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РАЗРАБОТКА И ВНЕДРЕНИЕ РАДИОПРИЕМНИКА В МИКРОВОЛНОВОМ ДИАПАЗОНЕ

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Аннотация. В этой статье рассматривается дизайн и реализация радиоприемника в микроволновом диапазоне. В исследовании сначала анализируются характеристики и сценарии применения микроволновой полосы, а затем приводится подробное описание системной архитектуры приемника, включая ключевые модули, такие как антенна, низкошумовый усилитель, миксер и обработка IF. В части, касающейся реализации аппаратных средств, основное внимание уделяется разработке высокочастотных схем, обеспечению целостности сигналов и соображениям электромагнитной совместимости. Для реализации программного обеспечения внедряются алгоритмы цифровой обработки сигналов и применения программных радиотехнологий. И наконец, эффективность сконструированного приемника проверяется с помощью эксплуатационных испытаний и практических примеров применения. Это исследование обеспечивает системное решение для разработки микроволновых радиоприемников, что имеет большое значение для технологического развития смежных областей.

Ключевые слова: устройство управления; Радиотехника; Высокочастотная схема; Обработка сигналов; Программное обеспечение радио; Проектирование системы

DESIGN AND IMPLEMENTATION OF A RADIO RECEIVER IN THE MICROWAVE RANGE

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Abstract. This paper explores the design and realization of a radio receiver in the microwave range. The study first analyzes the characteristics and application scenarios of the microwave band, followed by a detailed description of the system architecture design of the receiver, including key modules such as the antenna, low-noise amplifier, mixer, and IF processing. In the hardware realization part, the discussion focuses on high-frequency circuit design, signal integrity assurance and electromagnetic compatibility considerations. For the software realization, digital signal processing algorithms and the application of software radio technology are introduced. Finally, the effectiveness of the designed receiver is verified through performance tests and practical application cases. This study provides a systematic solution for the development of microwave radio receivers, which is of great significance to the technological development of related fields.

Keywords: microwave receiver; radio technology; high-frequency circuit; signal processing; software radio; system design.

1 Introduction

With the rapid development of wireless communication technology, the microwave frequency band is increasingly widely used in radar, satellite communication, 5G network and other fields. As the core component of these systems, the performance of microwave radio receivers directly affects the quality of the whole communication system. However, due to the special nature of the microwave frequency band, designing high-performance receivers faces many challenges, such as high-frequency circuit design, signal integrity assurance, and noise suppression.

The aim of this study is to investigate the design and implementation methods of radio receivers in the microwave range, and to improve the performance and reliability of receivers through innovations in system architecture design, hardware implementation and software processing. The significance of the research is to provide technical support for the development of microwave communication systems, and to promote the technological progress and application expansion in related fields.

Overview of microwave radio receiver

The microwave band usually refers to electromagnetic waves with a frequency range between 300MHz and 300GHz, which is characterized by high frequency, wide bandwidth and strong directionality. These characteristics make microwave in the radar, satellite communications, wireless LAN and other fields have a wide range of applications. As a key component of these systems, the main function of a microwave radio receiver is to receive, amplify and process microwave signals, converting them into usable IF or baseband signals.

The working principle of microwave receiver mainly includes signal reception, low noise amplification, frequency conversion and signal processing steps. The receiver first captures the weak microwave signal through the antenna, and then undergoes preliminary amplification by a low-noise amplifier to minimize the noise effects of the subsequent circuits. Next, the mixer converts the high-frequency signal into an intermediate-frequency signal for subsequent processing. Finally, the IF processing module further amplifies, filters and demodulates the signal to output the required information.

2 The system architecture design

The system architecture design of microwave radio receiver is the key to ensure its performance. The antenna, as the front-end of the system, needs to be designed by considering factors such as gain, directionality and impedance matching. Commonly used microwave antennas include parabolic antennas, microstrip antennas and array antennas, etc., and the selection needs to be weighed according to specific application scenarios.

