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Semi-blind channel identification for individual data bursts in GSM wireless systems

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Abstract

We investigate the application of semi-blind equalization principle in practical wireless cellular systems. Specifically, we focus on the popular global system for mobile (GSM) cellular receiver in an effort to improve system efficiency without compromising performance. We begin by briefly introducing a linear quadratic amplitude modulation (QAM) approximation for the Gaussian minimum shift keying (GMSK) signal used in GSM, which can be modeled as a single input two output discrete linear system model after sampling and de-rotation (Ding and Li, IEEE J. Selected Areas Commun. 16 (October 1998) 1493–1505). We develop two different semi-blind algorithms based on the linear system model by combining both second-order statistical (SOS) information and information from training. These semiblind methods can overcome some serious limitations of SOS blind algorithms. We also analyze the semi-blind identifiability conditions. Finally, we compare simulation results for GSM receivers using both pure training and semiblind channel identification methods. © 2000 Elsevier Science B.V. All rights reserved.

Zusammenfassung

Wir untersuchen die Anwendung von semiblinden Entzerrprinzipien in praktischen drahtlosen zellularen Systemen. Dabei konzentrieren wir unsere Anstrengungen auf den zellularen Empfänger des populären *Global System for Mobile* (GSM), um die Systemeffizienz ohne Kompromiss in Bezug auf die Leistungsfähigkeit zu verbessern. Wir beginnen mit einer kurzen Einführung der linearen *Quadratic Amplitude Modulation* (QAM), die eine Approximation des im GSM genutzten *Gaussian Minimum Shift Keying* (GMSK) Signals ist. Die QAM kann nach Abtastung und der Derotation als diskretes lineares Systemmodell mit einem Eingang und zwei Ausgängen modelliert werden. Wir entwickeln zwei auf dem linearen Systemmodell basierende semiblinde Algorithmen durch Kombination der Information, die zum einen durch Statistiken zweiter Ordnung (SOS) und zum anderen durch Training gewonnen wird. Diese semiblinden Methoden Kőnnen einige starke Einschränkungen der auf SOS basierenden blinden Algorithmen überwinden. Außerdem untersuchen wir die Bedingungen, die für die semiblinde Identifizierbarkeit gelten. Schließlich vergleichen wir Simulationsergebnisse für GSM Empfänger, die zum einen durch reine Trainings- und zum anderen durch semiblinde Kanalidentifiaktionsmethoden erstellt wurden. © 2000 Elsevier Science B.V. All rights reserved.

Résumé

Nous étudions l'application du principe d'égalisation semi-aveugle dans des systèmes cellulaires sans fils pratiques. Spécifiquement, nous nous concentrons sur le populaire receveur cellulaire GSM dans un effort d'améliorer l'efficacité du

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système sans compromettre ses performances. Nous commençons par introduire brièvement une approximation de la modulation d'amplitude quadratique (QAM) linéaire pour un signal codé par décalage minimum gaussien (GMSK) utilisé en GSM, qui peut être modélisé comme un système linéaire à une entrée unique et à deux sorties après échantillonnage et dé-rotation. Nous avons développé deux algorithmes différents semi-aveugles basés sur le modèle de système linéaire, en combinant à la fois une information statistique de second ordre (SSO) et une information d'entraînement. Ces méthodes semi-aveugles peuvent surpasser certaines limitations sérieuses des algorithmes aveugles SSO. Nous avons aussi analysé les conditions d'identifiabilité semi-aveugles. Finalement, nous comparons les résultats de simulations pour des récepteurs GSM en utilisant des méthodes d'identification de canaux semi-aveugles et purement par apprentissage.

Keywords: GSM; Maximum likelihood sequence estimation; Blind equalization; Semi-blind equalization; Channel estimation; TDMA

1. Introduction

In the past decade, wireless communication experienced explosive growth. The convenience and flexibility offered by mobile communication have made it one of the fastest growing areas of telecommunications. Despite tremendous progress achieved in the mobile cellular industry, there still exist some technical difficulties that limit its future expansion. One of the key problems it faces is the fast frequency selective fading channels due to mobile speed and multi-path propagation. Severe inter-symbol interference (ISI) can occur for wireless receivers under such distortive channels.

An effective approach to combat ISI and other sources of interference is the use of an optimum receiver employing maximum likelihood sequence estimation (MLSE). MLSE requires knowledge of the channel impulse response, which is not readily available to the receiver, especially in a mobile environment. Thus, accurate channel estimation is crucial to the design of an optimum receiver. In order to estimate the unknown and time-variant channel response, the traditional approach in mobile communication systems (such as GSM) is to transmit short training sequences [5] periodically to assist the receiver in channel estimation [1]. Periodic training can consume considerable channel capacity that could be otherwise used, at least partially, for "information" data transmission. For example, in GSM, each time division multiple access (TDMA) data burst contains 26 training bits and 116 information data bits. The need for accurate channel identification and for high throughput efficiency reflects a design conflict between system performance and system efficiency. Moreover, since mobile radio channels can be quite long in some special environments, the fixed length of training sequence may not be long enough to allow accurate estimation of channels with long-delay spans. As a result, system performance may be far worse under these circumstances. It is for these two main reasons that we investigate the potential application of blind and semi-blind channel identification method for future TDMA systems derived from GSM.

Currently, there are two major time-division multiple access (TDMA) burst-mode transmission standards for wireless cellular service, namely, the IS-136 digital cellular standard and the GSM standard. In this study, we focus on the GSM standard that has become the most widely deployed second generation wireless cellular and PCS systems in the world. GSM is a TDMA system where each frequency band of 200 kHz is shared by eight users separated in time by their non-overlapping time bursts. Each burst consists of two 58-bit streams of information data separated by a mid-amble of 26 training bits for channel equalization and receiver synchronization. Obviously, such a sizable mid-amble may be used for real data transmission if blind/semi-blind equalization can be successfully employed. In recent works [3,4], several blind equalization algorithms based on high-order statistics (HOS) have shown great potential in their ability to improve the GSM system efficiency. On the other hand, [4] has shown that due to sensitivity to channel order mismatch and channel-dependent limitation, many blind algorithms based on second-order statistics (SOS) often fail to achieve satisfactory performance.