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Research Article

Low Complexity data transmission over wireless system

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Abstract

It is proposed low-complexity block turbo equalizers for orthogonal frequency-division multiplexing (OFDM) system in a channel. The presented work is based on a soft minimum mean –square error (MMSE) block linear equalizer (BLE) that exploits the banded structure of the frequency –domain channel matrix, as well as a receiver window that enforces this banded structure. This equalization approach allows us to implement the proposed designs with a complexity that is only linear in the number of subcarriers. The turbo equalizer based on biased MMSE criterion is used simulation results show that the proposed iterative MMSE BLE achieves a better bit error rate (BER) performance. The proposed equalization algorithms are also tested in the presence of channel estimation errors. Comparison of equalization scheme has been analyzed.

Keywords: *Inter-carrier interference, orthogonal frequency–division multiplexing (OFDM), Channels, turbo equalization , interleaver, BPSK Modulation.*

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1. Introduction

Orthogonal frequency-division multiplexing (OFDM) is one of the most important modulation schemes for wireless communications, since it is widely used in many standards such as DVB-T/H, DAB, IEEE 802.11 and IEEE 802.16 (Nee *et al*. 2000; Faria *et al*. 2006). OFDM can eliminate intersymbol interference (ISI) introduced by a frequency-selective channel by therefore renders simple one-tap equalization for each subcarrier (Wang *et al.* 2000). However, high-mobility terminals and scatters induce a different Doppler shift on each propagation path, giving rise to a time-selective or time-varying channel, hereby destroying the orthogonally among subcarriers. The related inter-carrier interference (ICI) severely degrades the performance of the one-tap equalizer (Wang *et al.* 2006*)*. As a consequence, to reduce the performance degradation; OFDM system in high-mobility scenarios should adopt smarter equalization techniques.

In order to counteract the effects of a time-varying channel, several different equalization techniques have been proposed (Stamoulis *et al*. 2002). These techniques range from linear equalizer, based on the zero-forcing (ZF) or the minimum mean-squared error (MMSE) criterion (Barhumi *et al*. 2006; Huang *et al*. 2007; Jeon *et al*. 1999; Rugini *et al*. 2005; *Schniter et al. 2004; Baneli et al*. 2005; Gorokhov *et al*. 2004; Choi *et al*, 2001) to decision-directed equalizers based on decision-feedback. Each equalization technique is characterized by a different performance-complexity tradeoff. However, the specific structure of the Doppler-induced ICI in OFDM systems presents some distinctive feature that can be exploited by the equalizer. The first feature is the limited support of the Doppler spread.

Among all the equalizers for OFDM in channels, one of the most promising approaches is the iterative MMSE. This iterative approach is inspired by turbo equalization (Tüchler *et al.* 2002; Singer *et al.* 2002) where soft information is used in an iterative fashion to improve the bit error rate (BER) performance, and it will therefore also be labeled as the serial turbo MMSE equalizer in the sequel. Optimal joint processing of equalization and decoding at the receiver is prohibitive due to the heavy computational burden. Instead, the equalization and decoding tasks can be performed separately and carried out iteratively, with soft information being interchanged between these two parts. For example, turbo MMSE equalizers iteratively improve the mean and the co-variance of the estimated symbol vector by exploiting extrinsic information and performing soft cancellation. Different turbo MMSE equalizers exist in the technical literature, such as serial or block versions. The difference between a serial and a block approach is that in the serial case each symbol is equalized separately using sliding window MMSE equalizer whereas in the block case all the symbols in a block are jointly equalized (Dangl *et al.* 2007; Wang *et al.* 1999).

