A NON-LINEAR SCHEME FOR PMEPR REDUCTION IN MC-CDMA SYSTEM

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Abstract- **The main feature of the next-generation wireless systems will be the convergence of multi-media services such as speech, audio, video, image, and data. This implies that a future wireless terminal, by guaranteeing high speed data, will be able to connect to different networks in order to support various services: switched traffic, IP data packets, and broadband streaming services such as video. Multicarrier Code Division Multiple Access (MC-CDMA) scheme is the promising candidate for future broadband wireless systems, as it provides higher flexibility, transmission rates and spectral efficiency. It combines an orthogonal frequency division multiplexing (OFDM) modulation with a Code Division Multiple Access (CDMA) scheme and hence exploits the advantages of OFDM as well as CDMA.**

A well-known, major drawback of conventional orthogonal frequency-division multiplexing (OFDM) transmission schemes is their strong envelope fluctuation and high peak-to-mean envelope power ratio (PMEPR), leading to power amplification difficulties. That is the OFDM signal which is the superposition of large number of modulated subcarriers, usually exhibits a high instantaneous peak value with respect to average value leading to envelope fluctuations. This is cited as a major drawback in OFDM scheme. This drawback is found in MC-CDMA too. As MC-CDMA signals have high envelope fluctuations and a high peak-to-mean envelope power ratio (PMEPR), which leads to amplification difficulties.

In order to avoid the out-of-band radiation levels which are inherent to nonlinear distortion, power amplifiers for OFDM transmission are required to have linear characteristics and/or a significant input back off has to be adopted. Therefore, reduced power efficiency is the price to pay for high bandwidth efficiency. A class of low-complexity signal-processing schemes for reduced PMEPR, spectrally efficient MC-CDMA transmission was proposed.

I. INTRODUCTION

The main feature of the next-generation wireless systems will be the convergence of multi-media services such as speech, audio, video, image, and data. This implies that a future wireless terminal, by guaranteeing high speed data, will be able to connect to different networks in order to support various services: switched traffic, IP data packets, and broadband streaming services such as video. Multicarrier code-division multiple-access (MC-CDMA) scheme is the potential candidate for future generation wireless systems.

In traditional communications, the important components of a communications system include the transmitter, communication channel and receiver. The objective of a communications system is to successfully deliver information data from the source to receiver through a given channel. In multiuser communication systems, the focus is to establish same transmission objectives but for multiple users which share a communication channel. The significance of multiuser systems is shown by the provision of applications such as mobile cellular phones, asymmetric digital subscriber lines (ADSL) services and other uses such as satellite communications. There are several multiple access schemes that can be used to provide a communication service to multiple users. Some of the fundamental multiple access schemes are Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA) and Space Division Multiple Access (SDMA).

The Orthogonal Frequency Division Multiplexing (OFDM) modulation is one specific form of FDMA multiple access scheme. OFDM is an effective multiple access technique that possesses many desirable properties. The OFDM method is bandwidth efficient, easily implemented and OFDM signals are robust against multipath fading. A particular important problem that exists in OFDM transmission is that OFDM signals often exhibit high peak-to-average power ratio (PAPR). In practice this high PAPR frequently cause signal distortion and increase bit error rate when high power amplifier (HPA) is used. The objective of this project is to conduct an in depth investigation of a particular technique of subcarrier pulse shaping proposed in the literature for PAPR reduction in OFDM signals.

As other multicarrier signals, MC-CDMA signals have high envelope fluctuations and a high peak-to-mean envelope power ratio (PMEPR), which leads to amplification difficulties. This is particularly important for the uplink transmission, since efficient low-cost power amplification is desirable at the mobile terminals (MTs). Moreover, the transmission over time-dispersive channels destroys the orthogonality between spreading codes, which might lead to significant multiple-access interference levels and frequent running of HPA into saturation region reduces the power efficiency. To reduce the envelope fluctuations of the transmitted signals, while maintaining the spectral efficiency, the MC-CDMA signal associated to each MT is submitted to a clipping device, followed by a frequency domain filtering operation. However, the nonlinear distortion effects can be high when an MC-CDMA transmitter with reduced envelope fluctuations is intended.

