RS CODED OFDM BY UNIQUE WORD PREFIX

Mr.Nilesh Patil, Prof.Pradnesh Shah

Abstract— **We expand our recently introduced concept of unique word orthogonal frequency division multiplexing (UW-OFDM). In UW-OFDM the cyclic prefixes (CPs) are replaced by deterministic sequences, the so-called unique words (UWs). The UWs are generated by appropriately loading a set of redundant subcarriers. By that a systematic complex number Reed–Solomon (RS) code construction is introduced in a quite natural way, because an RS code may be defined as the set of vectors, for which a block of successive zeros occurs in the other domain w.r.t. a discrete Fourier transform. (For a fixed block different to zero, i.e., a UW, a coset code of an RS code is generated.)A remaining problem in the original systematic coded UW-OFDM concept is the fact that the redundant subcarrier symbols disproportionately contribute to the mean OFDM symbol energy. In this paper we introduce the concept of non-systematic coded UW-OFDM, where the redundancy is no longer allocated to dedicated subcarriers, but distributed over all subcarriers. We derive optimum complex valued code generator matrices matched to the best linear unbiased estimator (BLUE) and to the linear minimum mean square error (LMMSE) data estimator, respectively. With the help of simulations we highlight the advantageous spectral properties and the superior bit error ratio (BER) performance of non-systematic coded UW-OFDM compared to systematic coded UW-OFDM and to CP-OFDM in additive white Gaussian noise (AWGN) as well as in frequency selective environments.**

Index Terms- **Channel coding/decoding,Equalization, FFT/IFFT, Interleaving/Deinterleaving, Unique word generator**

I. INTRODUCTION

In conventional OFDM signaling, subsequent symbols are separated by guard intervals, which are usually implemented as cyclic prefixes (CPs) [1]. By this, the linear convolution of the signal with the channel impulse response is transformed into a cyclic convolution, which allows for a low complex equalization in frequency domain. In this paper, we propose to use known sequences, which we call unique words (UWs),instead of cyclic prefixes. The technique of using UWs has already been investigated in-depth for SC/FDE systems, where the introduction of unique words in time domain is straight forward [2], since the data symbols are also defined in time domain. In this work, we will show how unique words can be introduced in OFDM time domain symbols, even though the data QAM (quadrature amplitude modulation) symbols are defined in frequency domain. Furthermore, we will present two different receiver concepts adjusted to the novel transmit signal structure. Fig. 1 compares the transmit data structure of CP- and UW-based transmission in time domain [3]. Both structures make sure that the linear convolution of an OFDM symbol with the impulse response of a dispersive (e.g. multipath) channel appears as a cyclic convolution at the receiver side. Christian Hofbauer has been funded by the European Regional Development Fund and the Carinthian Economic Promotion Fund (KWF) under grant. Nevertheless, there are also some fundamental differences between CP- and UW-based transmission. The UW is part of the DFT (discrete Fourier transform)-interval, whereas the CP is not. Due to that and in contrastto previous attempts of applying UW to OFDM [4],our UW-OFDM approach achieves an almost identicalbandwidth efficiency as conventional CP-OFDM.. The CP is random, whereas the UW is a known deterministicsequence. Cyclicity of an OFDM symbol is a necessary condition that needs to be fulfilled in order to be able to perform OFDM transmission in a multipath environment. Traditionally a cyclic prefix (CP) is used to guarantee the cyclicity. While this method is well examined and understood, there is another possibility to ensure the cyclicity. If a unique word (UW) is chosen in advance and introduced at the end of each OFDM symbol, cyclicity appears, too. The better way of guard interval is done by using unique word(UW) .This solves the disadvantages of CP having medium BER behaviour and bandwidth efficiency . Since unique words represent known sequences, they can advantageously be used for synchronization and channel estimation purposes. Furthermore, the proposed approach introduces a complex number Reed-Solomon (RS-) code structure within the sequence of subcarriers. Viterbi algorithm is used for coding and decoding.

II. PROJECT METHODOLOGY

In this project we will design OFDM transmitter and receiver with UW concept using reed soloman coder and decoder. The block diagram will be shown as below.