The Doppler shift caused by the high mobility also makes the channel estimation problem more challenging. The turbo equalization algorithms developed in this paper assume that the receiver has perfect channel state information (CSI) and the transmitter has no access to CSI, obtained for instance by using the techniques

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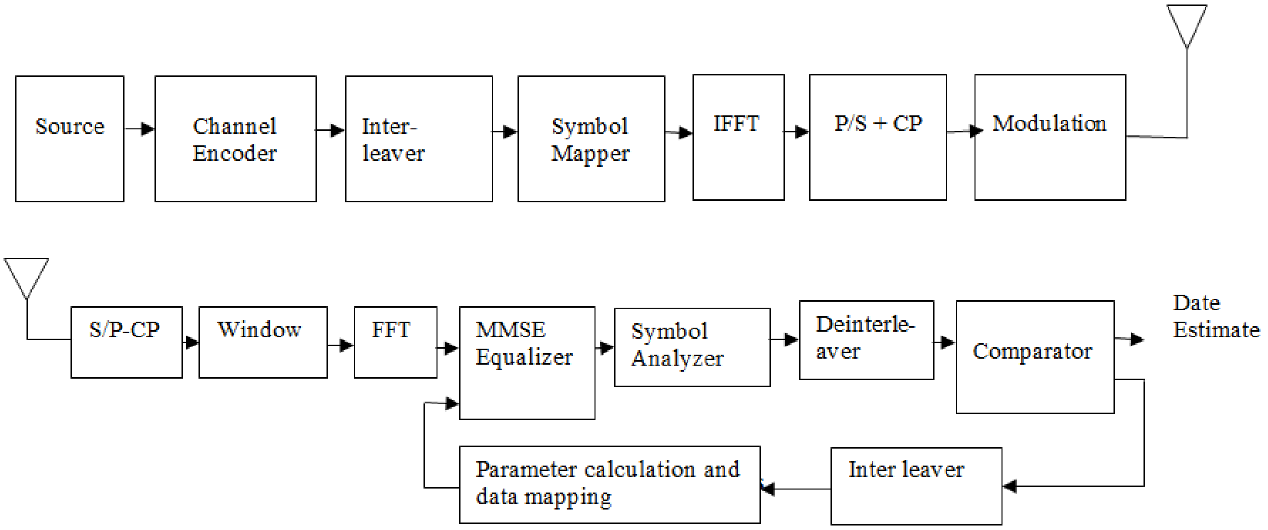

Fig.1 System model for the proposed block turbo equalizers

developed in (Tang *et al.* 2007).Further improvements, beyond the scope of this paper, could be obtained by exploiting some knowledge about the channel estimation error (Dangl *et al.* 2007) or by incorporating channel estimation into the iterative equalization and decoding loop (Otnes *et al*. 2004).

Our system deals with computational complexity issues and shows how the proposed equalizers can be implemented with low complexity.

2. Software used

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or FORTRAN.

2.1.1 Signal processing toolbox

The Signal Processing Toolbox is a collection of tools or functions expressed mostly in M-files, that implement a variety of signal processing tasks.

Command line functions for:

- Analog and digital filter analysis
- Digital filter implementation
- FIR and IIR digital filter design
- Analog filter design
- Statistical signal processing and spectral analysis
- Waveform generation

Interactive tools (GUIs) for:

- Filter design and analysis
- Window design and analysis
- Signal plotting and analysis
- Spectral analysis
- Filtering signals

2.1.2Communication toolbox

Communications System Toolbox provides algorithms for the design, simulation, and analysis of communications systems. These capabilities are provided as MATLAB functions, MATLAB System object, and Simulink blocks. The system toolbox enables source coding, channel coding, interleaving, modulation, equalization, synchronization, and channel modeling. We can also analyze bit error rates, generate eye and constellation diagrams, and visualize channel characteristics. Using adaptive algorithms, we can model dynamic communications systems that use OFDM, OFDMA, and MIMO techniques. Algorithms support fixed-point data arithmetic and C or HDL code generation.

Key features

- Algorithms for designing the physical layer of communications systems, including source coding, channel coding, interleaving, modulation, channel models, MIMJO, equalization, and synchronization
- GPU-enabled System objects for computationally intensive algorithms such as Turbo, LDPC, and Viterbi decoders
- Eye Diagram Scope app and visualization functions for constellations and channel scattering
- Bit Error Rate app for comparing the simulated bit error rate of a system with analytical result

- Channel models, including AWGN, Multipath Rayleigh Fading, Rician Fading, MIMO Multipath Fading, and LTE MIMO Multipath Fading.
- Basic RF impairments, including nonlinearity, phase noise, thermal noise, and phase and frequency offset.
- Algorithms available as MATLAB functions, MATLAB System objects, and Simulink block.
- Support for fixed-point modeling and C and HDL code generation.