II. CHOICE OF PMEPR REDUCTION TECHNIQUE

There have been many proposal of methods in which the power ratio can be reduced in MC-CDMA multi-carrier signals. Some researchers have developed methods of achieving low PMEPR through the application of “partial transmits sequence, block coding and selected mapping”. Other techniques of lowering the PMEPR ratio which have been published involve complicated applications of supplementary FFT function blocks requiring more functional components. In addition, non-hardware based approaches that also incur other disadvantages such as adding information in overhead parameters or handshaking algorithms to control PMEPR levels. Additional information bearing causes OFDM signal to be less bandwidth efficient.

Though a class of low-complexity signal-processing schemes for reduced PMEPR, spectrally efficient MC-CDMA transmission proposed requires supplementary FFT function blocks, but this scheme combines a nonlinear operation in the time domain with a linear, filtering operation in the frequency domain. This frequency-domain filtering, besides not requiring an increased guard time to avoid intersymbol interference (ISI), can be very selective, e.g., completely removing the out-of-band radiation effects of the preceding nonlinear operation.

More recently, a similar class of signal-processing schemes for the same goals was analyzed. The difference lies in the type of nonlinear operation with each class: a nonlinearity operating on the complex MC-CDMA samples in [8], and a nonlinearity which separately operates on their real (I) and imaginary (Q) parts in [9]. Our scheme considers the former class only, which provides better performance, and studies the cases where a given scheme (nonlinear time-domain operation followed by frequency-domain filtering) is repeatedly used, in an iterative way.

Though the proposed method that is focused on does not require additional FFT’s operators and only require single FFT and IFFT functions in the transceivers to operate. The technique involves the shaping of time limited subcarrier pulses. The modification of subcarrier pulse shapes does not add extra information to the existing structure of MC-CDMA signals and hence bandwidth efficiency is unaffected. Coding methods as described previously can assist in controlling interchannel interference through channel coding.

Therefore, through the use of this non-linear signal processing scheme, certain pulse shape characteristics can be tested in search for the best pulse characteristics. The objective is to find the general pulse shape characteristics that promote the improvements in lowering the factor of high PMEPR found in MC-CDMA signals.

III. TRANSMISSION OF MC-CDMA SIGNAL

A WIDE CLASS OF NONLINEAR SIGNAL-PROCESSING SCHEME

With the basic signal-processing schemes considered here for MC-CDMA transmission is shown in Figure 1, each block of time-domain samples is generated as follows.

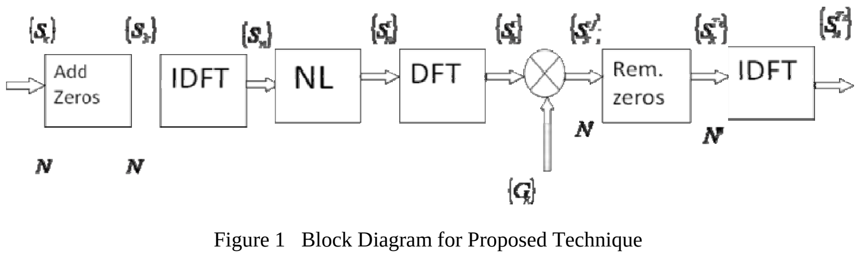

Figure 1 Block Diagram for Proposed Technique

- The zero padded frequency-domain block { , k= 0,1,…N’-1}, where N’ is a power of two, is formed by adding N-N’ zeros to the original frequency-domain block is given Eqn.(1).

$$S_k; k = -\left(\frac{N}{2}\right), -\left(\frac{N}{2}\right) + 1, \ldots \left(\frac{N}{2}\right) - 1 \quad (1)$$

- The Inverse Discrete Fourier Transform (IDFT) of this frequency-domain block is computed, leading to the time domain block {S'_n ; n=0,1,...N-1} with S'_n is given Eqn.(2).

$$S'_n = \frac{1}{N}\sum_{K=0}^{N'-1} S'_K \exp\left(j2\pi\left({nk}/{N}\right)\right) \quad (2)$$

- Each sample is submitted to a nonlinear operation(an envelope clipping)according to, S_n^c leading to the modified block {S_n^c ; n=0,1,…,N'-1}, where S_k^{Tx} is given Eqn.(3).

