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Chaos Communication: An Overview of Exact, Optimum and Approximate Results Using Statistical Theory

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This paper overviews exact and optimum results for a type chaos shift-keying (CSK) system, in particular, for the antipodal system in which a bit is transmitted by modulating a chaotic segment and decoded by use of the corresponding unmodulated segment, the so-called reference segment. Both single- and multiple- user versions with both known- and transmitted- reference segments are considered, the so-called coherent and non-coherent cases. There are two main themes in the paper – the use of statistical likelihood theory leads to optimum or improved decoders – the bit error performance of decoders can be obtained exactly for chaotic segments which are generated by chaotic maps with explicit convolution forms. As a first use of statistical theory, it will be shown that in the simplest of single-user CSK systems, the correlation decoder is actually the optimal likelihood decoder. An argument is then given [Lawrance et al. (2003)] to yield an exact expression for its bit error rate and it is shown how to calculate from it with spreading sequences generated by chaotic maps which have explicit convolutions. The theory leads to a lower bound result which was the original inexact result obtained by Gaussian approximation, and cited by Kolumban et al. (2002) and many others. The exact bit error result is extended to when there is a type of alternating jamming or interference and the role of a key quantity termed the jamming factor (JF) is emphasized. Attention then moves to coherent multiple-user CSK systems, motivated by the extensive approximate Gaussian results in Lau et al. (2003), Tam et al. (2007), and to their optimal decoding following the likelihood route [Lawrance et al. (2008)]. In this way a generalized correlation decoder is derived, generalized in the sense that it employs the autocorrelations of the spreading segment. Exact BER results are obtained and exemplified by calculations using logistic map and Bernoulli map spreading. These are compared with those from the correlation decoder and shown to be particularly superior at the desirable high SNR levels. The structure of the results indicates the roles of SNR and a quantity defined as the spreading to interference ratio (SIR) in determining the BER of such systems; comparisons are also made to the form of Gaussian results. To conclude, some of the earlier correlation decoder results are extended and compared to non-coherent systems in terms of BER, both in the single- and multiple-user cases. Comments concerning the improved design of noncoherent systems, following Yao et al. (2006), and areas awaiting investigation, conclude the presentation.

Keywords: Communication systems, Chaos shift keying, Correlation decoding, Likelihood-based decoding, Exact calculation of bit error rate, Gaussian approximations, Statistical theory

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