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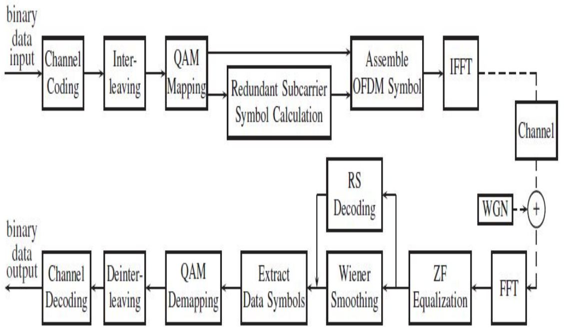
Mr. Nilesh B. B. Patil, Electronics & Telecommunication, msbte/ rviot/ses,Kharghar,NaviMumbai,India,7738376827. (e-mail: nileshbarshepatil@gamil.com).

Prof. Pragnesh Shah, Electronics, Mumbai/piit/mes,Panvel,India, 9768809872, (e-mail: shahpragnesh.n@gmail.com).



Input : random number with 64 0r 128 bits
Output : BER and MSE graphs
Intermediate steps : QAM mapping,RS with UW symbols.

A . Steps for methodology

As an OFDM has wide verity of applications, so it is necessary to design an OFDM system without inter-symbol interference(ISI) as well as intercarrier interference(ICI). To achieve this goal, guard interval is provided within the subcarriers. In conventional method cyclic prefix has been used as guard interval.

Channel coding/decoding: OFDM avoids the problem of inter symbol interference by transmitting a number of narrowband subcarriers together with using a guard time. This does give rise to a another problem, however which is the fact that in a muitipath fading channel, all subcarriers will arive at the receiver with different amplitudes . in fact,some subcarriers may be completely lost because of deep fades. Hence even though most subcarriers may be detected without errors, the overall bit error ratio (BER) will be largely dominated by a few subcarriers with the smallest amplitude, for which the bit-error probability is close to 0.5. To avoid this domination by the weakest subcarriers, forward error correction coding is essential. By using coding across the subcarriers, error of weak subcarriers can be corrected up to a certain limit that depends on the code and the channel. A powerful coding means that the performance of an OFDM link is determined by the average received power, rather than by the power of weakest subcarrier. At the receiver the encoded data is recovered by decoding which is exact reverse of encoding.

***Interleaving/Deinterleaving*:** Because of frequency selective fading of typical radio channels, the OFDM subcarriers generally have different amplitudes. Deep fades in the frequency spectrum may cause group of subcarriers to be less reliable than others, thereby causing bit errors to occur in bursts rather than being randomly scattered. most forward error correction codes are not designed to deal with error bursts.Therefore interleaving is applied to randomize the occurrence of bit errors prior to decoding. At the transmitter, the coded bits are permuted in a certain way, which makes sure that adjacent bits are separated by several bits after interleaving. At the receiver the reverse permutation is performed before decoding.A commonly used interleaving scheme is block interleaver, where input bits are written in a matrix column by column and read out row by row. Instead of block interleaver, it is also possible to use a convolutional interleaver. This interleaver cyclically writes each input symbol or bit into one of k shift registers that introduces a delay of 0 to k-1 symbol duration. The shift registers are read out cyclically to produce the interleaved symbols.

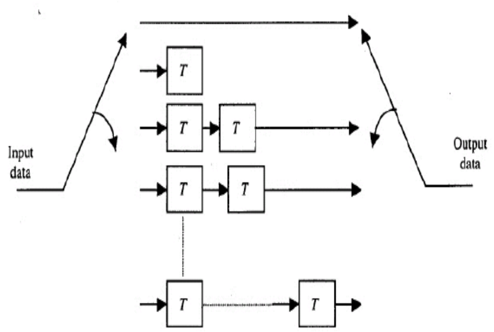


Fig 1: Convolutional Interleaver

QAM mapping/Demapping: Quadrature amplitude modulation (QAM) is the most popular type of modulation in combination with OFDM. Especially rectangular constellation are easy to implement as they can be split in to independent pulse amplitude modulated (PAM) components for both the in-phase and the quadrature part. Noise immunity is better in case of QAM because signal vectors differ not only in phase but also in amplitude. Fig.4.4 is constellations of QPSK, 16-QAM, and 64-QAM.In the receiver, the incoming QAM symbols have to be demapped.

