

学校编码 : 10384

学号 : 23320141153222

厦门大学

硕士 学位 论文

一种新型的网格编码差分混沌调制技术的系统设计与性能分析

Design and Performance Analysis of a Novel
Trellis-Coded Differential Chaotic
Modulation System

合艳春

指导教师: 王琳

专业名称: 通信与信息系统

答辩日期: 2017年5月

厦门大学学位论文原创性声明

本人呈交的学位论文是本人在导师指导下, 独立完成的研究成果。本人在论文写作中参考其他个人或集体已经发表的研究成果, 均在文中以适当方式明确标明, 并符合法律规范和《厦门大学研究生学术活动规范(试行)》。

另外, 该学位论文为()课题(组)的研究成果
, 获得()课题(组)经费或实验室的资助, 在(
)实验室完成。(请在以上括号内填写课题或课题组负责人或
实验室名称, 未有此项声明内容的, 可以不作特别声明。)

声明人(签名) :

年 月 日

厦门大学学位论文著作权使用声明

本人同意厦门大学根据《中华人民共和国学位条例暂行实施办法》等规定保留和使用此学位论文，并向主管部门或其指定机构送交学位论文(包括纸质版和电子版)，允许学位论文进入厦门大学图书馆及其数据库被查阅、借阅。本人同意厦门大学将学位论文加入全国博士、硕士学位论文共建单位数据库进行检索，将学位论文的标题和摘要汇编出版，采用影印、缩印或者其它方式合理复制学位论文。

本学位论文属于：

() 1. 经厦门大学保密委员会审查核定的保密学位论文，于
年 月 日解密，解密后适用上述授权。

() 2. 不保密，适用上述授权。

(请在以上相应括号内打“√”或填上相应内容。保密学位论文应是已经厦门大学保密委员会审定过的学位论文，未经厦门大学保密委员会审定的学位论文均为公开学位论文。此声明栏不填写的，默认为公开学位论文，均适用上述授权。)

声明人(签名)：

年 月 日

摘要

本文提出了一种新型的编码调制技术——网格编码差分混沌调制技术 (TC-DCM: Trellis-Coded Differential Chaotic Modulation)，其主要的思想是将网格编码调制技术 (TCM: Trellis-Coded Modulation) 和以混沌信号为载波的多元差分混沌移位键控调制技术 (M-DCSK: M-ary Differential Chaotic Shift Keying) 相结合。由于混沌信号具有类噪声的内在的扩频特性，在调制的同时直接对信号进行扩频，利用其良好的相关特性和连续带宽的功率谱特性，该系统具有较好的抗多径干扰的能力，弥补了传统的网格编码调制系统在这方面的不足。此外，由于该系统继承了传统的网格编码调制技术的高带宽利用率的特性，且在接收端解调不需要获取信道的状态信息，适合在一些带宽受限且较难获得信道状态信息的传输系统中工作，如：水声通信、深空通信和卫星通信等系统。同时，由于系统采用结构简单的非相干接收机，接收端无需精确的混沌同步、RAKE接收和解扩单元，使得该系统的硬件复杂度大大降低，在某些要求控制成本且对信道鲁棒性强的传输系统中，如：水下传感器网络，该系统是一种具有高带宽有效、抗多径干扰的低成本传输方案。

文章首先对传统的网格编码调制技术进行了系统的介绍，给出其系统设计框图并阐述了设计码型时所用到的关键技术。然后，就本文中使用的多元差分混沌移位键控调制技术进行了详细的介绍与分析，给出了该系统的理论误码率公式并与仿真结果进行了验证比较。

然后，详细的阐述了新型的网格编码差分混沌调制系统的设计原理，并且分别给出了该系统在高斯白噪声信道和瑞利平坦衰落信道下的理论和仿真的误码性能分析结果。同时，将采用不同码率和不同状态数的网格编码差分混沌调制方案分别与其对应的未编码的差分混沌移位键控调制系统，在相同的带宽效率的情况下进行对比获得了可观的编码增益。此外，在相同的频谱效率下，将新系统与传统网格编码调制的直接序列扩频系统 (TCM DS/SS: Trellis-Coded Modulation Direct-Sequence Spread-Spectrum) 在多径瑞利衰落信道下进行了仿真对比分析，新系统展现出对信道的强鲁棒性，在不需要获得信道的状态信息的情况下也能够获得较好的抗多径