3. BCJR algorithm

In order to implement an efficient turbo decoder, a suitable decoding algorithm has to be chosen. Turbo codes have been originally implemented with BCJR (Bahl *et al.* 1974) algorithm. However, this algorithm performs complex mathematical operations such as multiplication, division and logarithmic calculations.

Therefore, engineers have avoided implementing this complex algorithm and preferred the sub-optimal derivatives of the BCJR (MAP) algorithm such as the Log-MAP and the Max-Log-MAP algorithms which are much simpler to Implement but yield worse BER performances (Robertson *et al.1997*).With the advent of the technology, it is possible to Implement the BCJR algorithm on a single FPGA.

3.1 Reformulation of the BCJR algorithm

In this section we will reformulate the BCJR algorithm via some matrix manipulations. In the following we will consider a recursive convolution encoder with a constraint length K and code memory v = K – 1. There are 2v states of this encoder. We also suppose that BPSK modulation is used, i.e. bit one is mapped to +1, and bit zero is mapped to-1.

A. Calculation of the Forward Metrics (Alpha Coefficients)

Let us begin with the recursive equation to obtain the "α Coefficients" of the BCJR algorithm

$$\alpha_k(m)=\frac{\sum_{m'}\sum_{i=-1}^{i=+1}\alpha_{k-1}(m')\gamma_i(R_k,m',m)}{\sum_{m}\sum_{m'}\sum_{i=-1}^{i=+1}\alpha_{k-1}(m')\gamma_i(R_k,m',m)}$$

Where m = 0, 1, 2… M, is the index of the states with M =2v – 1.

B. Calculation of the Backward Metrics (Beta Coefficients)

A similar procedure was followed to formulate the "β coefficients" of the BCJR algorithm in matrix notation in (sazil et al. 2005; sazil et al. 2007).

$$\beta_k(m)=\frac{\sum_{m'}\sum_{i=-1}^{i=+1}\beta_{k+1}(m')\gamma_1(R_{k+1},m,m')}{\sum_{m}\sum_{m'}\sum_{i=-1}^{i=+1}\alpha_k(m)\gamma_1(R_{k+1},m,m')}$$

C. Gamma Calculation Unit

The state transition metrics (gamma coefficients) is calculated as.

$$\gamma_i(R_k,m',m)=\frac{1}{2\pi\sigma^2}\frac{\exp(z_k/2)}{1+\exp(z_k)}\exp(iz_k/2)$$
$$.q(d_k=i\mid S_k=m,S_{k-1}=m')$$
$$.\exp\{\frac{-1}{2\sigma^2}[(x_k-i)^2+(y_k-Y_k)^2]\}$$

4. Data interleaving

Interleaving is a technique for making forward error correction more robust with respect to burst errors;In mathematics, an interleave sequence is obtained by merging or shuffling two sequences.

Let S be a set, and let (X_i)and (Y_i), i=1,2,3….be two sequences in S.The interleave sequence is defined to be the sequence X_0,Y_0,X_1,Y_1Formally, it is the sequence (Z_i), i=0,1,2……………given by

$$Zi \coloneqq \{ \quad xkifi = 2kiseven$$

$$ykifi = 2k + 1\ isodd$$

5. MMSE Equalizer

In statistics and signal processing, a minimum mean square error (MMSE) estimator is an estimation method which minimizes the mean square error (MSE) of the fitted values of a dependent variable, which is a common measure of estimator quality To recover the originally transmitted information, an equalizer has to be used to combat the distortion effects of the channel. For strictly linear systems, many different equalization strategies may be used. The most commonly known minimum mean-square error (MMSE)equalizers X be a N×1unknown (hidden) random vector variable, and let Y be a M ×1known random vector variable (the measurement or observation), both of them not necessarily of the same dimension. An estimator$\hat{x}$(y)of x is any function of the measurement y. The estimation error vector is given by e=($\hat{x}$ -x) and its mean squared error (MSE) is given by the trace of error covariance matrix