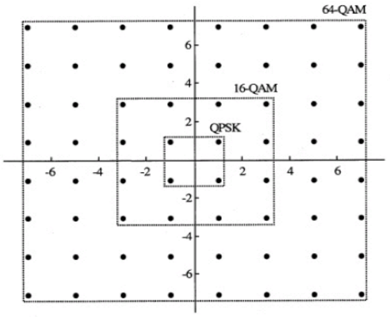


Fig. 2: QPSK, 16-QAM & 64-QAM Constellation

FFT/IFFT: IFFT modulates a block of input QAM values on to a number of subcarriers. In the receiver, the subcarriers are demodulated by an FFT, which performs the reverse operation of an IFFT. an interesting feature of IFFT/FFT is that the FFT is almost identical to an IFFT. In fact, the IFFT can be made using an FFT by conjugating input and output of the FFT and dividing the output by the FFT size. This makes it possible to use the same hardware for both the transmitter and the receiver. Of course, this saving in complexity is only possible when the modem does not have to transmit and receive simultaneously, which is the case for the standard. In practice, this transform can be implemented very efficiently by the IFFT because, IFFT drastically reduces the amount of calculations by exploiting the regularity of the operation in the IDFT.

Equalization: When the signal is passed though the channel, distortion is introduced in the terms of amplitude and delay creating problem of ISI. This distortion can be compensated with the help of equalizers. At the receiver, the FFT (fast Fourier transform)operation is followed by a ZF equalization as in classical CPOFDM. Zero Forcing

Equalizer refers to a form of linear equalization algorithm used in communication systems which inverts the frequency response of the channel. The Zero-Forcing Equalizer applies the inverse of the channel to the received signal, to restore the signal before the channel. It has many useful applications. The name Zero Forcing corresponds to bringing down the intersymbol interference (ISI) to zero in a noise free case. This will be useful when ISI is significant compared to noise. For a channel with frequency response F(f) the zero forcing equalizer C(f) is constructed by C(f) = 1/F(f). Thus the combination of channel and equalizer gives a flat frequency response and linear phase F(f)C(f) = 1.

If the channel response (or channel transfer function) for a particular channel is H(s) then the input signal is multiplied by the reciprocal of it. This is intended to remove the effect of channel from the received signal, in particular the Intersymbol interference (ISI). The zero-forcing equalizer removes all ISI, and is ideal when the channel is noiseless. However, when the channel is noisy, the zero-forcing equalizer will amplify the noise greatly at frequencies f where the channel response H(j2Πf) has a small magnitude (i.e. near zeroes of the channel) in the attempt to invert the channel completely. A more balanced linear equalizer in this case is the minimum mean-square error equalizer, which does not usually eliminate ISI completely but instead minimizes the total power of the noise and ISI components in the output.

Unique word generator : In conventional OFDM signaling, subsequent symbols are separated by guard intervals, which are usually implemented as cyclic prefixes. In UW-OFDM it is proposed to use known sequences, which we call unique words, instead of cyclic prefixes. The technique of using UWs has already been investigated in-depth for SC/FDE systems, where the introduction of unique words in time domain is straightforward, since the data symbols are also defined in time domain. Unique words can also be introduced in OFDM time domain symbols, even though the data QAM (quadrature amplitude modulation) symbols are defined in frequency domain. Furthermore, many optimized receiver concepts adjusted to the novel transmit signal structure are possible.

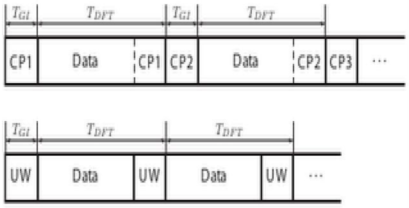


Fig 3: Transmit data structure using CPs (above) or UWs (below)

The figure compares the transmit data structure of CP and UW based transmission in time domain. Both structures make sure that the linear convolution of an OFDM symbol with the impulse response of a dispersive (e.g. multipath) channel appears as a cyclic convolution at the receiver side. Nevertheless, there are also some fundamental differences between CP and UW based transmission:

- The UW is part of the DFT (discrete Fourier transform) interval, whereas the CP is not. Although we need to spend dedicated subcarriers - which we call redundant subcarriers - for creating a UW in the time domain, we achieve approximately the same bandwidth efficiency in our approach as in conventional CP-OFDM. This is due to the fact that the length of one OFDM symbol reduces from T_DFT + T_GI to T_DFT.
- The CP is random, whereas the UW is a known deterministic sequence. Therefore, the UW can advantageously be utilized for synchronization and channel estimation purposes.

