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Higher performance scheme for 4G-LTE Network system using Turbo Equalization Technique

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Abstract— **In mobile radio communication systems, wanting to pass a large stream of information through a channel whose band is often limited tends to create interference between Symbols (IES). This interference can degrade the received signal very strongly. It is therefore necessary to design receptors to effectively combat IES. The various solutions offered generally use equalization and channel coding processes. To improve the performance of the system, a receiver is introduced that performs a joint processing of equalization and channel decoding to significantly improve the transmission quality. This receiver is called turbo equalizer (TE). In our paper, we are mainly interested in simulation analysis to improve the performance of 4G-LTE mobile radio transmission, through the use of turbo equalization technique. To do this, we will validate the theoretical notions by simulations carried out on the Matlab software.**

Keywords **— LTE, TE, IES, 4G**

I. INTRODUCTION

In this research, we address the context of iterative decoding systems at the mobile radio channel. This work is part of the implementation of new high-speed mobile radio services. The main obstacle to the implementation of such systems is the nature of the mobile radio channel. Indeed, the mobile radio channel is a frequency selective and time variable channel. The higher the data rate, the more this frequency selectivity is reinforced, resulting in a high IES in reception. At high data rates, the channel distortion is very important and it is impossible to recover the transmitted data with a simple receiver. A complex receiver structure is required that uses expensive equalization and channel estimation algorithms. The OFDM technique can simplify the equalization problem by changing the frequency selective channel into a flat channel. Inter-symbol interference (ISI) can occur in the received signal due to multipath fading. To remove ISI many types of equalizers can be used. An equalizer compensates for channel imperfections, such as amplitude and phase distortions and propagation delay. However, the variable nature of the channel, with the presence of deep fading, remains a major obstacle to increasing transmission rates.

II. MAIN STRUCTURES OF EQUALIZERS

The main function of equalizers is to invert the estimates impulse response of the frequency selective transmission channel. The architectures of equalizers used in practice are numerous, we can quote:

- A first technique called "Maximum Likelihood Sequence Estimation (MLSE)" which gives excellent results provided that the channel is known or well estimated,
- Linear Equalizers (LE): the performance of these equalizers degrades remarkably when the propagation conditions deteriorate,
- Decision Feedback Equalizer (DFE): used for severely degraded channels.

For the optimization of equalizer coefficients, there are essentially two criteria:

1. The first criterion consists of forcing the impulse response of the channel/equalizer pair to zero except at t = 0: this equalization approach is called zero forcing (ZF). It is extremely sensitive to noise.
2. The second criterion consists in adapting the equalizer coefficients by minimizing the mean square error between the equalized sequence and the estimated sequence. This approach is called Minimum Mean Square Error (MMSE).

III. INTERFERENCE CANCELLING EQUALIZER (AI)

The interference canceller equalizer (AI) is relatively little used [1][2], until now in equalization. The structure of the interference canceller is given in figure-1, it is formed by a filter $C(z)$ adapted to the frequency response of the channel and a filter $W(z)$ allowing the reconstruction of the interference between symbols present at the output of the adapted filter (we note here that the central coefficient of the filter $W(z)$ is zero$w_0 = 0$).

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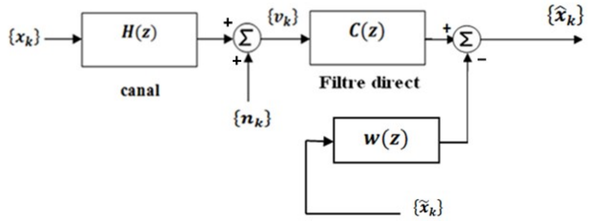

Fig.1Interference cancelling equalizer (AI).

