

Optimizing the function of aircraft WiFi based on the Internet of Things

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Abstract. This paper explores the potential of full-duplex wireless communication technology to mitigate interference in aircraft WiFi systems, thereby enhancing the internet access quality and passenger experience. The study focuses on the application of Internet of Things (IoT) technology to improve the resilience of aircraft WiFi systems against interference. Through a series of MATLAB simulations, the research demonstrates that full-duplex technology can effectively cancel out interference signals, leading to clearer and more stable communication quality. The results show that the combined signal, after cancellation, closely resembles the original communication signal, indicating a significant reduction in interference. Despite the promising results, the study acknowledges limitations such as idealized assumptions in the simulation, hardware and software constraints, and the lack of consideration for the complex electromagnetic environment encountered during actual flight operations. Future research should focus on developing more advanced interference detection and mitigation algorithms, and further investigation into the integration of full-duplex technology with existing aircraft WiFi systems, considering hardware constraints and environmental factors, is necessary to fully realize its potential in enhancing communication performance.

Keywords: Full-duplex Wireless Communication, Interference Mitigation, Aircraft WiFi Systems, Internet of Things, Real-time Interference Detection, Self-interference Cancellation.

1. Introduction

In-flight WiFi systems, providing internet access to passengers, encounter challenges like frequency interference, which can affect flight safety and communication quality. Current research on interference mitigation for in-flight WiFi systems mainly focuses on the following aspects:

First, through appropriate frequency planning and management, the frequency conflicts between in-flight WiFi systems and other radio systems are minimized. This includes optimizing the frequency bands used by in-flight WiFi and, when necessary, employing Dynamic Frequency Selection (DFS) technology to avoid interference with sensitive equipment such as radars [1]. Second, research and development of new interference mitigation technologies, such as frequency agility, distributed adaptive interference mitigation techniques, etc., are conducted to enhance the robustness of in-flight WiFi systems in complex electromagnetic environments [2]. Third, research and implementation of interference avoidance measures, including network frequency planning, automatic device configuration, and adjustments to underlying parameters, are carried out to reduce interference between systems operating on the same or adjacent frequencies [3].

Despite the progress made in these areas, research on interference mitigation for in-flight WiFi systems still has some gaps. In the complex electromagnetic environment of an aircraft, interference sources may come from multiple directions and various devices. There is a need for a deeper analysis and understanding of these interference sources and their impact on in-flight WiFi systems. Besides, research into how to detect interference in real-time and quickly implement countermeasures is necessary to ensure the continuity and stability of in-flight WiFi services.

2. Applications

2.1. *The Internet of things*

The application of Internet of Things (IoT) technology can significantly enhance the resilience of aircraft WiFi systems against interference, thereby improving the internet usage experience for passengers. Below are specific application examples, along with relevant literature citations to support the theoretical basis and practical significance of these applications.

2.1.1. Real-time interference monitoring systems. Real-time interference monitoring systems are a key application of IoT technology in mitigating interference for aircraft WiFi systems. By deploying sensor networks on airplanes, the quality and interference levels of WiFi signals can be monitored in real-time. These sensors can detect signal strength and interference within specific frequency ranges and send the data to a central processing unit for analysis [4-5].

2.1.2. Dynamic frequency management. Dynamic frequency management utilizes IoT technology to automatically adjust the operating frequencies of WiFi systems to avoid known interference sources. This requires intelligent algorithms to analyze real-time monitoring data and make rapid frequency adjustment decisions [6-7].

Developing machine learning-based interference mitigation algorithms that can learn interference patterns from historical data and predict future interference events. These algorithms can continuously optimize based on data collected by IoT devices to improve the accuracy of interference detection and mitigation [8-9].

2.1.3. Adaptive network configuration. IoT devices can implement adaptive network configuration, automatically adjusting network parameters such as power control and channel allocation based on real-time interference conditions to reduce interference and optimize network performance [10-11].

