On the allocation of double-binary turbo coded bits in the case of 16-QAM modulation

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***Abstract*—It is well known that the 16-quadrature amplitude modulation (16-QAM) differently protects the bits of the same symbol. In turbo-coded transmission systems, several ways for allocating the bits generated by the turbo encoder can be considered. Thus, the bits generated by the turbo encoder can occupy different positions in the modulator input symbol. In this paper, we investigated the performance of transmission systems, in terms of bit/frame error rate versus signal to noise ratio (BER/FERvsSNR), in case of using double-binary turbo codes (DBTC) and 16-QAM square modulation, in AWGN channel, for various allocation modes. In our simulation we considered two coding rates, namely ½ and ¾. Intensive simulations up to FER ≈ 10^{-7}, allow some practical tips on choosing the best allocation methods, both in the water fall and error floor regions.**

Keywords—mapping; quadrature amplitude modulation; transmission channel; turbo code

I. INTRODUCTION

In digital communications modulation is often expressed in terms of I and Q, which define a space obtained using two orthogonal sinusoidal carriers [1]. Most digital modulation maps the data to a number of discrete points on the I/Q plane, known as constellation points. Most of the communications standards (LTE, DVB, deep-space communications, etc) use digital modulation together with the turbo-coding in order to assure error protection. It provides a good compromise between the bit/frame error rate (BER/FER) versus signal to noise ratio (SNR) performance and bandwidth efficiency. Perhaps the most commonly used constellation for signal points is the square one, in which case the modulation is called square sixteen – Quadrature Amplitude Modulation (16-QAM), (see Fig. 1a). This modulation is provided for LTE [2] and DVB [3]. In Recommendation for Space Data System Standard [4] it has the form of Sixteen Asymmetric Phase Shift Keying (16-APSK); see Fig. 1b. In the case of 16-APSK, the constellation points are equidistantly arranged on two concentric circles of different radiuses. In the literature, there are arguments for other constellations as well, such as the one presented in Fig. 1c, called star 16-QAM [5], [6].

The BER/FERvsSNR performances for turbo coded square 16-QAM modulation are presented in [7] (for single-binary convolutional turbo codes) and in [8] (for block turbo codes). Over the years, several methods concerning (turbo) coded modulation have been studied and proposed. A solution to increase the performance is the used of bit interleaver coded modulation (BICM) [9]. It involves the insertion of an interleaver between the coding and the modulator blocks.

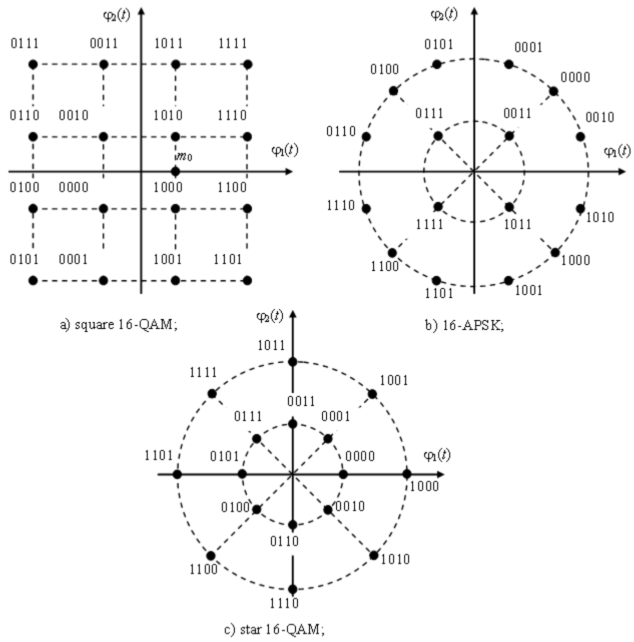

Fig. 1. Common types of constellations in signals space for the digital modulation with 16 signal points. $\varphi_1(t)$ – in-phase carrier, $\varphi_2(t)$ - quadrature carrier.

In this paper, we considered the double binary turbo-codes (DBTC) and the square 16-QAM modulation with Gray allocation (as shown in Fig. 1a), without bit interleaving. As shown in Fig. 1, a constellation point is identified by 4 bits. However, the square 16-QAM can be separated into two Pulse-Amplitude Modulations with four signal points (4-PAM). Thus, each of the two carriers may be separately modulated by the two bits (di-bit). Since four bits (two of information and