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ScienceDirect
Int. J. Electron. Commun. (AEÜ) 61 (2007) 104–117
International Journal of Electronics and Communications
www.elsevier.de/aeue

Air interface identification for Software Radio systems

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Received 20 June 2005

Abstract

Reconfigurable Software Radio (SR) equipment is considered as the next evolutionary step in the mobile communications. One of the most crucial properties of a SR terminal is that it is capable of using a wide range of air interface standards, providing a seamless interoperability between different standards and an enhanced roaming capability, paving way to a more flexible and efficient use of spectral resources. This multimode operation has to be supported by a number of key functionalities, one of which is the air interface identification. A SR terminal, when switched on, has to be able to locate and identify the air interfaces available in the frequency environment, and while connected to a network, it has to monitor the presence of alternative air interfaces to perform interstandard handover if necessary. In our work, we propose exploiting the distinct cyclostationary properties of signals from different air interfaces as features for air interface identification.

Keywords: Software Radio; Cognitive radio; Cyclostationarity; Air interface identification

1. Introduction

Wireless digital communications is experiencing a veritable boom since the beginning of the last decade and has been one of the fastest growing segments in the telecommunications industry. The wireless revolution has started in the nineties, with the introduction of the second generation mobile communications systems, such as GSM and DECT in Europe, IS136 and IS90 in the USA and PDC in Japan. The third generation mobile standards, like UMTS in Europe, are just beginning to enter service. Furthermore, wireless local area network (WLAN) and personal area network (PAN) systems are drawing more and more interest. Digital Audio Broadcasting (DAB) and terrestrial Digital Video Broadcasting (DVB-T) systems represent two examples, where digital wireless technology was able to penetrate the area of terrestrial broadcasting, which was traditionally dominated by analog transmission schemes.

The main drawback of this explosion in the number of wireless standards is that the users require different equipment for each of these services. As a consequence, there has been growing interest in terminals capable of using multiple transmission standards (also called air interface standards). In the nineties, Mitola has introduced the concept of Software Radio (SR), which is a design philosophy for building transceivers that can accommodate a significant range of radio frequency bands and air interface standards through software running on general purpose digital signal processors [1]. For an ideal SR, this range includes all the frequency bands and standards required by the user. The multistandard capable SR terminals are expected to provide the users with an unprecedented flexibility, making it possible to choose, among the set of existing air interface standards, the particular standard, which is best suited to the user needs at a given time, in terms of provided service, cost, traffic requirements and quality of service, leading to a considerable

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1434-8411/$ - see front matter
doi:10.1016/j.aeue.2006.03.005

network independence. However, in order to fully exploit this flexibility, more intelligence and environmental awareness is required, both from resource management systems, and from user terminals. In [2], Mitola has described the *Cognitive Radio*, an "intelligent" agent controlling the SR user terminal capable of adapting itself to the traffic, frequency environment and user needs and habits. The Cognitive Radio continuously observes its physical environment, and makes decisions about how to use the available resources in a most efficient manner.

Perhaps the most crucial facet of the environmental awareness of a SR user terminal is the ability to locate and identify the air interface standards existing in its frequency environment. Only after having located and identified the available standards, the SR can choose the most suitable air interface for the specific task at hand and reconfigure itself according to the specifications of the chosen air interface standard. In this work, a unified approach to the blind air interface identification problem based on cyclostationarity is presented, which is significantly robust against multipath fading and AWGN, and capable of identifying air interface signals with rather complicated signal structures.

This paper is organized as follows: In Section 2, an overview on the air interface identification task is provided. Section 3 presents the mathematical preliminaries for cyclostationary processes. Section 4 investigates the cyclostationary characteristics signal structures which are encountered in today's wireless environment, in Section 5 a detection strategy for cyclostationary signatures is presented. Section 6 presents simulation results for the proposed identification strategy under realistic channel conditions for different signal types and finally Section 7 summarizes the work.

2. Air interface identification

The air interface identification strategy presented in this work is based on three fundamental assumptions:

1. The air interface identification is to be performed in an environment with a fully dynamic frequency allocation scheme, i.e. each transmission standard can be operated on any frequency band, according to the user demands and traffic considerations. Lately, there have been tremendous research efforts in the area of dynamic, demand oriented frequency allocation methods indicating a clear global trend towards more efficient and flexible resource allocation methods and more interoperability between different standards, making the above assumption quite reasonable for a future SR system.
2. The air interface identification is to be performed blindly (i.e. without cooperation from the network), which is a worst-case assumption.
3. There may exist only a limited number of possible standardized air interfaces, and the SR terminal has knowledge stored in its database about all the relevant parameters of every air interface standard it is capable of using, or is able to download them, as new standards emerge.

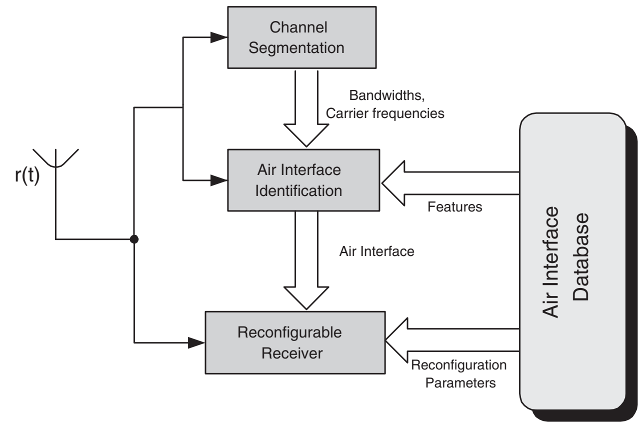

Fig. 1. The SR structure under consideration.

The first and the second assumptions jointly imply that information about the bandwidths and carrier frequencies of the signals of interest are not available to the SR terminal prior to the identification. Therefore, an automatic channel segmentation stage has to precede the identification stage, detecting the number of individual RF signals in the frequency environment and estimating their bandwidths and carrier frequencies. Subsequently, the individual air interface signals are brought to baseband, filtered and presented to the air interface identification stage for further processing.

The third assumption merely implies that the SR has a priori knowledge about all the air interfaces it is capable of using, which reduces the identification problem to a recognition problem, i.e. the identification stage has to recognize the signal of interest as one of the known air interface standards, or reject it as unknown. Fig. 1 illustrates the SR receiver structure proposed in this work, where the channel segmentation and the air interface identification tasks are performed by a separate dedicated receiver chain, enabling a simultaneous reception and monitoring of the frequency environment. In this work, we assume that the channel segmentation has been performed previously, and focus on the identification of the air interface signals, which have been isolated and downconverted. For a detailed discussion on channel segmentation, the reader is referred to [3,4].

In the literature, most commonly, modulation type classification schemes are proposed for the purpose of air interface identification. Such schemes use the phase, amplitude or instantaneous frequency information from the received signal to recover modulation type specific features required for the classification. The generation of features is performed using well-known tools of statistical signal processing, such as histograms, statistical moments of second or higher order, linear or nonlinear transformations (such as DFT, Wavelet