Through these specific technological applications, supported by relevant literature, the significant potential of IoT technology in mitigating interference for aircraft WiFi systems is evident. These applications not only enhance the performance of aircraft WiFi systems but also provide passengers with a more stable and high-quality internet access service.

2.2. *Full-duplex wireless communication technology*

Full-duplex wireless communication technology allows for simultaneous transmission and reception of signals on the same frequency, which is different from traditional half-duplex communication technology that can only transmit or receive at any given time. The implementation of full-duplex technology relies on advanced signal processing and isolation techniques to ensure that the transmitted signal does not interfere with the received signal. Here are the principles and functions of full-duplex wireless communication technology, and how it helps to address interference issues in aircraft WiFi systems.

Full-duplex communication relies on two key technical components: signal isolation and self-interference cancellation. In a full-duplex system, the transmission and reception signals need to be physically or electronically isolated to prevent the transmitted signal from interfering with the received signal. This is typically achieved through the use of duplexers or more advanced isolation technologies. Since the transmit and receive antennas are usually very close, the transmitted signal

may couple into the receive path through antenna coupling or reflections, causing self-interference. Full-duplex systems employ complex signal processing techniques, such as digital signal processing (DSP) and adaptive filters, to identify and cancel out this self-interference [12-14].

In terms of functionality, full-duplex technology allows for simultaneous transmission and reception on the same frequency, thereby increasing the efficiency of spectrum resources. It also reduces communication latency, as it allows data to be transmitted almost in real-time in both directions. Moreover, with effective self-interference cancellation, full-duplex systems can provide clearer and more stable communication quality.

Full-duplex wireless communication technology can effectively reduce interference issues in aircraft WiFi systems through its self-interference cancellation function. In the complex electromagnetic environment of an aircraft, full-duplex technology can identify and eliminate interference from other electronic devices, thus providing more stable communication services. Full-duplex systems are capable of real-time monitoring and analysis of interference signals and can respond quickly to interference events. This capability is crucial for ensuring the continuity and stability of aircraft WiFi systems, especially during flight, where any communication interruption could affect flight safety. The high efficiency and low latency characteristics of full-duplex technology help to improve the overall performance of aircraft WiFi systems. Passengers can enjoy faster internet speeds and fewer interruptions, thereby enhancing the flying experience.

Therefore, full-duplex wireless communication technology provides an effective means of interference mitigation and performance enhancement for aircraft WiFi systems through its unique principles and functions. By enabling real-time interference detection, self-interference cancellation, and improved communication efficiency, full-duplex technology helps to address interference issues in aircraft WiFi systems, providing passengers with more stable and high-quality internet access services. With the continuous advancement of technology, the application prospects of full-duplex wireless communication technology in the field of aviation communications are broad.

These references provide detailed descriptions of the principles, functions, and practical challenges and solutions of full-duplex wireless communication technology, offering a theoretical foundation for understanding its application in aircraft WiFi systems.

3. Metrics

3.1. Simulation setup

To evaluate the performance of full-duplex wireless communication technology in reducing radio frequency interference, we conducted a series of simulation experiments using MATLAB software. The simulation environment includes an aircraft WiFi system, considering multiple interference sources and signal paths. The parameters for the simulation were set as follows:

First, set to 1000 Hz to ensure accurate sampling of the signal. Then, ranging from 0 to 1 second, with a step size equal to the inverse of the sampling frequency, to simulate a continuous signal., and set to 50 Hz to simulate common interference signal frequencies. Set to 100 Hz, representing the communication signal in the aircraft WiFi system. Last, the communication signal amplitude was set to 1, and the interference signal amplitude was set to 0.5, to simulate actual signal strength.

