Chapter 3
Modulation and Coding Techniques for Inter-Vehicular Communications

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ABSTRACT
Direct inter-vehicular communications are presumably more difficult to perform than communications within a cellular network or between a moving vehicle and the roadside, where there is a large fixed infrastructure. It is assumed in this chapter that the mobile channel between the two vehicles is so rapidly variable that it is not possible to measure it in real-time. The authors therefore selected and considered only modulation and coding techniques for which the knowledge of the channel state was not necessary at both the transmitter and the receiver, that is, differential and noncoherent communications. To be realistic, only space-time coding communication systems with two transmit antennas were considered. The authors have purposely avoided too much theoretical development, with the intent of making clear that the implementation of all the techniques mentioned in this chapter, it should not be a too difficult task for the electronic technology of today. Future research directions are also suggested to conclude the chapter.

INTRODUCTION
The science of intelligent transportation systems (ITS) cleverly exploits the achievements of other technical disciplines like electronics, telecommunications, computer science, automatic control, information technology and so on to improve the quality and safety of the traffic. Direct vehicle-to-vehicle (V2V) communication has recently received considerable attention from both the academia and the car industry. This is certainly a bit bumpier to realize than the communication
within a cellular network, since both vehicles are supposed to be on the move and thus, the wireless channel between them is strongly time variable. Moreover, the requirements for the reliability of a V2V communication link are more stringent: avoidance of collisions may closely depend on it. In this chapter, we thus try to select and recommend for use only those modulation and coding techniques that are known to be less exigent with the quality of the mobile radio channel. But while such techniques are robust and work well on a poor channel, their data rate performance is accordingly lower. This clearly puts a constraint on the amount of information that can be transmitted on a V2V digital link. On the other side, we see at the present stage of the technology no urgent reason to offer two drivers running on a highway the possibility to directly transmit to each other large computer files, music or movies, or to play chess. Vital information as measured in bits should be short.

The literature on V2V is abundant. However, most papers and articles dedicated to this important topic give little consideration to the physical layer, assuming more or less that this technical problem has already been solved. However, as witnessed by the incessant flow of new papers dealing with transmission techniques that could support V2V communications, it is not so. Let us start by noting that textbooks describing wireless communications have hundreds of pages. In this chapter, we take the realistic approach to review the modulation and coding techniques that do not require the knowledge of the wireless channel. The simplest such modulation is frequency-shift keying (FSK); it is robust and naturally noncoherent, but unfortunately allows for a rather low data rate. The phase-shift keying (PSK) is a coherent modulation requiring the recovery of the carrier frequency at the receiver; however, its differential version needs no such operation, which makes it fit for V2V direct communication. Fortunately, differential PSK can be combined with trellis coded modulation (TCM) in order to improve the transmission performance. Another powerful means to improve the performance of a wireless digital link is the transmit antenna diversity. In this chapter, we consider only communication systems with two transmit antennas, but more than two can be used. There are two reasons for this choice: the first one is the limited editorial space. The second one, maybe more important, is that, according to the mathematical theory of orthogonal designs, square orthogonal matrices with complex-valued entries do not exist for a size larger than $2 \times 2$. This technique is known as space-time block coding. It generally requires the acquisition of channel state information (CSI) at the receiver. However, a version of it called unitary space-time modulation was devised for which CSI is not necessary. A differential encoding of space-time block codes is also possible; it can be viewed as a generalization for two transmit antennas of the differential PSK. We then present in some detail super-orthogonal space-time trellis coded differential PSK. The actual trend is, of course, to increase the transmission data rate for which wireless channels with larger bandwidth are needed. But broadband channels require adaptive equalization. All the techniques mentioned above are narrowband single-carrier coding and/or modulation methods for which equalization is not an issue. They can be used for broadband channels as well, but the equalization in this case is difficult to perform. To avoid the equalization of broadband channels, multicarrier modulation is usually preferred. For wireless channels, it is known as orthogonal frequency division multiplexing (OFDM). Instead of using a single-carrier, OFDM uses a rather large set of frequencies between which harmonic relations exist. Therefore, OFDM is a highly synchronous and coherent transmission technology. In order to apply it to V2V communications, OFDM must be somehow transformed into a noncoherent technique. We summarize a possibility of doing this from the open literature but certainly the research will continue in this direction.
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