Estimation of LEO Satellite Channels

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Abstract

In this paper, we propose a new channel estimation algorithm for low earth orbit satellite digital communications. Low earth orbit satellite channels impart severe spreading in delay and Doppler on the transmitted signal. We model the channel as a tapped-delay-line filter with time-varying complex coefficients. The time evolution of the taps is described by an auto-regressive model. A coupled filter using recursive prediction error methods is proposed for estimating the parameters of the channel. Its performance is demonstrated via simulations.

1 Introduction

Several low earth orbit (LEO) satellite systems have been proposed for commercial mobile communication services (e.g. Iridium, Orbcomm, Globalstar, and Teledesic). In this paper, we consider characterization and estimation of LEO satellite communication channels.

LEO satellite communication channels are time-varying and multipath, and thus cause significant fading [1, 2, 3]. The motion of the land-based mobile, traversal of the satellite relative to the earth, and changing absorption, scattering, refraction, and diffraction effects of the environment cause both fast and slow fading.

Fast fading is a consequence of multipath propagation. Measurements with mobile receivers have shown that the fast fading is Rayleigh distributed (or Rician, in the case of a line-of-sight path) [**?**, 2, 4, 5]. Thus, the transmitted signal is both Doppler and delay spread by the channel [6, 7]. For LEO satellite channels, the Doppler *spread* is related to the motion of the mobile, as in terrestrial systems. (This is in addition to the large Doppler *shift* which is imparted on the transmitted signal due to the relative motion of the satellite, up to 40 kHz.) Delay spreading is most significant when the satellite is at low elevation angles. However, due to the low digital symbol rate (e.g. 2.4 kbaud for Iridium) the delay spread causes only small amounts of intersymbol interference (ISI).

Slow fading (also known as shadowing) results from the changing terrain contours (e.g. nearby buildings, trees, mountains), and has been found to have a log-normal distribution [1, 2, 4, 5]. Shadowing is most pronounced at low elevation angles.

Optimal equalization and detection for such doubly spread and dual fading time-scale channels is non-trivial. In this paper, we present an on-line technique for estimating the satellite channel to aid equalization and detection at the receiver. We propose a coupled estimator using recursive prediction error methods [8]. The algorithm is able to estimate the parameters of the delay and Doppler spread channel and also the channel mean. Further, changes in these parameters caused by shadowing, variation in elevation of the satellite, and changes in mobile direction and velocity can be tracked.

For our coupled estimator, the channel is modelled as a finite impulse response (FIR) tapped-delay-line filter with time-varying taps. Since the statistics of the fading of the LEO channel can be considered stationary for periods large enough to estimate the parameters, we introduce an auto-regressive (AR) model for the time-evolution of the channel taps. The model is presented in Section 2.

In Section 3, we present the coupled estimator. It consists of a Kalman filter for tracking the channel taps, together with an estimator for the channel mean and AR parameters. We discuss features of this algorithm relevant to the LEO satellite channel application.

The performance of our coupled estimator is demonstrated in Section 4. LEO satellite channels were simulated (independently of the estimation model using Jakes spectrum for the Doppler spread channel variation [2]), and the coupled estimator was applied in a variety of scenarios. We discuss aspects of the algorithm which are important for LEO satellite communications. The paper concludes with a summary in Section 5.

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