$$S_n^c = g_c|S_n|\exp\left(jarg(S'_n)\right) \quad (3)$$

- A discrete Fourier transform (DFT) brings the nonlinearly modified block back to the frequency domain, where a shaping operation is performed by a multiplier bank with selected coefficients, {Gk; k=0,1,…,N'-1 }, so as to obtain the block , with is given by the Eqn.(4).

$$S_k^{CF} = S_k^c G_k; k = 0, 1, \ldots . N' - 1 \quad (4)$$

- The final frequency-domain block S_k^{Tx} results from by removing the zeros, where S_k^{Tx} is shown in Eqn.(5).

$$S_k^{Tx}; k = 0, 1, \ldots \ldots . . N' - 1 \quad (5)$$

- Appending zeros to each input block prior to computing the required IDFT is a well-known OFDM implementation technique, which is equivalent to oversampling, by a factor given in Eqn.(6) below, the ideal MC-CDMA burst.

$$M_{Tx} = \frac{N'}{N} \geq 1 \quad (6)$$

- The subsequent nonlinear operation is crucial for reducing the envelope fluctuations, whereas the frequency-domain filtering using the set given in Eqn.(7) can reduce the resulting spectral spreading (of course, with some regrowth of the envelope fluctuations).

$$G_k; k = 0, 1, 2, \ldots \ldots , N' - 1 \quad (7)$$

The removal of subcarriers with zero amplitude reduces the computational effort and corresponds to decimation in the time domain. For a given and a careful selection of , the nonlinear characteristic (for a given input level) and the set can {Gk} ensure small envelope fluctuations while maintaining low out-of-band radiation and in-band self-interference levels. When the nonlinear operation is chosen to be an ideal envelope clipping, with clipping.

$$g_c(R) = \begin{cases} R, & R \leq S_M \\ S_M, & R > S_M \end{cases} \quad (8)$$

It should be mentioned that this wide class of signal-processing schemes includes, as specific cases, schemes proposed so far. where the same clipping is adopted when assuming ,the condition in Eqn.(8) with for the in-band subcarriers, and out-of-band. It should also be mentioned that, for an ideal envelope clipping, the proposed signal-processing scheme can be shown to be equivalent to the peak cancellation method.

A more sophisticated technique, allowing improved PMEPR reducing results, could be simply developed on the basis of the signal-processing approach described above. Such a technique consists of repeatedly using, in an iterative way, the signal-processing chain which leads from to in Fig.1. The technique proposed in [17] corresponds to the particular case where the nonlinear operation is an envelope clipping, and the frequency-domain filtering is characterized by for the Gk=0 for the out-of-band subcarriers.

IV. RESULTS AND DISCUSSION

A. Definition of PMEPR

The continuous time signal x(t) represents the sum of all the parallel transmission streams as expressed in Eqn.(9). Peak-to-mean envelope power ratio can clearly be recognised through the understanding of the individual numerator and denominator expressions. The former specifies the maximum transmitted signal squared value, which represents the peak power of the total transmitted MC-CDMA signal. The latter defines the average power across the sum of composite time domain signals defined by x(t). The average transmitted signal power can be found through the time average expectation of the entire signal power of the combined N sub-channels**.**

$$\boldsymbol{PMEPR} = \frac{\boldsymbol{Max}|\boldsymbol{x(t)}|^{\boldsymbol{2}}}{\boldsymbol{E}\left[|\boldsymbol{x(t)}|^{\boldsymbol{2}}\right]} \qquad (9)$$

A ratio is taken between the peak and the average power of the MC-CDMA signal to give a power ratio. PMEPR measurement of power ratio is derived from sampled discrete information in the signal information.

B. Maximum PMEPR Plot

The particular equation of interest is the maximum PMEPR equation defined in Eqn.(4), which specifies the worst case PMEPR. The definition of maximum PMEPR is entirely based on the summing of the pulse values throughout the pulse interval. The important factor that should be noted is that increasing pulse heights directly affects the maximum PMEPR.

