During the research activity we worked with colleagues from the Department of Communications of the Faculty of Electronics and Telecommunications, University Politehnica Timişoara, with colleagues from the Department of Telecommunications at the Faculty of Electronics, Telecommunications and Information Technology of the Technical University "Gheorghe Asachi" Iaşi and with colleagues from the department of Télécom Bretagne Electronique, Brest, France.

Most important research results:

In **[1]** we presented a new family of turbo codes (TC) called multi-non-binary turbo codes (MNBTC) that generalizes the concept of turbo codes to multi-non-binary (MNB) parallel concatenated convolutional codes. An MNBTC incorporates, as component encoders, recursive and systematic multi-non-binary convolutional encoders. The more compact data structure for these encoders confers some advantages on MNBTCs over other types of turbo codes, such as better asymptotic behavior, better convergence and reduced latency. This paper presents in detail the structure and operation of an MNBTC: MNB encoding, trellis termination, Max-Log-MAP decoding adapted to the MNB case. It also shows an example of MNBTC whose performance is compared with the state-of-the-art turbo code adopted in the DVB-RCS2 standard.

The standardized turbo codes (TC) use recursive systematic convolutional transducers of rate $b/(b+d)$, having a single feedback polynomial ($b+d$RSCT). In **[2]** we investigated the realizability of the $b+d$RSCT set through two single shift register canonical forms (SSRCF), called in the theory of linear systems constructibility and controllability. The two investigated SSRCF are the adaptations, for the implementation of $b+d$RSCT, of the better-known canonical forms controller (constructibility) and observer (controllability). Constructibility is the implementation form actually used for convolutional transducers in TCs. The study shows that any $b+1$RSCT can be implemented in a unique SSRCF observer. As a result, we build a function, $\xi:\mathcal{H}\rightarrow\mathcal{G}$, which has as definition domain the set of encoders in SSRCF constructibility, denoted by $\mathcal{H}$, and as co-domain a subset of encoders in SSRCF observer, denoted by $\mathcal{G}$. By proving the non-injectivity and non-surjectivity properties of the function ξ we prove that $\mathcal{H}$ is redundant and incomplete in comparison with $\mathcal{G}$, i.e. the SSRCF observer is more efficient than the SSRCF constructibility for the implementation of $b+1$RSCT. We show that the redundancy of the set $\mathcal{H}$ is dependent on the memory m and on the number of inputs b of the considered $b+1$RSCT. In addition, the difference between $\mathcal{G}$ and $\xi(\mathcal{H})$ contains encoders with very good performance when used in a TC structure. This difference is consistent for $m \approx b > 1$. The results on the realizability of the $b+1$RSCT allowed us some considerations on $b+d$RSCT, with $b,d>1$, as well, for which we proposed the SSRCF controllability. These results could be useful in the design of TC based on exhaustive search.

The interleaving for MNBTCs 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. In **[3]** we investigated 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.

In **[4]** we made a study concerning the allocation possibilities of the bits generated by the double binary turbo encoder (DBTE) in the modulator symbol, in the case of the quadrature amplitude squared modulation with 265 signal points (256-QAM), in AWGN channel. We compared the BER/FERvsSNR performances of memory 3 and 4 double-binary turbo codes (DBTC), defined in DVB-RCS and DVB-RCS2 standards. We considered both DBTC common coding rate, ½, and the coding rate of ¾ obtained using puncturing. The simulations results lead to some conclusions for the selection of the best allocation methods, both in the water fall region and in error floor region.

In **[5]** a study of the iterations stopping criteria adapted to MNB turbo-decoders, based on the evolution of a posteriori probability density (APP) is presented. The BER/FERvsSNR performaces of MNBTCs equipped with the iterations stopping mechanism proposed in this study are compared with those obtained using the genie iterations stopping criterion. Details about the redundancy in the number of processed iterations as compared to the ideal criterion are also presented.

Nakagami-*m* channels are communication channels that can be modeled using the Nakagami-*m* distribution. The Nakagami-*m* distribution provides a wide range of models for channels exhibiting fading (fluctuating channels). By suitably choosing the *m* parameter, a certain fading intensity/strength can be simulated. In **[6]** we made a study to assess the performance of different types of turbo-codes (TC) over Nakagami channels.

The closure/termination of convolutional encoders (CE) trellises can be achieved through several strategies, each offering advantages and disadvantages compared with the others. Because MNBTCs operate with shorter lengths of blocks of data than other families of TC, the strategy of terminating component CE trellises has a stronger influence on the encoding rate, and, implicitly, on the BER/FERvsSNR performance. In **[7]** we compared the BER/FERvsSNR performance for the main strategies for terminating the CE trellises, components of MNBTCs.

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 **[8]** we investigated the BER/FERvsSNR performance of transmission systems, in case of using 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 $\approx 10^{-7}$, allow some practical tips on choosing the best allocation methods, both in the water fall and error floor regions.

In **[9]** we present a method for BER/FERvsSNR performance prediction for TCs, when they are used with high-order modulations. The method is based on two simplifying hypotheses and assumes that the BER/FERvsSNR performance, in the case of BPSK modulation, is known. For the simulations we have chosen the DBTC used in the DVB-RCS standard. The experimental results confirm the good accuracy of the proposed prediction method and validate our assumptions. The method has been applied in the case of 16-QAM, but it can be easily extended to any other type of modulation.

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