Both statements hold for OFDM as well as for SC/FDE systems. However, in OFDM - different to SC/FDE - the introduction of UWs in time domain leads to another fundamental and beneficial signal property: A UW in time domain generates a word of a complex number RS (Reed Solomon) code along the subcarrier symbols. Another interpretation of this fact which we prefer here, is an introduction of correlations along the subcarriers. These correlations can advantageously be used as a-priori knowledge at the receiver to significantly improve the BER (bit error ratio) performance.

R-s decoding/wiener smoothing: Either the Wiener smoother or our algebraic RS decoder is applied to the OFDM symbol, depending on the specific receiver concept. A class of nonbinary codes that does reach the above bound are the *reed- solomon* codes. These codes have great power and utility, and are today found in many applications from compact disc players to deep-space applications. Reed-Solomon codes are nonbinary cyclic codes with symbols made up of m-bit sequences, where m is any positive integer having a value greater than 2. *R-S (n, k)* codes on m-bit symbols exist for all n and k for which $0 < k < n < 2m + 2$ where k is the number of data symbols being encoded, and n is the total number of code symbols in the encoded block. For the most conventional *R-S (n, k)* code,$(n, k) = (2m - 1, 2m - 1 - 2t)$ where t is the symbol-error correcting capability of the code, and $n – k = 2t$ is the number of parity symbols. An extended R-S code can be made up with $n = 2m$ or $n = 2m + 1$, but not any further.

The introduction of UWs in time domain leads to another fundamental and beneficial signal property: A UW in time domain generates a word of a complex number RS (Reed Solomon)-code in the OFDM frequency domain symbol vector. Therefore, the UW could be exploited for algebraic error correction or (more appropriately) for erasure correction for highly attenuated subcarriers. However, as it turns out, algebraic RS decoding leads to solving a very ill-conditioned system of equations and thus cannot achieve a reasonable solution, as soon as even only little noise is present in the system. Another interpretation of the introduction of UWs in time domain is that it leads to correlations along the subcarriers. Therefore, a receiver based on a Bayesian estimation is obvious, too. A receiver based on a Bayesian estimation will in fact significantly improve the BER behavior by exploiting the covariance matrix of the subcarrier symbols.

III. CONCLUSION

In this work we introduced a novel OFDM signaling concept, where the guard intervals are built by unique words instead of cyclic prefixes. The proposed approach introduces a complex number Reed-Solomon code structure within the sequence of subcarriers. As an important conclusion we can state, that besides the possibility to use the UW for synchronization and channel estimation purposes (of course for that, a UW different from the zero word needs to be chosen), the novel approach additionally allows to apply a highly efficient LMMSE Wiener smoother, which significantly reduces the noise on the subcarriers, especially on highly attenuated subcarriers. Simulation results illustrate that the novel approach outperforms classical CP-OFDM in a typical frequency selective indoor scenario. Furthermore, our novel approach of introducing UWs provides these benefits over conventional CP-OFDM while still keeping almost the same bandwidth efficiency.

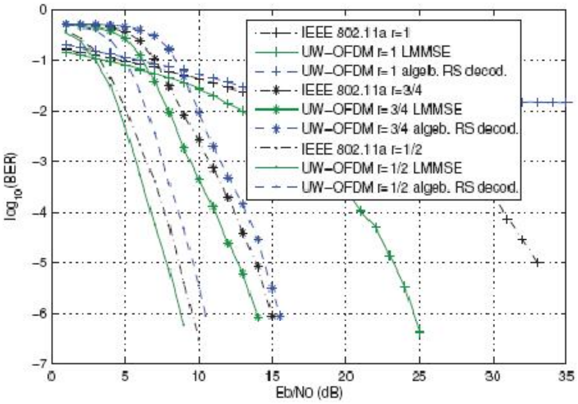


Fig 4: BER comparison between the novel UW-OFDM approach and the IEEE 802.11a standard for the channel snapshot displayed above.

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Mr. Nilesh Babarao Barshe Patil, Bachelor of extc , HoD of extc dept. r.v.i.o.t., Students of second ME PIIT in Mumbai university batch 2011, having research experience in communication field ,he has keen in interest in electrical and communication field. He has interest in global information system. He has attended several workshops and faculty development programs.

Prof. Pragnesh Sha , Assistant Professor in PIIT ,Prof. Pragnesh Shah has more than ten years of experience in teaching undergraduate as well as postgraduate students. He has attended several workshops and faculty development programs. He has more than 15 Research Papers to his credit