$$MSE=tr\{E\{(\hat{x}-x)(\hat{x}-x)^T\}\}$$

Where the expectation is taken over both x and y. When x is a scalar variable, then MSE expression simplifies to $E=\{(\hat{x}-x)^2\}$. Note that MSE can equivalently be defined in other ways, since

$$t_r\{E\{ee^T\}\}=E\{t_r\{ee^T\}\}=E\{e^Te\}=\sum_{i=1}^{n}E\{e_i^2\}$$

The MMSE estimator is then defined as the estimator achieving minimal MSE.

6. Algorithm

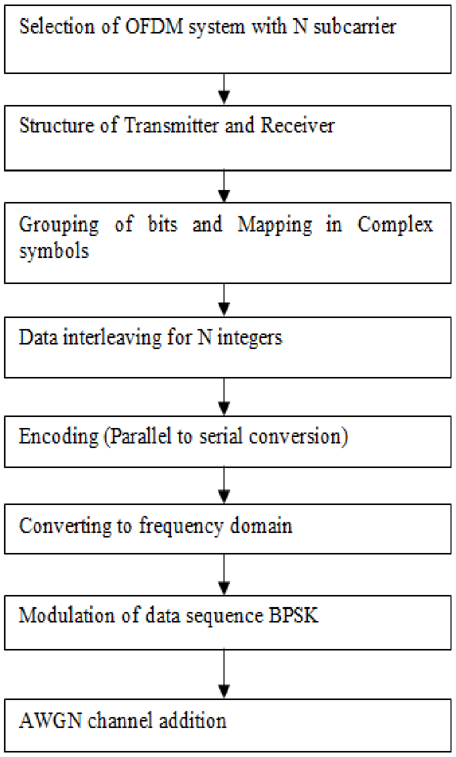

Fig.2. Algorithm of Transmitter block

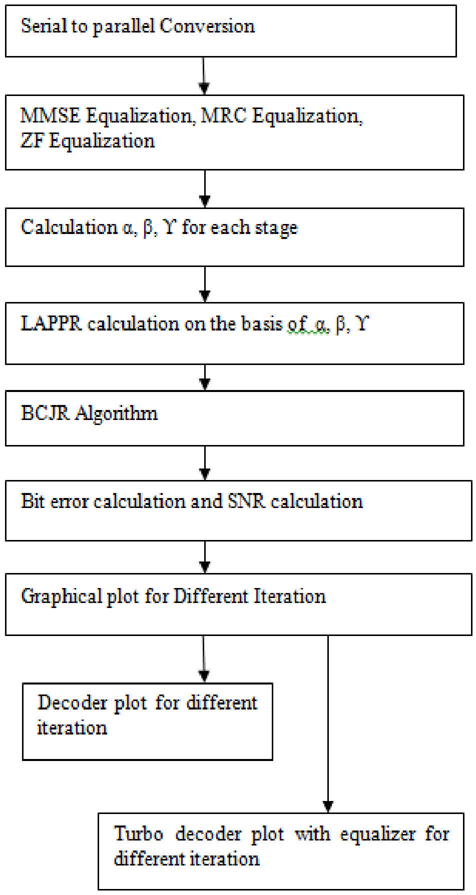

Fig.3. Algorithm of Receiver block

7. Results and Discussion

1. Turbo codes have many influence due to number of iteration constraint, length interleaver design and modulation.
2. Random interleavers provide the best all round performance.
3. Performance floor around E_b/N_0 of 3dB yield BER around 10^{-6} to 10^{-8}.

7.1 Simulation

1. Generation 2×2 MIMO OFDM channel two transmitter and two receivers.
2. Design of turbo encoding and decoding.
3. Proper OFDM transmission scheme.
4. BPSK channel was assumed BCR MAP decoder algorithm used.

