Study On Intra-Symbol Interleaving For Multi-Non-Binary Turbo Codes

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***Abstract*—Multi-Non-Binary Turbo Codes (MNBTC), i.e. the latest generation of turbo codes, operate with arrays of symbols, each symbol consisting of several bits. The interleaving for these multi-binary arrays of symbols required in turbo coding involves two steps: an inter-symbol interleaving and an intra-symbol interleaving. Inter-symbol interleaving mixes the data arrays columns. This can be achieved by using already existing dedicated interleavers. The novelty is intra-symbol interleaving, mixing symbols or even bits in each column of the data array. This paper investigates several possible intra-symbol interleaving methods in terms of their bit/frame error rate versus signal to noise ratio (BER/FERvsSNR) performances. The study allows some practical conclusions.**

***Keywords*—AWGN channels, communications systems, forward error correction, intra-symbol interleaving, multi-non-binary turbo codes.**

I. Introduction

TODAY, more than two decades since the advent of turbo codes (TC) **[1]**, a widely accepted fact is that the bit/frame error rate (B/FER) versus signal to noise ratio (SNR) performance of TCs is also influenced by the interleaving quality. However, interleaver "quality" is difficult to quantify. Interleaving distance **[2]** is a measure of the degree of scattering produced by the interleaver. Obviously, a higher interleaving distance is desirable. However, the rectangular interleaver that offers the greatest interleaving distance performs poorly in terms of B/FERvsSNR. But the rectangular interleaver has a regular structure. In other words, besides a high degree of scattering, the interleaver should also provide a good mixing of the data block bits. A measure of the mixing can be dispersion **[3]**. It is considered that maximum dispersion is produced by purely random interleaver. But the purely random interleaver has the minimum interleaving distance possible. Over time, several types of interleavers have been proposed, to ensure both greater interleaving distance and high dispersion. In this regard, we note the type S **[4]**, dithered relative prime (DRP) **[5]**, almost regular permutation (ARP) **[6]** or quadratic polynomial permutation (QPP) **[7]** interleaver. Although it has a very good performance, the S-interleaver is not used because it has the drawback of requiring substantial memory. ARP and QPP interleavers are used in the DVB-RCS **[8]**, and LTE **[9]** standards, respectively. These types of interleaves have been designed for single binary turbo codes (SBTC). Additional information on the intrinsic qualities of interleavers can be given through the spectrum of interleaving distances **[10]**.

With the advent of double binary turbo codes (DBTC) **[11]-[12]** emerged the need for intra-symbol interleaving. For DBTCs, data are arranged in $2\times N_d$ arrays (matrices), where N_d is the length of the interleaver that performs the inter-symbol interleaving. In the DVB-RCS standard **[8]**, intra-symbol interleaving involves swapping the positions of bits in even serial number symbols. It is worth noting that the two interleavings (intra- and inter-symbol) need to be correlated **[13]**.

Multi-non-binary turbo codes (MNBTC) **[14]** further compact the data block. In their case, the size of the data block is $R\times Q\times N_m$, where R is the number of the turbo encoder's non-binary inputs, and Q is the number of bits of a symbol. Thus, in this case, the intra-symbol interleaving operates on the $R\times Q \geq 4$ bits. Of course, for the same total number of bits in the data block for SBTC, DBTC and MNBTC, the interleaver's N_m dimension that performs the inter-symbol interleaving for MNBTCs decreases $R\times Q$ times compared to SBTCs and $R\times Q/2$ times compared to DBTCs. Obviously this will lead to a decrease in the quality of the interleaving in the absence of an intra-symbol interleaving. Thus the role of intra-symbol interleaving for MNBTCs is to compensate the reduction of the inter-symbol interleaving length.

Because for a MNBTC the number of bits that comprise the symbol operating the intra-symbol interleaving is ($R\times Q \geq$ 4 bits) higher than for DBTCs, the opportunities to perform this interleaving are also more numerous.

In this paper we investigated B/FERvsSNR performances with three different intra-symbol interleaving versions for MNBTCs, having $R = Q = 2$ and $N_m = 376$ bits, performances that we have compared with the version lacking intra-symbol interleaving. Of the three types of intra-symbol interleaving chosen, two of them have regular, periodic structures, and the third has a random structure. Practical results recommend regular structure intra-symbol interleaving. The paper is structured as follows: Section 2 describes the structure of a MNBTC data block, and the intra-symbol interleaving variants used. In Section 3 we presented the experimental results, and conclusions are given in Section 4.

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