C. Cumulative Distribution Function

The occurrences of peak fluctuations seems to be following CDF in a conventional MC-CDMA system. The CDF of a probability distribution function evaluated at a number ‘x’, is the probability of the event occurrences that a Random Variable(X) with that distribution is less than or equal to ‘x’. The typical range of PMEPR values are shown in Figure 2.

The behavior of the PMEPR is seen to decrease with increasing ‘n’ which reflects on the increasing correlation between subcarriers. The rate of decay in PMEPR plot is reduced as ‘n’ tend to a large value as the curves approach a horizontal asymptote.

For the normalised sine pulse case, the plot of the maximum PMEPR against the shape parameter ‘n’ in terms of CCDF for each iteration is illustrated in Figure 3.

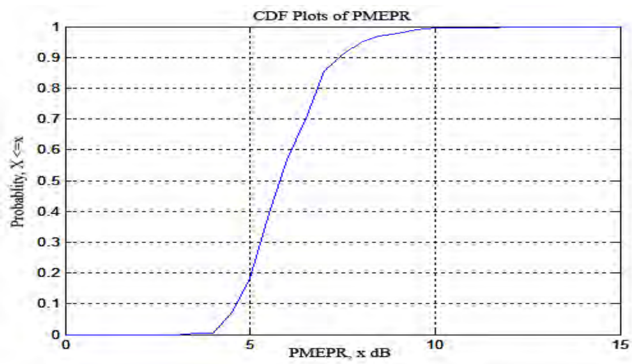

Figure 2 CDF plot of PMEPR

TABLE 1
COMLEMENTARY CUMULATIVE DISTRIBUTIONFUNCTION

No. of Iteration	PMEPR (dB)	SNR (dB)
0	8.7550	20
1	7.5660	19.4
2	6.8031	17.4
3	4.8830	16.3
4	4.1113	15.9

By plotting the maximum PMEPR for a normalised sine pulse, an attractive result was gained. It can be observed that the normalisation of sine pulses have brought PMEPR levels lower than the unmodified sine pulse. The maximum PMEPR has changed considerably achieving a greater rate of PMEPR reduction per ‘n’. This implies that lowering the energy of the pulses has direct impact on the lowering of PMEPR.

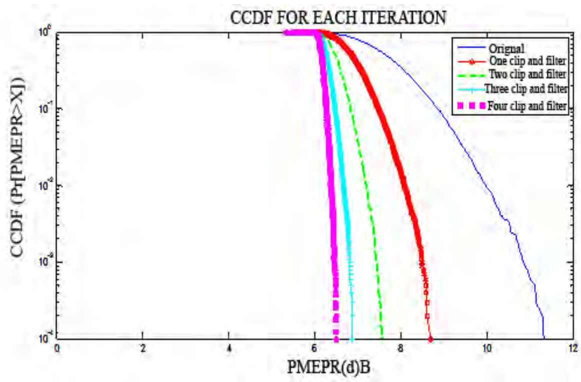

Figure 3 CCDF plots of each iteration

An OFDM modulation with N=64 subcarriers and an M-QAM constellation, with a Gray mapping rule, on each subcarrier is considered. The set of multiplying co efficient{Gk; k=0,1,2,…N’-1} has a trapezoidal shape, with Gk=1 for the N data subcarriers (in-band region), dropping linearly to 0 along the first (N1-N)/2 out-of-band subcarriers at both sides of the in-band region, which means N1 nonzero subcarriers. The nonlinear operation is chosen to be an ideal envelope clipping .

On considering the basic, single-iteration signal-processing schemes, Figure 4 is concerned with the bandwidth-efficiency issues when using these schemes, with a clipping level of 2.0. A well-known PSD-related function was adopted: the so-called fractional out-of-band power (FOBP), defined for a symmetrical PSD. Clearly, this clipping can lead to high out-of-band radiation levels.

However, by using a frequency-domain filtering with Gk=1 for the data subcarriers and 0 for the remaining ones (i.e.) we can reduce these levels to those of conventional MC-CDMA. Further reduction is achieved if this filtering is combined with the windowing procedure.

