ELSEVIER

Signal Processing 80 (2000) 1999–2015

SIGNAL PROCESSING

www.elsevier.nl/locate/sigpro

Burst mode equalization: optimal approach and suboptimal continuous-processing approximation☆

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Received 5 January 1999; received in revised form 15 August 1999

Abstract

We consider a transmission by burst where the data are organized and sent by bursts. At each end of the burst of data, a sequence of symbols is assumed known, and the channel considered as constant over the burst duration. The optimal structure of the burst mode equalizers is derived. The class of linear and decision feedback equalizers is considered, as well the class of ISI cancelers that use past but also future decisions: for each class of equalizers the MMSE, the unbiased MMSE and the MMSE zero forcing versions are derived. Unlike in the continuous-processing mode, the optimal burst mode filters are time varying. The performance of the different equalizers are evaluated and compared to each other in terms of SNR and probability of error: these measures depend on the position of the estimated symbol and on the presence of known symbols. Finally, we show that, by choosing correctly the number and position of the known symbols, (time-invariant) continuous-processing filters applied to burst mode can be organized to give sufficiently good performance, so that optimal (time-varying) burst processing implementation can be avoided.

Zusammenfassung

Wir betrachten die Burst-Übertragung, wobei die Daten in Bursts organisiert und gesendet werden. Am Ende jedes Datenburst wird eine Symbolsequenz als bekannt und der Kanal wird als konstant über der Burstdauer vorausgesetzt. Die optimale Struktur des Burst-Modus-Entzerrers wird hergeleitet. Es wird sowohl die Klasse der linearen, entscheidungsrückgekoppelten Entzerrer als auch die Klasse der lCl-Canceler betrachtet die sowohl vergangene als auch zukünftige Entscheidungen benutzen. Für jede Entzerrerklasse werden der MMSE, der biasfrcic MMSE und MMSE nullerzwingende Versionen abgeleitet. Im Gegensatz zum kontinuierlichen Verarbeitungsmodus sind die optimalen Burstmodus-Filter zeitvariant. Die Leistung der verschiedenen Entzerrer wird bewertet und untereinander in Hinblick auf SNR und Fehlerwahrscheinlichkeit verglichen. Diese Maße hängen von der Position des geschätzten Symbols und der Präsens unbekannter Symbole ab. Schließlich zeigen wir, dass durch die richtige Wahl der Nummer und Position der bekannten Symbole, (zeitinvariante) kontinuierlich verarbeitende Filter angewandt auf den Burstmodus derartig organisiert werden können, dass hinreichend gute Ergebnisse erzielt werden können, so dass optimale (zeitvariante) burstverarbeitende Implementierungen umgangen werden können.

☆The work of Elisabeth de Carvalho was supported by Laboratories d'Electronique Philips under contract Cifre 297/95. The work of Dirk Slock was supported in part by Laboratories d'Electronoque Philips under contract LEP 95FAR008.

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0165-1684/00/$ - see front matter
PII: S0165-1684(00)00066-9

Résumé

Nous considérons une transmission par rafales où les données sont organisées et envoyées en rafales. A chaque fin de la rafale de données, une séquence de symboles est supposée connue, et le canal est considéré constant sur la durée de la rafale. Nous dérivons la structure optimale de l'égaliseur de mode rafale. Nous considérons la classe des égaliseurs linéaires et à retour de décision, ainsi des éliminateurs ISI qui utilisent les décisions passées mais aussi futures: pour chaque classe d'égaliseur, la MMSE, la MMSE non biaisée et la variante MMSE Zero Forcing sont dérivées. Contrairement au mode de traitement continu, les filtres de mode en rafales optimaux sont variables dans le temps. Nous évaluons les performances des différents égaliseurs et nous les comparons entre eux en terme de rapport signal à bruit et de probabilité d'erreur: ces mesures dépendent de la position du symbole estimé et de la présence de symboles connus. Finalement, nous montrons que, en choisissant correctement le nombre et la position des symboles connus, des filtres de traitement continus (invariants dans le temps) appliqués au mode en rafale peuvent être organisés pour donner des performances suffisamment bonnes, de sorte que une implémentation de traitement de rafales optimale (variable dans le temps) peut être évitée.

Keywords: Burst mode equalization; Multichannel; Linear equalizer; Decision feedback equalizer; ISI canceler; Non-causal decision feedback equalizer; Unbiased MMSE equalizer

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Nomenclature

$(\cdot)^*$	complex conjugate	$A_{i,j}$	element i,j of the matrix A
$(\cdot)^{\mathrm{T}}$	transpose	$\hat{\theta}$	estimate of parameter θ
$(\cdot)^{\mathrm{H}}$	Hermitian transpose	E	mathematical expectation
$(\cdot)^{-1}$	inverse	I	identity matrix of adequate dimension
A_i	element i of the vector A	w.r.t.	with respect to

1. Introduction

In most of the actual mobile communication systems, the data are divided and transmitted in bursts. In general, the bursts are separated by guard intervals, which avoid interburst interference, and contain known symbols, like synchronization bits or a training sequence to estimate the channel. This is typically the case of GSM (global system for mobile communications), where the channel is assumed constant over the duration of a burst and is estimated by a middamble training sequence, and the Viterbi algorithm is applied to estimate the transmitted data symbols.

We propose a scenario where a sequence of known symbols is attached to each end of the burst of information symbols. This scheme is proven to include the GSM case. The channel is assumed constant during the transmission of a burst. As we are operating with a finite amount of data, the usual time-invariant continuous-processing equalizers are not optimal anymore. We propose a derivation of the optimal burst mode equalizers, which are time varying. Three classes of equalizers are considered: the usual linear and decision feedback equalizers, as well as the ISI canceler. This last equalizer uses past but also future decisions and was proposed in its continuous-processing version in [10,7], and in its burst mode version in [11,6] where it is called non-causal decision feedback equalizer (NCDFE); in this paper, we use the term NCDFE to designate the ISI canceler. In a burst mode implementation of the NCDFE, a classical linear or decision feedback equalizer is used to give a first estimation of the symbols. Based on these decisions, the NCDFE computes new estimates and its output can be used to do other iterations. This NCDFE is potentially the most powerful