Ingeniería Investigación y Tecnología, volumen XVI (número 3), julio-septiembre 2015: 383-390
ISSN 1405-7743 FI-UNAM
(artículo arbitrado)
doi: http://dx.doi.org/10.1016/j.riit.2015.05.011

Wireless Synchronization Preamble Detection Scheme Using Bispectra-Based Statistics in the Presence of Stationary Noise

Esquema de detección del preámbulo de sincronización de los sistemas inalámbricos basado en la estadística del biespectro en presencia de ruido estacionario

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Information on the article: received: March 2014, reevaluated: July 2014, accepted: November 2014

Abstract

Higher-order statistical analysis has been applied in many areas of communication systems, such as blind equalization, pattern recognition and channel estimation; among others. In this paper, wireless preamble sequences in additive noise are processed to reduce the signal to noise ratio of synchronization signals thereby improving interconnectivity. For such end, detection structures using matched filtering in the form of passive implementation along with cumulant-based processing are proposed. A framework based on bispectra is used to obtain the probability of detection confirming successful synchronization in the presence of Gaussian and non-Gaussian noise. Signal bispectra and power of the tests are estimated over a number of samples within the length of standard wireless preamble signals.

Keywords:

- wireless systems
- matched filter
- broadband interference
- non-Gaussian noise
- Bispectra
- stationary noise
- radio receiver

Resumen

El análisis estadístico de alto orden ha sido aplicado en muchas áreas de los sistemas de comunicaciones, como igualación ciega, reconocimiento de patrones y estimación del canal; entre otros. En este artículo se procesan las secuencias del preámbulo mezcladas con muestras de ruido, con el objeto de reducir la relación señal a ruido de las señales de sincronización inalámbricas y por este medio mejorar la interconectividad. Se proponen estructuras de detección basadas en filtrado acoplado en su forma pasiva conjuntamente con el procesamiento basado en cumulantes de alto orden. Se desarrolla un esquema basado en el biespectro para obtener la probabilidad de detección confirmando sincronización en presencia de ruido Gausiano y no-Gausiano. El biespectro de la señal y la prueba de hipótesis se estiman con un número de muestras cuya longitud es menor o igual que la longitud de las secuencias de sincronización en una trama.

Descriptores:

- *sistemas inalámbricos*
- *filtro acoplado*
- *interferencia de banda amplia*
- *ruido no-Gaussiano*
- *biespectro*
- *ruido estacionario*
- *radio receptor*

Introduction

Wireless systems need to satisfy simultaneously the communication and computing demands through different radio protocols. The current tendency is towards the usage of multiple-radio systems that preserve good performance through a range of synchronization techniques required for supporting coherent operation. Currently, orthogonal multicarrier frequency division multiplexing and multicarrier (code division multiple access) CDMA are considered for transmission wireless standards (Hanzo *et al*., 2003; Keller and Hanzo, 1996).

In a commonly found environment surrounding wireless systems interference from radio systems crowding into small areas as well as incidental radiation from electrical devices arise. These sources of interference, which are coupled to the radio receiver in the form of additive non-Gaussian noise, become a foremost impairment. Wireless systems are designed to operate most effectively against the usually assumed additive white Gaussian noise (AWGN) and therefore non-Gaussian coupled to the radio receiver degrades greatly the interconnectivity. Additionally, the non-Gaussian nature of the noise is strengthened by a large sort of near-field interferences from computing platforms that are currently integrated with wireless subsystems (Slattery *et al*., 1999). In this article, the detection of wireless synchronization sequences using higher-order statistical analysis (HOSA) is proposed. Among other applications, HOSA is effective in developing algorithms to counteract channel distortion (Nikias and Petropulu, 1993) and also for detecting and classifying signals that features higher-order polyspectra energy (Giannakis and Tsatsanis, 1990). Here, for the first time, higher-order cumulant processing is proposed to detect the preamble of wireless 802.11 standards.

Synchronization of wireless systems is critical. Keller and Hanzo (1996) developed synchronization algorithms relying on the autocorrelation function between received and stored samples of synchronization frames. The periodicity of the synchronization pattern in consecutive frames allows frequency tracking and frame synchronization. Nonetheless, these functions are influenced by additive Gaussian noise at lower signal-to-noise ratios (SNR's) (Keller and Hanzo, 1996) and, consequently, wireless range is diminished. In dense networks preamble signals create interference that is handled in the form of Gaussian interference (Sridhara, 2007; Nagaraj *et al*., 2009). In Nagaraj *et al*. (2009) differential correlation type preamble detection sets time coherence to perform statistical metric computation and flag the presence or absence of preamble at the receiver input. For our proposal, higher-order cumulant processing would be helpful in discriminating the presence of multiple wireless systems, however; latency of matched filtering proceeding by cumulant-based processing needs to be addressed carefully. This issue is beyond the scope of the present article. Here, receiver schemes that detect the presence of wireless systems are proposed and their performance is analyzed statistically considering stationary Gaussian and non-Gaussian interference. First, a receiver based on passive matched filtering for synchronization of wireless systems is introduced. Then, the correlation properties of the cumulants and the proposed detectors are analyzed. The processing of wireless preamble using a matched filter preceded by higher-order cumulant computation for different sample sizes and signal-to-noise ratios are investigated. Later, a hypothesis testing framework that obtains the preamble detection statistics for a given false alarm probability is developed. Finally, conclusions of the proposed matched filter strategy are outlined.

Preamble bispectra

Wireless transmission standards 802.11 specify message and synchronization frames for the Medium Access Control and Physical layers (Agere Systems Inc., 2004). Wireless standards 802.11a and 802.11b are based on the principles of Orthogonal Frequency Division Multiplexing (OFDM) and multicarrier code division multiple access (MC- CDMA) systems; respectively (Hanzo *et al*., 2003). The transmitted frame of the wireless system consists of copies of the prescribed synchronization sequences, also named herein preambles, and the messages are transmitted in the form of OFDM symbols or in a multi-carrier CDMA scheme. Figure 1 displays the 802.11a and 802.11b preambles as defined by the IEEE standard (Agere Systems Inc., 2004). The preamble 802.11b is effectively a pseudorandom sequence while the standard 802.11a consists of large and short periodicity terms corresponding to a set of frequency tones.

The goal of the preamble processing technique is to achieve an improvement on the receiver sensitivity. Receiver sensitivity is impaired by different electromagnetic compatibility (EMC) effects, such as broadband emissions (Bronaugh and Lambdin, 1988) that produce interference of nature sufficiently non-Gaussian (Linares and Miranda, 1996). Some assumptions are as follows. First, noise prewhitening filter at the input is avoided and thus the ensuing receiver desense, and second, the preamble sequence has zero frequency and time misalignment along the frame structure which