On the Binary Allocation of Modulator Symbol in the Case of Turbo Coded 32-QAM Rectangular Modulation

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***Abstract*— This work is a continuation of the study on interfacing between turbo encoding and (digital) quadrature amplitude modulation (QAM). In the previous studies we have considered only the square constellations with 16, 64 and 256 signal points respectively. In this paper we investigated the performances of the turbo codes when using 32-QAM with a rectangular constellation. The placement variants of the turbo coded bits into the modulator symbol have bit/frame error rate (BER/FER) performance against signal to noise ratio (SNR) significantly different. Due to the presence of the 5 bits in 32-QAM modulator symbol, for a direct coupling between the turbo coding and the modulation blocks, in our simulations we used the 3/5 coding rate and two turbo codes (TCs). The first one is a double-binary turbo code (DBTC) defined in DVB-RCS2 standard and the second one is a triple binary turbo code (TBTC). If for DBTC it is required to use puncturing to obtain the coding rate of 3/5, for the TBTC this 3/5 coding rate is the natural one. The simulations made show that the two TCs behave similarly for all the cases of coding to modulation bit mapping (CMBM).**

Keywords—communication systems; correcting codes; iterative decoding; a posteriori probability; turbo-codes

I. INTRODUCTION

Quadrature Amplitude Modulation (QAM), in its different versions, is a customary presence in the current communication systems. The consistency of the signal points in the QAM constellation is given by an optimum balance between an increased spectral efficiency and a BER/FERvsSNR performance. The higher the number of the points in the constellation signals is the more the spectral efficiency increases. Thus, QAM with 16 signal points (16-QAM) offers a spectral efficiency of 4 bit/s/Hz, 64-QAM has a spectral efficiency of 6 bit/s/Hz, and the 256-QAM conducts to a spectral efficiency of 8 bit/s/Hz [1]. But, the price of this "increase" of the spectral efficiency is given by the degradation of the BER/FERvsSNR performance. More specifically, by involving turbo coding, 256-QAM requires a signal to noise ratio (SNR) of about 7 dB better than at 16-QAM to achieve the same BER/FER performance [2]-[3]. Thus, the quality of the transmission channel given by the SNR validates the use of one type of modulation.

An issue raised by the direct coupling between the output of the turbo encoder and the modulator is the binary allocation into the modulator symbol. This is due, on one hand, to the fact that the turbo encoder generates both information bits and parity bits and, on the other hand, because the QAM modulation protects differently the bits in different locations of the modulator symbol. The studies on the performance of turbo coded transmission systems, for different variants of coding to modulation bit mapping (CMBM) for square QAM are given in [2]-[4]. The square QAM modulation (16-, 64-, and 256-QAM) have the advantage of a possible separation between the two carriers of the modulator symbol. Thus, the square QAM modulation can be "decomposed" into two Pulse Amplitude Modulation (PAM). This decomposition simplifies both modulation and demodulation operations, but also the turbo decoding, in that it provides an "soft" output so necessary for the Maximum A Posteriori (MAP) decoding algorithms [5]. In the case of QAM with 32 signal points (32-QAM) the separation on the two carriers is possible, as it we will be shown in Section II, at the price of the increasing of the average energy per symbol of the modulated signal. The minimum energy per symbol, by maintaining symmetry to the two carriers, is obtained for a constellation as the one shown in Fig. 1a. However, this constellation is not separable. Thus, it impedes the construction of the soft outputs necessary to the turbo decoder, as we underlined above. In this paper we preferred a rectangular approach also for 32-QAM, to benefit from the advantages of separating the carrier. Such an approach was chosen also in [6].

The aim of this paper is to highlight the performance of different CMBM variants when using the rectangular 32-QAM. Section II makes a short presentation of a 32-QAM modulation: the signal points constellation, the structure of the modulator symbol and also the (soft) outputs generated by the modulator. The coupling between the turbo-encoder and the QAM modulator can be made directly or through a preliminary "rearrangement" of the bits of the turbo coded block. It is about a Bit-Interleaved Coded Modulation (BICM). This process "dilutes" the effects of the different methods of direct allocation. Since the modulator symbol at 32-QAM contains 5 bits, in the case in which we desire a direct coupling between the turbo encoder and the modulator, it is also necessary that