

学校编码：10384

分类号__密级__

学号：23320091152796

UDC__

廈門大學

碩 士 学 位 论 文

MIMO-OFDM 水声通信系统关键技术研究

Research on the Key Techniques of MIMO-OFDM

Underwater Acoustic Communication System

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论文提交日期：2012 年 5 月

论文答辩时间：2012 年 6 月

学位授予日期：2012 年 月

答辩委员会主席：_____

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2012 年 5 月

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摘要

OFDM 技术作为一种多载波调制技术,可以有效地克服频率选择性衰落。在带宽较窄的水声信道中,严重的多普勒频移和水声信道的时变性等造成了信道的不稳定,使水声信道呈现快速随机的深衰落;由于 OFDM 系统对载波频率偏移比较敏感,而水声通信过程中往往会存在较大的载波频率偏移,会造成严重的载波间干扰,直接影响系统的性能。所以增加 OFDM 系统的鲁棒性技术在水声通信领域应用中非常重要。

MIMO 技术近几年持续发展,作为无线通信领域的关键技术之一,各种无线通信系统中也越来越多地采用 MIMO 技术。在无线宽带移动通信系统方面,MIMO 技术相关的内容已经融入到第 3 代移动通信合作计划(3GPP)的标准中, MIMO 技术也融入到 B3G 和 4G 的系统中。MIMO-OFDM 在通信中的应用很广泛, MIMO 技术实现了频谱资源的重复利用,在不额外增加发射功率和传输带宽的前提下使系统的容量得到倍增,性能得以极大提高,这些优点使其在频谱资源日趋紧张的今天倍受青睐。针对于水声信道的特点,考虑将 MIMO 技术和 OFDM 技术融合,不仅能使水声信道的多径干扰得到抑制,还能提高频率选择性深衰落的性能增益,进而提高信道容量,实现高速的信息传输。本文将主要探讨水声通信中的 MIMO-OFDM 传输中的关键技术及 MIMO-OFDM 技术在水声通信中的应用研究。

本文的主要工作概括如下:

- (1) 基于对 MIMO 和 OFDM 通信系统的研究,构建基本的 MIMO-OFDM 通信系统。论文在叙述 MIMO-OFDM 技术的基础上,仿真了发射换能器和接收换能器不同组合数目的情况下 MIMO-OFDM 系统的性能。
- (2) 基于对水声信道和 MIMO-OFDM 系统的研究,构建 MIMO-OFDM 水声通信系统。并针对于水声信道特点,实现过采样、子载波调制、同步序列添加和提取等子模块。
- (3) 较高的峰值平均功率比(PAPR),是限制 OFDM 实用化的主要瓶颈之一, MIMO-OFDM 系统也存在相同的问题,本文针对降低 MIMO-OFDM 系统峰均比的各种方法进行研究和仿真。
- (4) 本文还将研究 MIMO-OFDM 系统中的关键技术:空时编码,信道编码,信道估计等等,并针对不同发射换能器数目与接收换能器数目系统情况进行仿真,最

后对 MIMO-OFDM 水声通信系统进行水池实验。

关键字：水声通信；MIMO-OFDM 通信系统；空时编码

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Abstract

OFDM technology is a multi-carrier modulation scheme which can overcome the frequency selective fading channels effectively. However, there is severe Doppler shift phenomenon and time variability in the narrow-bandwidth underwater acoustic channel, which causes the instability and a random deep fading of the underwater acoustic channel. The performance of the OFDM modulation scheme will decrease rapidly when it is applied to underwater acoustic channels directly since the underwater acoustic channel characteristics can be summarized as excessive carriers-frequency-offset and severe inter-carriers-interference. Therefore, the robustness of the OFDM technology needs to be improved in the field of the underwater acoustic applications.

The MIMO technology develops persistently in recent years. As one of the key technologies in the field of wireless communications, it is used in more and more wireless communication systems. In the wireless broadband mobile communication system, the MIMO scheme has been integrated into the 3rd generation mobile communications cooperation project standards (3GPP). It is also integrated into the B3G and 4G systems. MIMO-OFDM technology is used broadly in the communication. With this technology, spectrum resources can be reused and the capacity of the system is doubled at the condition of no extra transmit power and transmission bandwidth. Meanwhile, the performance can be improved, so it is greatly concerned today.

Here we consider a confluence of MIMO techniques and OFDM technologies which will not only suppress the interference of the multi-path channels, but also overcome the frequency selective deep fading characteristic in the underwater acoustic channel. Hence, the channel capacity will be improved and high-speed information transmission can be achieved. The key technologies of MIMO-OFDM and the research of MIMO-OFDM in underwater acoustic communication are mainly discussed in this paper.

The main contents are summarized as follows:

(1) Based on the MIMO-OFDM technology, the performance of the MIMO-OFDM systems in different numbers of emission transducers and receiving transducers is simulated.

(2) The MIMO-OFDM underwater acoustic communication system was build based on the research of underwater acoustic channels and MIMO-OFDM communication system, the sub-modules of over samplings, sub-carrier modulation, adding and extracting the synchronization sequences is achieved for the characteristics of the underwater acoustic channel.

(3) High peak-to-average-power-ratio (PAPR) is one of the main drawbacks which limit the practice application of the OFDM system, so does the MIMO-OFDM system. Various methods have been proposed to reduce the PAPR of the MIMO-OFDM system and they are simulated for the high PAPR OFDM systems and MIMO-OFDM systems in this paper.

(4) The key technologies of MIMO-OFDM systems, such as space-time coding, channel coding, channel estimation is studied and the experiments with different numbers of emission transducers and receiving transducers are completed in water pool.

Keywords: underwater acoustic communication; MIMO-OFDM communication system; space-time coding.

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