7.2 Performance of turbo decoder

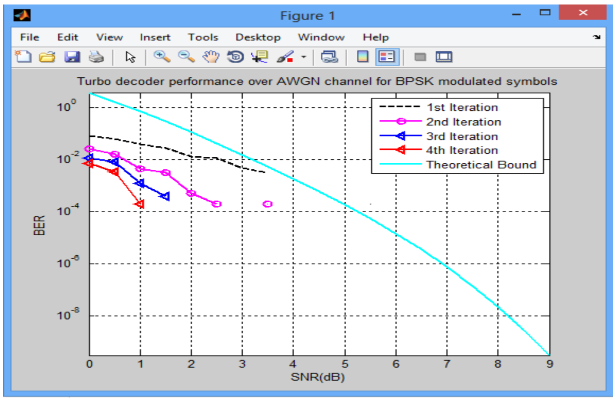

Fig.4. Performance of turbo decoder

Bit error rate of the order 10^{-3} is achieved with E_b/N_0 >3dB with most modest iteration. Coding gain of E_b/N_0 is 7dB was observed at BER 10^{-6} BER should improve with each iteration. First few iterations yield the most significant improvement in BER for any given $E_b/N_{0.}$BER converses for each value of $E_b/N_{0.}$There is a tradeoff between number of iteration processing power and E_b/N_0 for desired BER.

7.3Performance with Turbo equalization

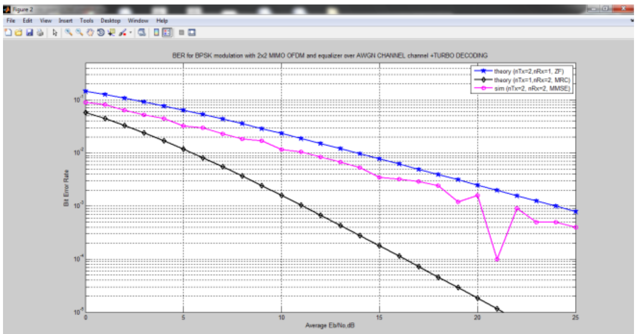

Fig.5. Performance with Turbo equalization

Bit error rate of the order in between 10^{-1} and 10^{-2} is achieved with E_b/N_0>3dB with most modest iteration. Coding gain of E_b/N_0 is 7dB was observed at BER in between 10^{-2} and 10^{-3} BER should improve with each iteration. First few iterations yield the most significant improvement in BER for any given E_b/N_0.BER converses for each value of E_b/N_0.There is a tradeoff between number of iteration processing power and E_b/N_0 for desired BER.For ZF the 3dB point is achieved at 10^{-1} BER for MRC E_b/N_0 of 3dB<10^{-1} BER achieved. For MMSE E_b/N_0 of 3dB is achieved in between ZF and MRC.

Conclusions

It is proposed low-complexity turbo equalizers for OFDM system in single channels. By ex-ploiting the banded structure of the frequency-domain channel matrix, as well as receiver windowing to enforce this band assumption, the complexity of the equalizers is linear in the number of subcarriers and derived turbo equalizers operating on the entire OFDM symbol, showing better performance. Simulation results shown that improve error.

It is also shown some simulation results in the presence of channel estimation errors. Future research could aim at improving the performance of channel estimation. This could be done by exchanging the soft information between the channel estimator and the equalizer to improve the system performance.

References

R. van Nee and R. Prasad (2000), OFDM for Wireless Multimedia Communications, *Norwood, MA: Artech House.*

G. Faria, J. A. Henriksson, E. Stare, and P. Talmola (2006), DVB-H: Digital broadcasting sevices to handheld devices,*Proc. IEEE*, vol. 94, pp. 194–209.

Z.Wang and G. B. Giannakis (2000), Wireless multicarrier communications: Where fourier meets Shannon, *IEEE Signal. Process. Mag.*, vol. 17, no. 3, pp. 29–48.

T. Wang, J. Proakis, E. Masry, and J. Zeidler (2006), Performance degradation of OFDM system due to Doppler spreading, *IEEE Trans.WirelessCommun.*, vol. 5, no. 6, pp. 1422–1432.

I. Barhumi, G. Leus, and M. Moonen (2006), Equalization for OFDM over doubly-selective channels, *IEEE Trans. Signal Process.*, vol. 54, no. 4, pp. 1445–1458.