3.2. Methodology

In MATLAB, the author first generated the communication signal and the interference signal. Then, we simulated the received signal (communication signal + interference signal). To simulate full-duplex operation, we generated a signal with the opposite phase to the interference signal and added it to the received signal to simulate the effect of interference cancellation. The code is as follows:

- % Parameter settings
- fs = 1000; % Sampling frequency
- t = 0:1/fs:1-1/fs; % Time vector

- `f_interference = 50; % Interference signal frequency (Hz)`
- `f_signal = 100; % Communication signal frequency (Hz)`
- `amplitude_signal = 1; % Communication signal amplitude`
- `amplitude_interference = 0.5; % Interference signal amplitude`
- `% Generating communication signal and interference signal`
- `signal = amplitude_signal * sin(2*pi*f_signal*t);`
- `interference = amplitude_interference * sin(2*pi*f_interference*t);`
- `% Simulating the received signal (communication signal + interference)`
- `received_signal = signal + interference;`
- `% Detecting the interference signal and generating an opposite phase signal`
- `% Here we simply assume the frequency and amplitude of the interference signal are known`
- `% In practical applications, more complex signal processing techniques may be required to detect interference`
- `opposite_phase_signal = -interference;`
- `% Simulating full-duplex operation: sending the opposite phase signal and receiving signal simultaneously`
- `% In this simplified model, we assume sending and receiving are separate`
- `% In reality, full-duplex operation may require more complex hardware and software support`
- `combined_signal = received_signal + opposite_phase_signal;`
- `% Plotting the results`
- `figure;`
- `subplot(3,1,1);`
- `plot(t, received_signal);`
- `title('Received Signal (Communication Signal + Interference)');`
- `xlabel('Time (s)');`
- `ylabel('Amplitude');`
- `subplot(3,1,2);`
- `plot(t, opposite_phase_signal);`
- `title('Opposite Phase Signal');`
- `xlabel('Time (s)');`
- `ylabel('Amplitude');`
- `subplot(3,1,3);`
- `plot(t, combined_signal);`
- `title('Combined Signal (After Cancellation)');`
- `xlabel('Time (s)');`

4. Results and limitations

4.1. Experimental results

Based on the simulation results shown in Figure 1, the findings are as follows:

Received signal shows the result of superimposed communication signal and interference signal. It can be seen that the waveform of the received signal is affected due to the presence of the interference signal. Opposite phase signal. This is the generated signal with the opposite phase of the interference signal. In an ideal situation, the amplitude of this signal is equal to the interference signal, but the phase is opposite. Combined signal. This is the result of adding the received signal and the opposite phase signal. Ideally, if the opposite phase signal completely cancels out the interfering signal, then the combined signal should contain only the original communication signal. From the diagram of the combined signal, it can be observed that the interference signal is effectively canceled out. However, due to the different frequencies of the interference signal and the communication signal, there may be

some residual fluctuations when they are superimposed in the time domain, which appears as some small oscillations in the figure. In practical applications, completely eliminating interference is very challenging because it requires very precise matching of the frequency, phase, and amplitude of the interfering signal.