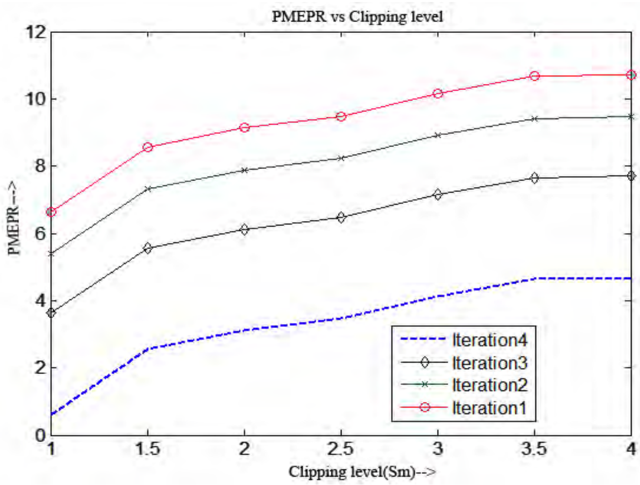

Figure 4 PMEPR Behaviour of each iteration

The transmitter employs a power amplifier which is quasi-linear within the range of variations of the input envelope, and the coherent detection operates under perfect synchronization and channel estimation.

On assuming L iterations for two users and an envelope clipping level with 2.0 , while Gk=1for the in-band subcarriers and 0 for the remaining From the Table 1, it is clear that the envelope fluctuations by using the iterative technique can be reduced. The maximum envelope can be already close to with just three or four iterations.

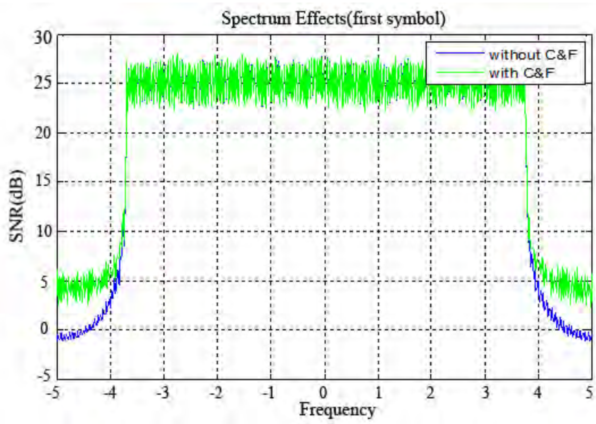

Figure 5 Non-linearity of HPA

D. BER Performance

The conventional BER performance of a MC-CDMA system without employing the an envelope clipping and filtering procedure in an iterative way is approximately as depicted in figure 6.

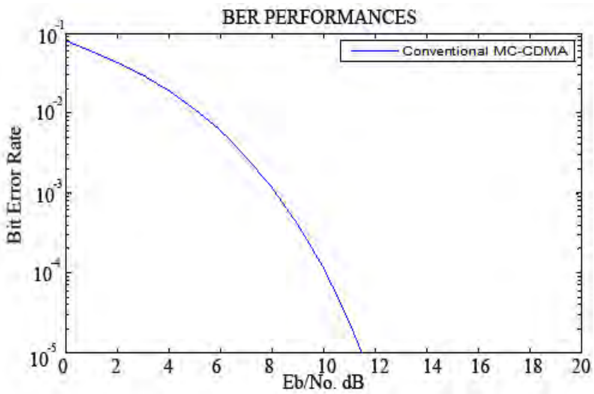

Figure 6 Conventional BER of MC-CDMA

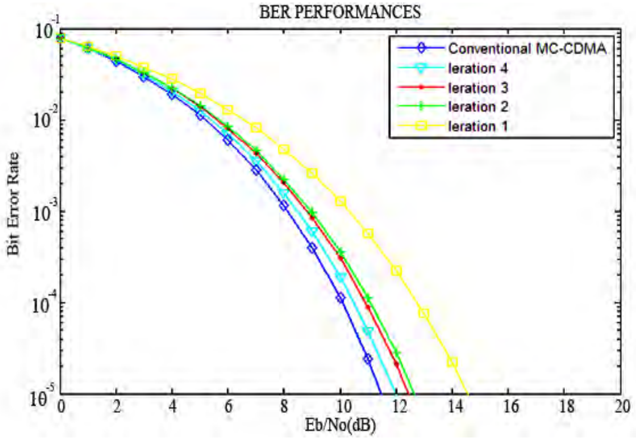

Figure 7   BER performances of each iteration

On considering the corresponding BER performances on an ideal additive white Gaussian noise (AWGN) channel, still with an envelope clipping as the nonlinear operation. As expected, the required Eb/N0 decreases when clipping level is increased, and the BER performances with are already close to the corresponding performances with infinite users. However, increased values of subcarriers imply a higher PMEPR, i.e., an increased power amplification backoff.