From the definition of the AI equalizer, the output $\hat{x}_k$ is expressed:

$$\hat{x}_k = \sum_{j=-\infty}^{\infty} c_j v_{k-j} - \sum_{j=-\infty, w_0=0}^{\infty} w_j \tilde{x}_{k-j} \quad (1)$$

where$\{\tilde{x}_k\}$is the sequence of estimated symbols. The optimal expressions for the interference cancelling equalizer filters are given by [1]:

In the un-normalized channel case:

$$\alpha = T \int_{-1/2T}^{1/2T} |H(f)|^2 df$$

$$C_{opt}(f) = \frac{\beta H^*(f)}{\alpha} \quad (2)$$

$$w_{opt}(f) = \beta \left[\frac{H(f)H^*(f)}{\alpha} - 1 \right] \text{ avec}$$

$$\beta = \frac{\alpha {\sigma_x}^2}{\alpha {\sigma_x}^2 + {\sigma_n}^2} \quad (3)$$

The minimum mean square error of the IA is given by [1]:

$$J_{min,AI} = \frac{{\sigma_x}^2 {\sigma_n}^2}{\alpha {\sigma_x}^2 + {\sigma_n}^2} \quad (4)$$

We assume that $\tilde{x}_k = x_k$ which leads us to the optimal unconstrained solution. In this case, the expression for the equalized output is given by :

$$\hat{x}_k = \beta \left[x_k + \frac{1}{\alpha} \sum_{n=0}^{L} h_n^* n_{k+n} \right] \quad (5)$$

According to equation (5), the inter-symbol interference is completely suppressed without noise amplification.

IV. TURBO EQUALIZATION IN FREQUENCY SELECTIVE AND INVARIANT CHANNELS

Digital communication receivers are composed of several disjoint functions, where each function performs a specific processing and ends with a decision. This concept presents a loss of information and does not lead to optimal receiver performance. It is possible to remedy this drawback by arranging that some elementary functions can benefit from the processing performed by other functions. In this part, which concerns the turbo equalization of frequency selective invariant channels in the presence of channel coding, we will see that an equalizer uses jointly the data estimated by the decoder and the signals coming from the transmission channel in order to try to get rid of the interference between symbols. Several authors have proposed solutions based on interference cancelling equalizers (IA), maximum likelihood detectors and channel coding to deal with this problem.

V. ETAT DE L'ART EN TURBO EGALISATION

Figure-2, shows a communication chain with a turbo equalizer. The schematic diagram of the turbo equalization is shown in figure-3. The iterative processing is carried out using several identical modules which transmit an estimate of the transmitted symbols to each other. This estimate is improved with each iteration. Figure-4, details the content of one of the modules. For a modulation (8-PSK, 16QAM), this module includes an equalizer followed by a decentralized, a channel decoder and an interleaved.

A. The equalizer.

The equalizer is responsible for reducing or eliminating the interference between symbols generated by the frequency selective channel. We have previously presented several types of equalizer structures. At the first iteration no a priori information is available. A decision feedback (DFE) or linear (LE) self-learning equalizer structure is used. At the output of the first iteration, a first estimate of the transmitted symbols is available. We want to use this information to improve the equalization of the next iteration. The a posteriori maximum likelihood equalizer (MAP), interference canceller (AI), or decision feedback equalizer (DFE) are appropriate structures for such processing since they allow us to suppress ISI using the estimated symbols from the past and future.

B. Interleaver/De-interleaver.

The interleaver / De-interleaver function is very important in turbo equalization. Indeed, the channel decoder is built on the basis that the data at its input are white and de-correlated with Gaussian distribution. Unfortunately, the input data to the decoder is always correlated with the noise, this correlation is due to several factors; among these factors we note the error packets at the output of the equalizer caused by the SNR attenuation. Therefore, it is necessary to distribute the error packets throughinterleaving so that the channel decoder processes white data.

C. Decoder.

The decoding function can be performed by the maximum likelihood a posteriori (MAP) or SOVA "Soft Output Viterbi Algorithm", its role is to remove errors caused by AWGN.