A. Stamoulis, S. N. Diggavi, and N. Al-Dhahir (2002), Intercarrier interference in MIMO OFDM, *IEEE Trans. Signal Process.*, vol. 50, no. 10, pp. 2451–2464.

X. Huang and H.-C.Wu (2007), “Robust and efficient intercarrier interference mitigation for OFDM systems in time-varying fading channels,” *IEEETrans. Veh. Technol.*, vol. 56, no. 5, pp. 2517–2528

W. G. Jeon, K. H. Chang, and Y. S. Cho (1999), An equalization technique for orthogonal frequency-division multiplexing systems in time-variant multipath channels,*IEEE Trans. Commun.*, vol. 47, no. 1, pp. 27–32.

L. Rugini, P. Banelli, and G. Leus (2005), Simple equalization of time-varying channels for OFDM,*IEEE Commun. Lett.*, vol. 9, no. 7, pp. 619–621.

P. Schniter (2004), Low-complexity equalization of OFDM in doubly selective channels, *IEEE Trans. Signal Process.*, vol. 52, no. 4, pp. 1002–1011

L. Rugini, P. Banelli, and G. Leus (2006), Low-complexity banded equalizers for OFDM systems in Doppler spread channels, *EURASIP J. Appl.Signal Process.*, vol. 2006, pp. 1–13, Article ID 67404.

A. Gorokhov and J. P. Linnartz (2004), Robust OFDM receivers for dispersive time-varying channels: Equalization and channel acquisition, *IEEE Trans. Commun.*, vol. 52, no. 4, pp. 572–583.

Y.-S. Choi, P. J. Voltz, and F. A. Cassara (2001), On channel estimation and detection for multicarrier signals in fast and selective rayleigh fading channels, *IEEE Trans. Commun.*, vol. 49, no. 8, pp. 1375–1387.

M. Tüchler, R. Koetter, and A. C. Singer (2002), “Turbo equalization: Principles and new results,” *IEEE Trans. Commun.*, vol. 50, no. 5, pp. 754–767.

M. Tüchler, A. C. Singer, and R. Koetter (2002), Minimum mean squared error equalization using *a priori* information, *IEEE Trans. SignalProcess.*, vol. 50, no. 3, pp. 673–683

M. A. Dangl, C. Sgraja, and J. Lindner (2007), An improved block equalization scheme for uncertain channel estimation,*IEEE Trans. WirelessCommun.*, vol. 6, no. 1, pp. 146–156.

X. Wang and H. Poor (1999), Iterative (turbo) soft interference cancellation and decoding for coded CDMA, *IEEE Trans. Commun.*, vol. 47, no. 7, pp. 1046–1061.

Z. Tang, R. C. Cannizzaro, G. Leus, and P. Banelli (2007), Pilot-assisted time-varying channel estimation for OFDM systems, *IEEE Trans.Signal Process.*, vol. 55, no. 5, pp. 2226–2238.

R.OtnesandM.Tüchler (2004), Iterative channel estimation for turbo equalization of time-varying frequency-selectivechannels,*IEEETrans.WirelessCommun.*, vol. 3, pp. 146–156

Bahl, L. R., Cocke, J., Jelinek, F., Raviv, J. (1974), Optimal Decoding of Linear Codes for Minimizing The Symbol Error Rate, IEEE Transactions on Information Theory, Vol. 20, pp. 284-287

Robertson, P., Hoeher P. (1997), Optimal and Sub-Optimal Maximum a Posteriori Algorithms Suitable for Turbo Decoding, *European Transactionson Telecommunication*, Vol. 8, pp.119-125.

Sazlı, M., H.(2005), “Neural Network Implementation of BCJR Algorithm Based on Reformulation Using Matrix Algebra”, *IEEE International Symposium on Signal Processing and Information Technology*, pp. 832-837.

Sazlı, M., H. (2007), “Neural Network Implementation of BCJR Algorithm”, *Digital Signal Processing, Elsevier*, Vol 17; pp. 353- 359

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