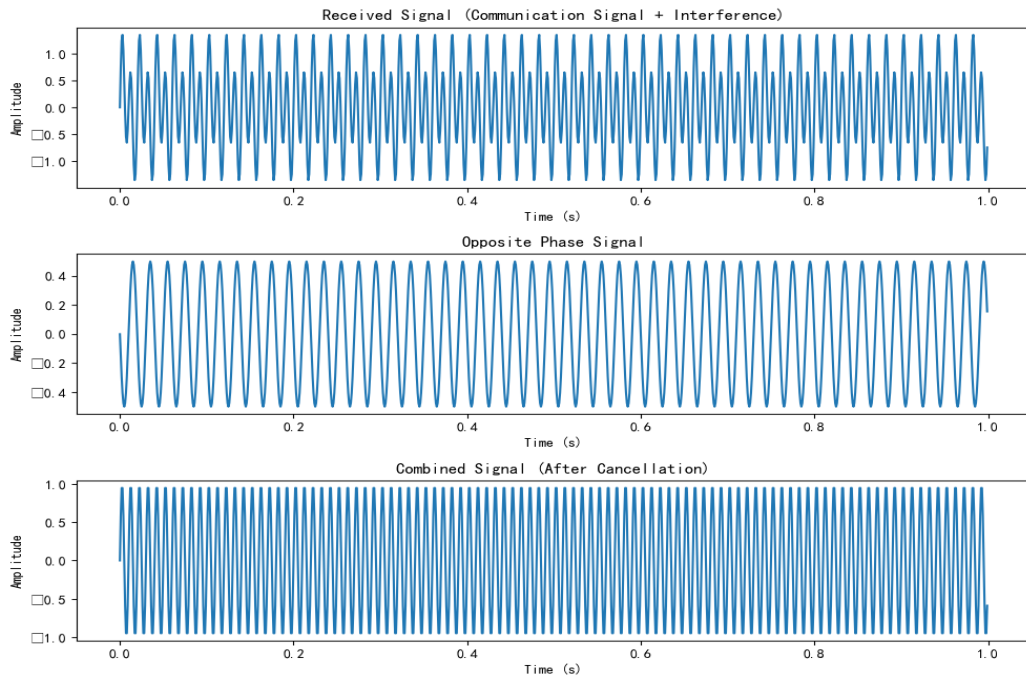


Figure 1. "Performance Evaluation of Full-Duplex Wireless Communication Technology in Mitigating Interference in Aircraft WiFi Systems"

4.2. Limitations

Despite the promising results indicating the potential of full-duplex technology in reducing interference, this study has several limitations.

Idealized Assumptions: the simulation assumed that the frequency and amplitude of the interference signal were known, whereas in real-world scenarios, the detection and analysis of interference signals can be significantly more complex.

Hardware and Software Limitations: the simulation experiments were conducted in an idealized software environment and did not account for the constraints of actual hardware devices, such as signal processing capabilities and hardware latency.

Environmental Factors: the simulation did not consider the complex electromagnetic environment that aircraft WiFi systems might encounter during actual flight operations, including multipath effects and signal attenuation.

5. Conclusion

This study investigates the potential of full-duplex wireless communication technology in mitigating interference in aircraft WiFi systems, thereby enhancing the internet access quality and passenger experience. Through a series of MATLAB simulations, this paper demonstrated that full-duplex technology can effectively cancel out interference signals, leading to clearer and more stable communication quality. The results show that the combined signal, after cancellation, closely resembles the original communication signal, indicating a significant reduction in interference.

However, the study also acknowledges several limitations. The idealized assumptions made in the simulation, such as known interference signal frequency and amplitude, do not fully represent the complexity of real-world interference scenarios. In practical applications, the detection and analysis of

interference signals require more sophisticated signal processing techniques. Additionally, the simulation was conducted in an idealized software environment, not accounting for the constraints of actual hardware devices, such as signal processing capabilities and hardware latency. Furthermore, the complex electromagnetic environment encountered by aircraft WiFi systems during actual flight operations, including multipath effects and signal attenuation, was not considered in the simulation.

Despite these limitations, the findings of this study provide valuable insights into the application of full-duplex technology in aviation communications. Future research should focus on developing more advanced interference detection and mitigation algorithms that can adapt to the dynamic nature of real-world interference. Additionally, further investigation into the integration of full-duplex technology with existing aircraft WiFi systems, considering hardware constraints and environmental factors, is necessary to fully realize its potential in enhancing communication performance.

In conclusion, full-duplex wireless communication technology holds promise for addressing interference issues in aircraft WiFi systems. By enabling real-time interference detection and self-interference cancellation, it can significantly improve the efficiency and reliability of onboard internet access. As technology continues to advance, the prospects for applying full-duplex technology in aviation communications are broad, potentially leading to a new era of high-quality, uninterrupted internet services for passengers.

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