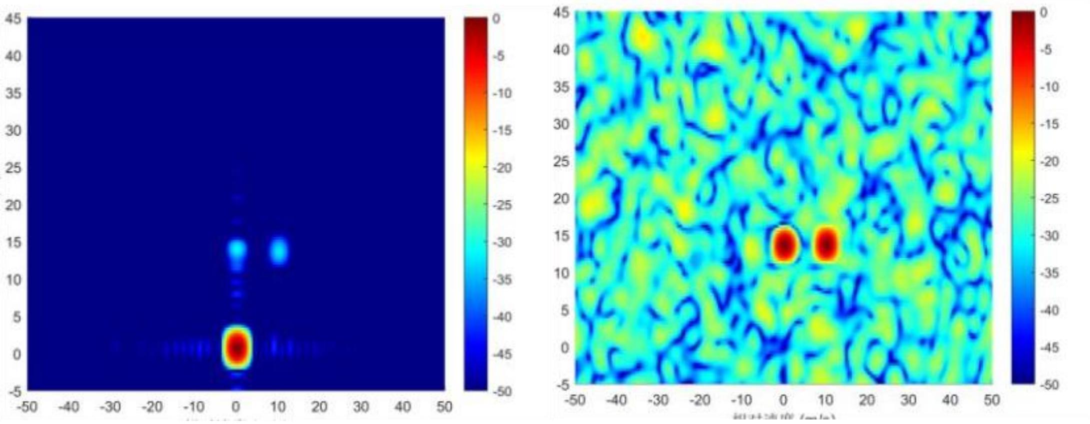

Fig.1 At RT=13.38m, the images before and after SIC processing [9]

When RT=13.38m, the left picture is the radar image before SIC processing, and the right picture is the image after processing (Fig.1). If RT is large, there is no coupling in the radar image, and the influence of self-interference signals in the radar image can be completely removed through SIC processing.

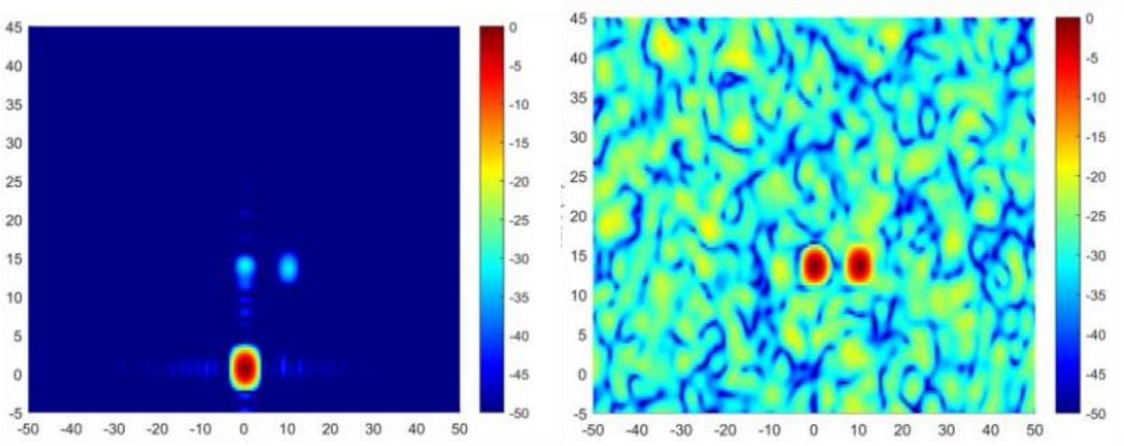

Fig.2 At RT=3.72m, the images before and after SIC processing [9]

When RT=3.72m, the left picture is the radar image before SIC processing, and the right picture is the image after processing(Fig.2). It can be concluded that if the RT size is moderate and there is a certain coupling in the radar image, the influence of the self-interference signal in the radar image can be completely removed through SIC processing.

