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Converse Bounds on Modulation-Estimation Performance for the Gaussian Multiple-Access Channel

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Abstract

This paper focuses on the problem of separately modulating and jointly estimating two independent continuous-valued parameters sent over a Gaussian multiple-access channel (MAC) under the mean square error (MSE) criterion. To this end, we first improve an existing lower bound on the MSE that is obtained using the parameter modulation-estimation techniques for the single-user additive white Gaussian noise (AWGN) channel. As for the main contribution of this work, this improved modulation-estimation analysis is generalized to the model of the two-user Gaussian MAC, which will likely become an important mathematical framework for the analysis of remote sensing problems in wireless networks. We present outer bounds to the achievable region in the plane of the MSE's of the two user parameters, which provides a trade-off between the MSE's, in addition to the upper bounds on the achievable region of the MSE exponents, namely, the exponential decay rates of these MSE's in the asymptotic regime of long blocks.

***Index terms*—** Parameter modulation-estimation, multiple-access channel, error exponents, MSE

I. Introduction

Before addressing the problem of joint modulation-estimation for the Gaussian MAC, let us refer first to the more fundamental single-user modulation-estimation problem. In this setting, a single continuous–valued random parameter U is encoded (modulated) into an N-dimensional power-limited vector $\mathbf{x}(U)$ and transmitted over an additive-white Gaussian noise (AWGN) channel [1]–[3] as shown in Fig. 1(a). The corresponding N-dimensional channel output vector is given by $\mathbf{y} = \mathbf{x}(U) + \mathbf{z}$, where $\mathbf{z}$ is a Gaussian noise vector with independent and identically distributed (i.i.d.) components, which are independent also of U. The channel output vector $\mathbf{y}$ is used by the receiver to estimate U by an estimator $\hat{U}(\mathbf{y})$. The goal is to derive a lower bound to the MSE, $\mathbf{E}(U - \hat{U}(\mathbf{y}))^2$, that applies to every modulator $\mathbf{x}(\cdot)$, that is subjected to a given power constraint, and to every estimator $\hat{U}(\mathbf{y})$ [3, Chapter 8]. More recently in [4], this class of transmission problems was given the name *parameter modulation-estimation*, which we believe, will likely become an important mathematical framework to analyze various remote sensing problems that may arise in fifth generation wireless networks. The purpose of this work is to extend the described problem, as well as its analysis and results, to the model of the discrete-time two-user Gaussian MAC, where two independent parameters, denoted by U_1 and U_2, are conveyed from two separate transmitters and jointly estimated at the receiver. This model is shown in Fig. 1(b). The aim is to derive

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