干扰性能，使其在带宽受限的复杂信道传输环境中具有很好的应用前景。最后，进一步分析了几种不同的卷积码编码类型在高斯白噪声信道和衰落信道下的误码性能，给出了适合在衰落信道中传输的码型，为进一步寻求在衰落信道中的最优码型奠定了基础。

关键词：网格编码调制技术；带宽受限系统；多元差分混沌移位键控调制

Abstract

In this paper, a novel coded modulation scheme named Trellis-Coded Differential Chaotic Modulation (TC-DCM) is proposed, which combines trellis codes with M-ary Differential Chaotic Shift Keying (M-DCSK). The new scheme not only reduces the multipath interference efficiently due to its inherent spreading property, but also avoids the use of Channel State Information (CSI), making the corresponding receiver design simpler and more suitable for some band-limited channel scenarios especially with severe multipath propagation where the CSI is hard to obtain, such as Underwater Acoustic communication systems and satellite communication systems. Besides, because there is no need for exact synchronization, despreading and the Rake receiver at the receiver, the new scheme offers a simple hardware design and is very robust against channel distortion, which is a good choice to utilize in applications where low cost, low energy consumption and high resistance against multipath fading are required like underwater acoustic sensor networks.

Firstly, a detailed introduction of the Trellis-Coded Modulation system and some key techniques utilized in this system are given. Secondly, the BER performances of M-DCSK system are derived and verified over Additive White Gaussian Noise (AWGN) channels and Rayleigh flat fading channels, respectively. The architecture of the TC-DCM system is presented. And the theoretical BER bounds of the new scheme have been derived over AWGN and Rayleigh flat fading channels. Compared to the corresponding uncoded systems with the same bandwidth, the TC-DCM systems with different states and different rates can obtain obvious coding gains over AWGN channels. Furthermore, the outstanding performances of the proposed scheme are confirmed by comparing it to the TCM Direct-Sequence Spread-Spectrum (TCM DS/SS) system with the same bandwidth efficiency over multipath Rayleigh fading channels without CSI. And to

further improve the performances of the system over the fading channels, the optimized trellis code design rules are proposed.

Keywords: Trellis-Coded Modulation; Band-limited System; M-ary Differential Chaotic Shift Keying