Figure 6 shows the BER for each iteration in comparison with required/conventional BER performance. The optimum values of clipping level are 2.0 for 4, 2.6 for 16, and3.2 for 64QAM.

Moreover, these optimum values of clipping levels are almost independent of the frequency-domain filtering effort. When not considering the iterative procedure analyzed in chapter 3, where the signal-processing chain is repeatedly used which leads from to peak amplitude clipped pulses, so as to provide an additional reduction of the envelope fluctuations while preserving a compact spectrum.

From the Figure 7, the BER performance of MC-CDMA with this reduction technique reaches the conventional MC-CDMA performance of for increased no. of iteration and degradation in SNR.

V. CONCLUSIONS AND FUTURE RESEARCH

In this work, a problem experienced in the OFDM modulation technique in the MC-CDMA system has been studied. The various multiple access techniques that were common in modern communications systems are introduced. OFDM modulation was introduced which was a specific form of multiple access technique based on FDMA and also discusses how OFDM modulation operates and commences the advantages and disadvantages of the modulation scheme. The PAPR problem that is commonly experienced in MC-CDMA signals was introduced providing the motivation for an effective solution.

Consequently a wide class of digital signal-processing schemes for MC-CDMA transmission which combine a nonlinear operation in the time domain, and a linear filtering operation in the frequency domain was presented and evaluated. The ultimate goal of these schemes is to reduce substantially the envelope fluctuation of ordinary MC-CDMA system, while keeping its high spectral efficiency and allowing a low-cost, power-efficient implementation.

A detailed evaluation of MC-CDMA signal transmission techniques which employ the signal-processing schemes considered here was carried out, involving computations of power spectra, BER performances, and achieved PMEPR values. Such evaluation has taken advantage of our statistical characterization of the transmitted blocks and included other implementation issues (such as the impact of the time-windowing procedures). A set of performance results was presented and discussed, showing that the proposed basic schemes can provide a significant PMEPR reduction while keeping a high spectral efficiency.

The iterative technique based on the basic schemes was shown to allow a further PMEPR reduction, also maintaining the spectral efficiency of conventional MC-CDMA, with only a moderately increased implementation complexity. When compared with other distortionless techniques, also capable of reducing the PMEPR of MC-CDMA signals, these signal processing techniques involving deliberate nonlinear distortion were shown to offer improved performance/complexity tradeoffs, for small constellations and a high number of subcarriers.

The non- linear signal processing scheme has been used to test narrowband and broadband pulses concluding that broadband pulses were far superior in reducing PMEPR. Numerical results demonstrate that improvements in PMEPR reduction require certain frequency characteristics of subcarriers pulses. Some of these characteristics include:

• Large main lobe width
• Low sidelobe peaks
• High or flat amplitude main lobe responses

The worst case PMEPR values are obtained through the use of rectangular subcarrier pulses with high sidelobe peaks in their response. It is suggested that pulses with relatively low side lobe peaks should be used to deviate the worst case scenario. This is because the worst case PMEPR is obtained by using rectangular pulses.

The non- linear signal processing scheme proves to be a simple approach to PMEPR reduction based on modifications to the existing MC-CDMA signal structure. Unlike techniques such as PTS and precoding, non-linear signal processing scheme does not require additional implementation complexity, modification in the receiver structure or overhead coding at the expense of bandwidth respectively. The non- linear signal processing scheme used in this thesis performs well in assisting the study of efficient signal characteristics that improve PMEPR reduction.

A typical scheme of signal processing has been tested in this project. More optimized schemes should be tested in order to gain a deeper understanding of other signal characteristics and their effects on the performance of PMEPR reduction.