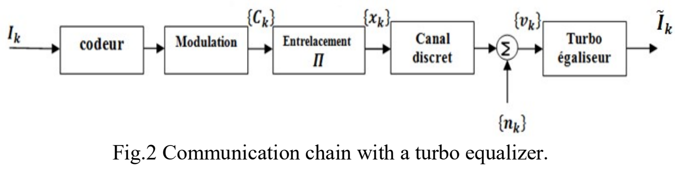

Fig.2 Communication chain with a turbo equalizer.

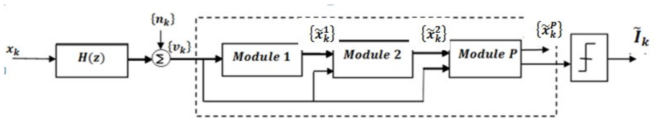

Fig.3 Schematic diagram of the turbo equalization.

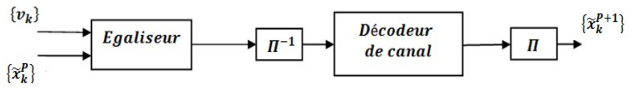

Fig.4 Diagram of a turbo equalization module.

VI. TURBO EQUALIZER MAP - MAP.

The structure of the turbo equalizer maximizing the posteriori probability was proposed by Berrou [3]. The structure of this turbo equalizer is shown in figure-5. Several authors have tried to improve the performance of this architecture by modifying the MAP algorithm of the decoder or the equalizer [4], or by using a turbo encoder instead of the RSC encoder [5]. Others have used a non-systematic code to replace the RSC encoder [6],etc.

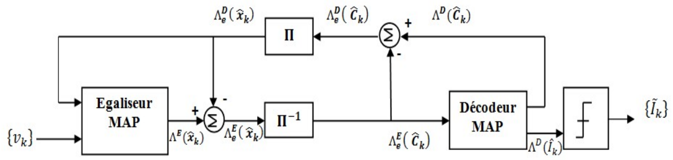

Fig.5 Operating principle of the MAP turbo equalizer - MAP.

The input to the MAP equalizer is the received sequence $\{v_k\}$. The equalizer calculates the log likelihood ratio of the coded bits, denoted by$\Lambda^E(\hat{x}_k)$, these values represent the a posteriori value of the coded bits. The MAP decoder receives as input the extrinsic part of the equalized output $\Lambda^E(\hat{x}_k)$, : this extrinsic value is given by :

$$\Lambda_e^E(\hat{x}_k) = \Lambda^E(\hat{x}_k) - \Lambda_e^D(\hat{x}_k) \qquad (6)$$

where$\Lambda_e^D(\hat{x}_k)$is the interleaved extrinsic part of the decoded output. The output $\Lambda_e^E(\hat{x}_k)$ is decentralizing before being decoded.

The MAP decoder calculates the likelihood ratio of the encoded bits denoted $\Lambda^D(\hat{C}_k)$and the estimated information bits denoted $\Lambda^D(\hat{I}_k)$. The extrinsic part of $\Lambda^D(\hat{C}_k)$, denoted$\Lambda_e^D(\hat{C}_k)$, represents the additional information of the current bit obtained by the decoder. This extrinsic information is obtained by the relation:

$$\Lambda_e^D(\hat{C}_k) = \Lambda^D(\hat{C}_k) - \Lambda_e^E(\hat{C}_k) \qquad (7)$$

where$\Lambda_e^D(\hat{C}_k)$is interleaved and then injected into the MAP equalizer: it serves as its a priori information. We note here that for the first iteration no a priori information is available: the equalizer assumes that the events $\{x_k = 1\}et\{x_k = -1\}$are equiprobable, i.e. the a priori value is zero for the first iteration.