厦门大学博硕士论文摘要库

参考资料

- [1]S. H. Strogatz. Nonlinear Dynamics and Chaos, with Applications to Physics, Biology, Chemistry, and Engineering [M]. Westview Press, USA, 2001.
- [2]F. C. M. Lau and C. K. Tse. Chaos-Based Digital Communication Systems: Operating Principles, Analysis Methods. Performance Evaluation [M]. Berlin: Springer-Verlag, 2003.
- [3]G. Heidari-Bateni and C. McGillem. Chaotic sequences for spread spectrum: an alternative to PN-sequences [C]. in Proc. IEEE Int. Conf. Selected Topics in Wireless Commun., Jun. 1992: 437-440.
- [4]H. Dedieu, M. P. Kennedy, and M. Hasler. Chaos Shift Keying: Modulation and Demodulation of a Chaotic Carrier Using Self-Synchronizing Chua's Circuits [J]. IEEE Trans. Circuits Syst. II, 1993, 40(10): 634-642.
- [5]G. Kolumban, G. K. Vizvari, W. Schwarz and A. Abel. Differential chaos shift keying: A robust coding for chaos communication [C]. in Proc. NDES ' 96, Seville, Spain, Jun. 1996: 87-92.
- [6]L. M. Pecora and T. L. Carroll. Synchronization in chaotic systems [J]. Phys. Rev. Letters, 1990, 64(8): 821-824.
- [7]L. Wang, G. Cai, and G. Chen. Design and performance analysis of a new multiresolution M-ary differential chaos shift keying communication system [J]. IEEE Trans. Wireless Commun., Sept. 2015, 14(9): 5197-5208.
- [8]G. Ungerboeck. Channel coding with multilevel/phase signals [J]. IEEE Trans. Inform. Theory, Jan. 1982, 28(1): 56 – 67.
- [9]A. J. Viterbi. Error bounds for convolutional codes and an asymptotically optimum decoding algorithm [J]. IEEE Trans. Inform. Theory, Apr. 1967, 13(2): 260-269.
- [10]G. Ungerboeck. Trellis Coded Modulation with Redundant Signal Sets, Part I: Introduction [J]. IEEE Comm. Mag., Feb. 1987, 25(2): 5-11.
- [11]G. Ungerboeck. Trellis Coded Modulation with Redundant Signal Sets, Part 11: State of the Art [J]. IEEE Comm. Mag., Feb. 1987, 25(2): 12-21.
- [12]Hideki. Imai and Shuji. Hirakawa. A New Multilevel Coding Method Using Error-Correcting codes [J]. IEEE Trans On Information Theory, 1977, 23(3): 371-377.
- [13]D. Divsalar and M. K. Simon. Multiple Trellis Coded Modulation (MTCM) [J]. IEEE Trans. Commun., Apr. 1988, 36(4): 410-419.
- [14]E. Bihlieri and P. J. McLane. Uniform distance and error probability properties of TCM schemes [J]. IEEE Trans. Commun. Jan. 1991, 39(1): 41-53.
- [15]D. Divsalar and M. K. Simon. Trellis coded modulation for 4800-9600 bits/s transmission over a fading mobile satellite channel [J]. IEEE J. Select. Areas Commun., 1987, 5(2): 162 -175.
- [16]D. Divsalar and M. K. Simon. The Design of Trellis Coded MPSK for Fading Channels: Performance Criteria [J]. IEEE Trans. Commun., Sept. 1988, 36(9): 1004-1012.
- [17]D. Divsalar and M. K. Simon. The Design of Trellis Coded MPSK for Fading Channels: Set Partitioning for Optimum Code Design [J]. IEEE Trans. Commun., Sept. 1988, 36(9): 1013-1021.
- [18]M. K. Simon and D. Divsalar. The performance of trellis coded multilevel DPSK on a fading mobile satellite channel [J]. IEEE Trans. Vehic. Technol., May. 1988, 37(2):78-91.
- [19]S. H. Jamali and T. Le-Ngoc. Coded-Modulation Techniques for Fading Channels [M]. New York: Kluwer, 1994.
- [20]S. G. Wilson, H. A. Sleeper, P. J. Schottler, et al. Rate 3/4 convolutional coding of 16-PSK: code design and performance study [J]. IEEE Trans. Commun., 1984, 32(12): 1308-1315.
- [21]L. V. Subramaniam, B. S. Rajan, and R. Bahl. Performance of 4- and 8-state TCM schemes with asymmetric 8-PSK in fading channels [J]. IEEE Trans. Veh. Technol, 2000, 49(1): 211-219.
- [22]R. Goswami, G. S. Rao, and R. Babu. 8 state rate 2/3 TCM code design for fading channel [C]. in Proc. IEEE India Conf., INDICON, 2008: 323-326.
- [23]F. Zhou, G. Qiao, and J. Su. Performance analysis of TCM coded OFDM system in underwater acoustic