Low noise amplifier (LNA) is an important component of the receiver, and its noise figure directly affects the sensitivity of the whole system. When designing an LNA, it is necessary to select appropriate high-frequency transistors and optimize the bias circuit and matching network to achieve a balance between low noise and high gain. The mixer is responsible for converting RF signals to IF signals, and commonly used mixer types include diode ring mixers and Gilbert cell mixers. Parameters such as conversion loss, isolation and linearity need to be considered during design.

The IF processing module includes IF amplifier, filter and demodulator. The design of IF amplifier needs to focus on gain control and stability, while the design of filter needs to choose a suitable topology according to the signal bandwidth and selectivity requirements. The choice of demodulator depends on the modulation mode, commonly used are amplitude demodulation, frequency demodulation and phase demodulation.

3 Hardware implementation

High-frequency circuit design is the core of microwave receiver hardware realization. In the PCB layout, it is necessary to consider the impedance matching of microstrip lines, ribbon lines and other transmission lines, as well as grounding and power decoupling and other issues. For component selection, special attention needs to be paid to high-frequency characteristics, such as the ESR of capacitors and the Q value of inductors. In addition, the impact of factors such as temperature stability and aging on component performance also needs to be considered.

Signal integrity is a key issue in microwave circuit design. Measures need to be taken to minimize the effects of reflections, crosstalk and electromagnetic interference. Commonly used methods include the use of matching networks, optimize cabling, add shielding layer. Power integrity should not be ignored, the need to design low noise power distribution network, and the use of appropriate decoupling capacitors.

Electromagnetic compatibility (EMC) design is an important part of ensuring that the receiver works properly. It is necessary to start with shielding, filtering and grounding to reduce the impact of electromagnetic interference. At the same time, it is also necessary to consider the electromagnetic radiation from the receiver itself to the outside world to ensure that it complies with the relevant standards.

4 Software implementation

Digital signal processing (DSP) plays an increasingly important role in modern microwave receivers. Commonly used algorithms include digital filtering, Fast Fourier Transform (FFT), digital downconversion and so on. These algorithms can effectively improve the flexibility and accuracy of signal processing. When implementing them, it is necessary to choose a suitable processor, such as FPGA or DSP chip, according to the system requirements and optimize the algorithms to improve the real-time performance.

Software radio (SDR) technology has revolutionized microwave receivers. By implementing as many functions as possible in software, SDR greatly improves system flexibility and reconfigurability. In microwave receivers, SDR technology can be used to implement functions such as flexible frequency conversion, modulation and demodulation, and signal processing. However, the realization of SDR also faces challenges such as high-speed data acquisition and processing, which require advanced data conversion and parallel processing techniques.

5 Performance Test and Application

In order to evaluate the performance of a microwave receiver, a series of tests are required. Commonly used test metrics include sensitivity, selectivity, dynamic range, noise figure, and so on. Test methods include laboratory tests using instruments such as signal generators and spectrum analyzers, as well as field tests in real application scenarios. The analysis of test results can help identify deficiencies in the design and provide a basis for optimization.

In real-world applications, microwave receivers face a variety of challenges. For example, in radar systems, they need to deal with strong interference and complex multipath effects; in satellite communications, they need to overcome signal attenuation and Doppler effects caused by long-distance transmission. Through case studies, these challenges can be better understood and effective solutions can be found. Meanwhile, the successful application cases also provide valuable experience for further optimization and improvement of microwave receivers.

6 Conclusion

This study has systematically explored the design and implementation methods of radio receivers in the microwave range. A series of innovative solutions are proposed through in-depth analysis of key aspects such as system architecture, hardware implementation and software processing. The study shows that reasonable design and optimization can significantly improve the performance and reliability of microwave receivers. Future research directions can focus on the application of higher frequency bands, more advanced signal processing algorithms, as well as integration and miniaturization to meet the increasing demand for wireless communications.

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