VII. PERFORMANCE OF THE TURBO EQUALIZER

In this section, we analyse the performance of the turbo equalizer in terms of bit error rate (BER) in the Proakis-B channel [7]. The BER performance is evaluated by a well specified method, each BER value was obtained by transmitting $1024*10^3$bits of information. In order to situate the performance of our turbo equalizer, we compare its different BER curves for the three iteration functions. The simulated turbo equalizer consists of an 8-state TCM encoder decoder with 3 bits in and 4 bits out, and generator polynomial(11,02,04,10)in octal, for a grey mapping, and also contains on an AI equalizer.

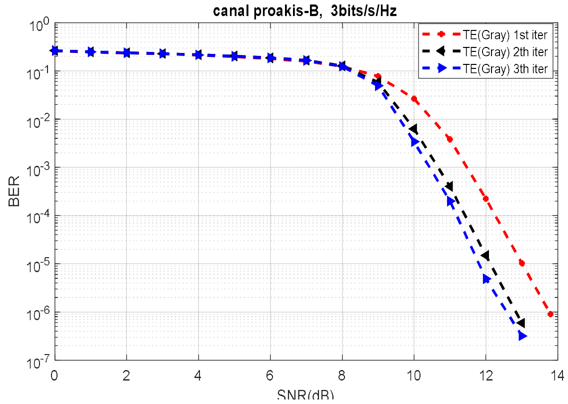

Fig.6 Comparison of system TE performance for the three iterations on the proakis-B channel.

In Figure-6, we plotted the bit error rate (BER) versus E_b/N_0à la sortie du décodeur de canal pour les trois itérations du turbo égaliseur. Pour un canal de Proakis-B [7], Nous concluons d'après la figure de simulation que la fonction de l'itératif de TE (turbo égaliseur) a fonctionné d'une façon proportionnelle avec la qualité de performance de TE, c'est-à-dire que, plus nous augmentons le nombre d'itération de turbo-égaliseur, plus on enregistre une diminution sur les valeurs des BER. Nous signalons que l'utilisation du processus itératif (l'itération) de TE permet d'améliorer les performances du turbo égaliseur en terme de BER.

VIII. PERFORMANCE OF THE TURBO EQUALIZER PROPOSED FOR THE SIMULATION ON THE LTE SYSTEM

in this new LTE system receiver, we propose to use an iterative adaptive equalization and co-channel coding processing. The equalization is performed by an interference canceller which allows to totally avoid the inter-symbol interference provided that the transmitted data are known, which is of course never the case. A solution then consists in obtaining an estimate of these data by exploiting the information coming from a previous processing including equalization and decoding. Thus defined, the turbo equalizer [8][9][10] consists of a succession of several treatments of the same source of information in order to take advantage of the gain brought by the channel decoder [11]. For a better approximation of the BER, a simulation of the transmission chain is necessary. In this section, results of bit error rate simulations with Turbo equalizer are illustrated. The transmission chain diagram of LTE system using Turbo equalizer is given in Figure-7.

IX. SIMULATION PARAMETERS

In this section, we analyse the performance of the turbo equalizer on a correlated and frequency selective EVA mobile radio channel [12]. The BER performance is evaluated by a very specific method, each BER value was obtained by transmitting 10^6 bits d'information. bits of information. The simulated TE consists of an 8-state TCM encoder decoder with 2 bits at the input and 3 bits at the output, and generator polynomial $(11,02,04)$ in octal. To promote convergence of the first iteration equalizer, RLS belonging to the turbo equalizer, a periodic training sequence is used that represents 20% of the data stream, i.e. 25 training symbols for 125 transmitted symbols. The transmitted training symbols are assumed to be known by the turbo equalizer at reception.

