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論 文 題 目	Construction A and D’ Lattices for Power-Constrained Communications
論 文 審 査 委 員	Brian Kurkoski, Professor, JAIST Kiyofumi Tanaka, Professor, JAIST Eiichiro Fujisaki, Professor, JAIST Gregory Schwartzman, Associate Professor, JAIST Hideki Yagi, Associate Professor, The University of Electro-Communications (Tokyo)

論文の内容の要旨

Lattices have the potential to provide reliable and power-efficient data transmission in the next-generation wireless communications. Information theory has provided remarkable insights into lattices and their applications for practical communication systems. The benefits of lattices for communications are: 1) high code rate 2) higher transmit power efficiency than conventional quadrature amplitude modulation constellations and 3) they form an essential component of compute-and-forward relaying, which provides high throughput and high spectral efficiency.

This dissertation addresses the designs and methods of nested lattice codes with good coding properties, a high shaping gain, and low-complexity encoding and decoding. Construction D' lattices based on quasi-cyclic low-density parity-check (QC-LDPC) codes are for coding and thus contribute to reliable data transmission. Construction A lattices based on convolutional codes are used to satisfy the channel power-constraint and provide shaping gain. These constructions have group property and provide high code rates.

Two encoding methods and a decoding algorithm for Construction D' coding lattices that can be used with shaping lattices for power-constrained channels are given. The multistage decoding algorithm uses successive cancellation by employing binary decoders of the component binary codes that form a Construction D' lattice. An indexing method for nested lattice codes is modified to avoid an integer overflow problem at high dimension. Convolutional code generator polynomials for Construction A lattices with the greatest shaping gain are given, as a result of an extensive search. It is shown that rate 1/3 convolutional codes provide a more favorable performance-complexity trade-off than rate 1/2 convolutional codes. For a given dimension, tail-biting convolutional codes have higher shaping gain than that of zero-tailed convolutional codes and truncated convolutional codes. A design for QC-LDPC codes to form Construction D' lattices is presented, where their parity-check matrices can be easily triangularized, thus enabling efficient encoding and indexing when formed a nested lattice code. The resulting QC-LDPC Construction D' lattices are evaluated using four shaping lattices: the E_8 lattice, the BW_{16} lattice, the Leech lattice and the best-found convolutional code lattice, showing a shaping gain of approximately 0.65 dB, 0.86 dB, 1.03 dB and 1.25 dB at dimension 2304.

Keywords: Construction D' lattices, Construction A lattices, nested lattice codes, QC-LDPC codes, shaping gain

論文審査の結果の要旨

This dissertation describes methods to construct a class of error-correcting code called lattice codes, which has potential application in future wireless communications system. Key characteristics of the construction are low transmit power, high reliability (high coding gain) and high data rates. The construction takes a practical approach, of using quasi-cyclic low-density parity-check codes to provide high coding gain, and convolutional codes to provide low transmit power. Lattices are appealing for wireless communications, but have not yet seen much practical use. This dissertation represents a step in this direction by giving a practical construction of lattice codes that have performance not far from the theoretical limit, while still being practical to encode and decode. The dissertation represents a comprehensive study, particularly of the design of convolutional codes for the shaping lattice.

This work resulted in publication in two conference proceedings, including the top-level IEEE International Symposium on Information Theory. Acceptance and publication at this symposium is more difficult that some journals, and is a significant accomplishment. There was also a publication in the International Symposium on Information Theory and Its Applications. A paper based on this dissertation is currently under review for publication in *IEEE Transactions on Communications*, and has gone through two review cycles, has received largely positive comments from reviewers, and can be considered to be nearing acceptance.

The committee agrees that this is an excellent dissertation and the committee approves awarding the doctoral degree to Fan ZHOU.