- channel [C]. in Proc. 2008 International Conference on Wireless Commun, Networking and Mobile Computing, WiCOM, 2008: 1-4.
- [24]S. L. Goff, A. Glavieux, and C. Berrou. Turbo-Codes and High Spectral Efficient Modulation [C]. in Proc. IEEE Int. Conf. Commun., New Orleans, La., May. 1994: 645-649.
- [25]S. M. Alamouti and S. Kallel. Adaptive trellis-coded multiple-phased shift keying Rayleigh fading channels [J]. IEEE Trans. Commun., Jun. 1994, 42(6): 2305 – 2341.
- [26]G. D. Boudreau, D. D. Falconer, and S. A. Mahoud. Analysis of the application of trellis coding to spread spectrum multiple access systems [C]. in Proc. MILCOM '88 Conf Proc., Oct. 1988: 616-626.
- [27]G. D. Boudreau, D. D. Falconer, and S. A. Mahmoud. A comparison of trellis coded versus convolutionally coded spread-spectrum multiple-access systems [J]. IEEE J. Select. Areas Commun., May. 1990, 8(4): 628-640.
- [28]K.V. Ravi, Tam Soh Khum, and H.K. Garg. Performance of turbo TCM in wideband CDMA indoor mobile applications [C]. in Proc. IEEE PIMRC, Sept. 2000: 898-902.
- [29]G. Kolumb á n., M. P. Kennedy, et al. Chaotic communications with correlator receivers: Theory and performance limits [J]. Proceedings of the IEEE, 2002, 90(5): 711-732.
- [30]Y. Xia, C. K. Tse, and F. C. M. Lau. Performance of differential chaos shift-keying digital communication systems over a multipath fading channel with delay spread [J]. IEEE Trans. Circuits Syst. II: Exp. Briefs., Dec. 2004, 51(12): 680-684.
- [31]L. F. Ye, G. R. Chen, and L. Wang. Essence and advantages of FM-DCSK technique versus conventional spread-spectrum communication methods [J]. Circuits, Systems and Signal Processing, Special Issue, Oct. 2005, 24(5): 657- 673.
- [32]G. Kolumban, G. Kis, M.P. Kennedy, and Z. Jako. FM-DCSK: A new and robust solution to chaos communications [C]. in Proc. International Symposium on Nonlinear Theory and Its Applications, Hawaii, USA, 1997: 117-120.
- [33]M. P. Kennedy, G. Kolumban, G. Kis, and Z. Jako. Performance evaluation of FM-DCSK modulation in multipath environments[J]. IEEE Transactions on Circuits and Systems I: Fundamental Theory and Applications, Dec. 2000, 47(12): 1702-1711.
- [34]S. Mandal and S. Banerjee. Performance of differential chaos shift keying over multipath fading channels [C]. in Proc. Indian Nat. Conf. Nonlinear Systems and Dynamics, Dec. 2003: 1-4.
- [35]Z. B. Zhou, J. X. Wang and Y. Z. Ye. Exact BER Analysis of Differential Chaos Shift Keying Communication System in Fading Channels [J]. Wireless Personal Communications, 2009, 53(2): 299-310.
- [36]G. Kaddoum, F. Gagnon, P. Charge, et al. A generalized BER prediction method for differential chaos shift keying system through different communication channels [C]. in Proc. Wireless Personal. Commun., 2012: 425-437.
- [37]W. Xu, L. Wang, and G. Kolumban. A novel differential chaos shift keying modulation scheme [J]. Int. J. Bifur. Chaos, Mar. 2011, 21(3): 799-814.
- [38]W. K. Xu, L. Wang, and G. R. Chen. Performance Analysis of the CS DCSK/BPSK Communication System [J]. IEEE Trans. Circuits and Syst.-I: Reg. Papers, 2014, 61(9): 2624-2633.
- [39]G. Kaddoum, F. Richardson, and F. Gagnon. Design and analysis of a multi-carrier differential chaos shift keying communication system [J]. IEEE Trans. Commun., 2013, 61(8): 3281-3291.
- [40]G. Kaddoum, and F. Shokraneh. Analog network coding for multi-user multi-carrier differential chaos shift keying communication system [J]. IEEE Trans. Commun., Mar. 2015, 14 (3): 1492-1505.
- [41]Z. Galias, and G. M. Maggio. Quadrature chaos-shift keying: theory and performance analysis [J]. IEEE Trans. Circuits Syst. I, 2001, 48(12): 1510-1519.
- [42]G. Cai, L. Wang, and T. Huang. Channel capacity of M-ary Differential Chaos Shift Keying modulation over AWGN channel [C]. in Proc. Int. Symp. Commun. Inf. Technol. (ISCIT), Sept. 2013: 91-95.
- [43]P. Chen, L. Wang, and G. Chen. DDCSK-walsh coding: a reliable chaotic modulation-based transmission technique [J]. IEEE Trans. Circuits Syst. II, Feb. 2012, 59(2): 128-132.
- [44]G. Kaddoum, Soujeri and E. Nijsure. Design of a short reference non-coherent chaos-based communication

systems [J]. IEEE Trans. Commun., Jan. 2016, 64(2): 690-689.

厦门大学博硕士论文摘要库

Degree papers are in the "[Xiamen University Electronic Theses and Dissertations Database](#)". Full texts are available in the following ways:

1. If your library is a CALIS member libraries, please log on <http://etd.calis.edu.cn/> and submit requests online, or consult the interlibrary loan department in your library.
2. For users of non-CALIS member libraries, please mail to etd@xmu.edu.cn for delivery details.

厦门大学博硕士论文摘要库