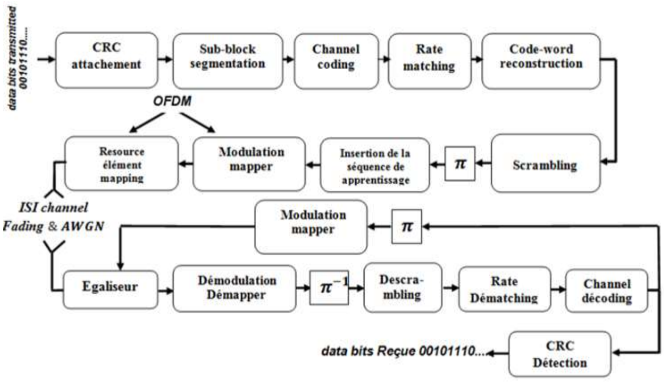

Fig.7 Physical layer specifications in LTE

It can be seen from Fig. 8, that the turbo equalization principle works well when by increasing the number of iterations, the BER at the output of the interference canceller equalizer is lower than that of a channel without inter-symbol interference (ISI). This demonstrates that the interference canceller suppresses ISI and provides white data to the TCM channel decoder.

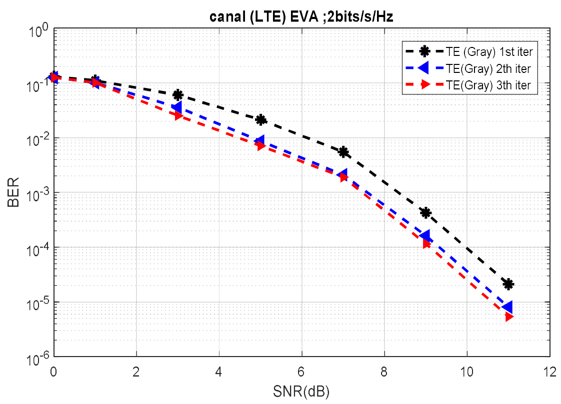

Fig.8 TE performance (AI, decoder-TCM) for different iteration processes.

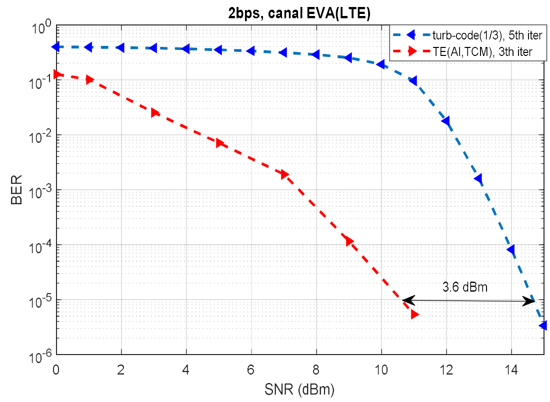

Fig.9 Comparison of the transmission performance of LTE system that uses a simple ZF equalizer, and the LTE system that uses turbo- equalizer (AI, TCM decoder), in the EVA channel.

From Figure-9, it can be seen that the turbo equalizer (AI, TCM) has a better BER performance, compared to the LTE system that uses a ZF equalizer and a turbo-code channel encoder MAP decoding in a separate way. The use of turbo equalizer technique allows us to gain G = 3.6 dB compared to the classical system which processes equalization and channel coding in a disjoint way.

X. CONCLUSION.

When the channel band is infinite (sufficiently wide - ideal channel), no problem arises and only the noise is the cause of transmission errors. On the other hand, when the band is limited or selective, the quality of the transmission can be degraded even in the absence of noise. In this case, the interference between IES symbols is significant. To overcome this problem, equalization must be implemented to correct these imperfections of the whole communication chain. In this paper we have used an equalization structure that is more efficient and suitable for LTE channels called turbo equalizer, it is an optimal equalizer. They can be used for disjointed reception. They are also tools for joint processing. From the evaluation of the performance of this turbo equalizer in terms of bit error rate for different SNR values. We have shown, from the different figures of the simulations, that the turbo equalizer reduces the effects of frequency and time selectivity of the LTE network transmission channels in a significant way.

As perspectives, we propose to:

- Associate the studied system with the multiple input multiple output (MIMO) channel and thus take advantage of the spatial and frequency diversity (OFDM).
- Program the studied system on VHDL, and implement it on FPGA.

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