VI. REFERENCES

[1] L. Cimini, Jr., “Analysis and simulation of a digital mobile channel using orthogonal frequency-division multiplexing,” IEEE Transaction Communication., vol. COM-33, pp. 665–675, July 1985.

[2] A. Jones and T. Wilkinson, “Combined coding for error control and increased robustness to system nonlinearities in OFDM,” Proceedings of IEEE Vehicular Technology Conference., vol. 2, Atlanta, GA, May 1996, pp. 904–908.

[3] S. Müller and J. Huber, “OFDM with reduced peak-to-average power ratio by optimum combination of partial transmit sequences,” Electronics Letters, vol. 33, no. 5, pp. 368–369, Feb. 1997.

[4] S. Müller, R. Bäuml, R. Fischer, and J. Huber, “OFDM with reduced peak-to-average power ratio by multiple signal representation,”Annual Telecommunication, vol. 52, pp. 58–67, Feb. 1997.

[5] L. Cimini, Jr. and N. Sollenberger, “Peak-to-average power reduction of an OFDM signal using partial transmit sequences,” IEEE Communication Letters, vol. 4, pp. 86–88, Mar. 2000.

[6] R. O’Neill and L. Lopes, “Envelope variations and spectral splatter in clipped multicarrier signals,” Proceedings of IEEE Personal, Indoor, Mobile Radio Conference., vol. 1, Sept. 1995, pp. 71–75.

[7] X. Li and L. J. Cimini, Jr., “Effects of clipping and filtering on the performance of OFDM,” IEEE Communication Letters, vol. 2, pp. 131–133, May 1998.

[8] R. Dinis and A. Gusmão, “A class of signal processing algorithms for good power/bandwidth tradeoffs with OFDM transmission,” Proceedings of IEEE International Symposium Information Theory, June 2000, pp. 216–216.

[9] “A new class of signal processing schemes for bandwidth-efficient OFDM transmission with low envelope fluctuation,” Proceedings of IEEE Vehicular Technology Conference, vol. 1, pp. 658–662, May 2001.

[10] H. Rowe, “Memory less nonlinearities with Gaussian input: Elementary results,” Bell Syst. Tech. Journal, vol. 61, pp. 1519–1525, Sept. 1982.

[11] H. Ochiai and H. Imai, “Performance of deliberate clipping with adaptive symbol selection for strictly bandlimited OFDM systems,” IEEE Journal on Selected of Areas Communication, vol. 18, pp. 2270–2277, Nov. 2000.

[12] J. Armstrong, “New OFDM peak-to-average power reduction scheme,” Proceedings of IEEE Vehicular Technology Conference, vol. 1, pp. 756–760 May 2001.

[13] H. Ochiai and H. Imai, “Performance analysis of deliberately clipped OFDM signals,” IEEE Transaction Communication, vol. 50, pp. 89–101, Jan. 2002.

[14] R. Dinis and A. Gusmão, “Performance evaluation of an iterative PMEPR-reducing technique for OFDM transmission,” Proceedings of IEEE GLOBECOM, vol. 1, pp. 20–2, Dec. 2003

[15] R. Nee and R. Prasad, OFDM for Wireless Multimedia Communications. Norwood, MA: Artech House, 2000.

[16] T. May and H. Rohling, “Reducing the peak-to-average power ratio in OFDM radio transmission systems,” Proceedings of IEEE Vehicular Technology Conference, vol. 3, pp. 2474–2478 ,May 1998.

[17] J. Armstrong, “Peak-to-average power reduction for OFDM by repeated clipping and frequency-domain filtering,” IEEE Electronics Letters, vol. 38, no. 5, pp. 246–247, Feb. 2002.

[18] R. Dinis and A. Gusmão, “On the performance evaluation of OFDM transmission using clipping techniques, ”Proceedings of IEEE Vehicular Technology Conference, vol. 5, pp. 2923–2928, Sept. 1999.

[19] G. Stette, “Calculation of intermodulation from a single carrier amplitude characteristic,” IEEE Transaction Communication., vol. COM-22, pp. 319–323, Mar. 1974.

[20] M. Abramowitz and I. Stegun, Handbook of Mathematical Functions. New York: Dover, 1972.