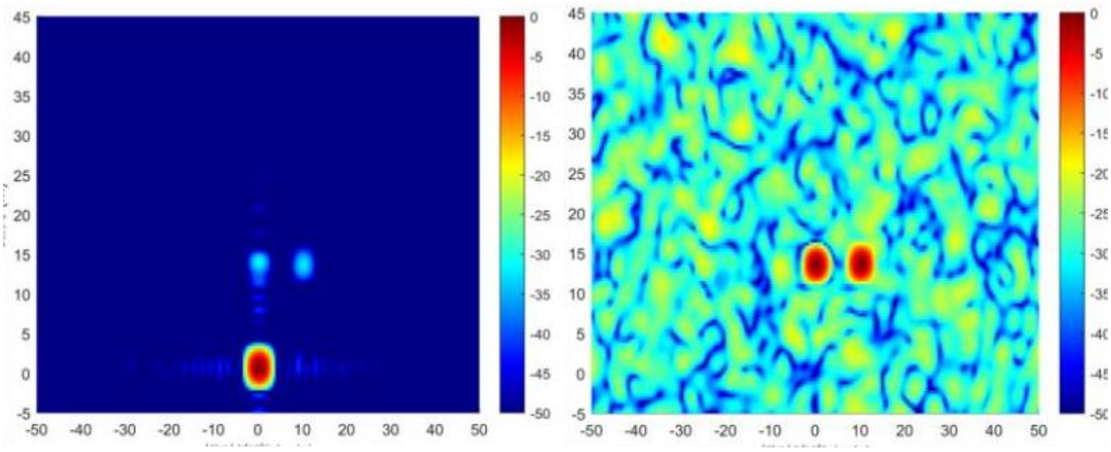

Fig.3 At RT=1.63m, the images before and after SIC processing [9]

When RT=1.63m, the left picture is the radar image before SIC processing, and the right picture is the image after processing (Fig.3). It can be concluded that if RT is too small, there is strong coupling, and the influence of self-interference signals in the radar pattern can be initially removed through SIC processing, but some self-interference signals still remain.

When the equivalent distance of the delay difference between callback signals is small, after processing by the self-interference elimination algorithm proposed in this article, the SINR of the target echo is improved, effectively eliminating the self-interference component of the echo signal. The further shortening of the delay difference means that although the self-interference signal can only be partially eliminated, it still has good results.

4. Conclusion

Given that the anti-interference performance of UAVs' wireless communications is known to be low, this article explores how to improve the anti-interference performance of UAVs. This paper uses integrated sensing and communication technology to suppress self-interference signals at a lower level, thereby enhancing the anti-interference ability of UAVs. If there is malicious signal interference, the original wireless communication model of the drone will be severely interfered. However, according to the self-interference signal echo model based on Integrated Sensing and Communication orthogonal frequency division multiplexing, the wireless communication of UAVs can be optimized to suppress self-interference. This article uses the least squares algorithm. Prediction analysis is performed after 3D radar image simulation is performed.

This article predicts based on existing research, that when RT is large, the influence of self-interference signals can be effectively eliminated; when RT is small, only part of the self-interference signals can be eliminated. After processing, the signal-to-interference-to-noise ratio of the target echo is greatly improved, effectively eliminating the self-interference component in the echo signal. Although as the delay difference shortens, the self-interference cancellation algorithm can only partially eliminate the self-interference signal, but it still has good results. According to the experimental results, after the target is processed, the signal-to-interference-to-noise ratio is greatly improved, which proves the effectiveness of the method introduced in this article.

The above method is not economical and affordable, and the method is relatively cumbersome. Therefore, the above method can be further improved and the self-interference elimination method can be simplified. Therefore, there is still a large room for development in communication perception integration-orthogonal frequency division multiplexing. The next step can be to consider improving the effectiveness and efficiency of the integrated communication sensing-orthogonal frequency division multiplexing method.

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