MITIGATION OF IMPULSIVE INTERFERENCE IN FREQUENCY SELECTIVE OFDM BASED SYSTEMS

Namrata Jain*

Namrata Sahayam**

Abstract

OFDM is a technique used for bandwidth efficient communication over the channel. It provides excellent possibilities to adapt to the frequency-selectivity of the channel. The influence of impulsive noise in OFDM transmission is not well analyzed yet. In this paper, an algorithm for mitigating impulsive interference in OFDM based systems is presented which provides an iterative way suited to suppress impulse interference. The algorithm does not require any prior knowledge about the impulsive interference but only marginal increase computational complexity is done as compared to the conventional blanking nonlinearity approach.

Keywords— *Frequency-selectivity; impulsive noise; iterative algorithm; OFDM*

---

* M.E., Communication System , Department of Electronics and Communication, Jabalpur Engineering College (JEC), Jabalpur, Madhya Pradesh, India

** Asst. Prof., Department of Electronics and Communication, Jabalpur Engineering College (JEC), Jabalpur, Madhya Pradesh, India

I. INTRODUCTION

It is well known that many attractive properties are provided by the data transmission over power-lines. The difficult transmission channel is a major drawback of the technology: the transmitted data is not only corrupted by colored Gaussian noise and narrowband interference, but also by impulsive noise. Especially in the high frequency domain the attenuation additionally becomes highly frequency selective [1] [2].

One promising scheme for data transmission over channels is OFDM. Orthogonal frequency-division multiplexing (OFDM) is a multi-carrier modulation technique, which has established itself in the recent years and is currently deployed in several communications systems such as digital audio broadcasting (DAB), digital video broadcasting (DVB), or 3GPP long term evolution (LTE), to mention just a few. These systems are often exposed to impulsive interference that originates from switching processes on the power distribution network, ignitions of passing vehicles, or other systems operating in the same frequency range [3]. OFDM provides excellent possibilities to handle the colored noise, the narrowband interference and the frequency selective attenuation of the channel. Some authors argue that impulse-like interference occurring in the time domain gets suppressed after demodulation (in the frequency domain) by spreading the impulses over a large number of carriers. In general, OFDM system is less sensitive to impulsive noise than the single-carrier system. Nevertheless, impulsive noise can significantly degrade the OFDM system performance. For example, it has been recently noted that impulsive noise could seriously affect to DVB-T system which uses 64QAM (Quadrature Amplitude Modulation) [4].

In recent years, several sophisticated algorithms for the mitigation of impulsive interference have been proposed [5] [6]. Here, we propose a new algorithm suited to significantly mitigate the impulsive noise interference on the OFDM transmission.

II. RELATED WORK

The work done in this field is an effort of implementation of a strong algorithm to mitigate the effect of impulsive interference.

Simple traditional method of impulsive noise cancellation in multi-carrier systems is to use nonlinearity in time domain before OFDM demodulation. This method is widely used in practice since it is very simple to implement. But these traditional methods provide unsatisfactory system performance improvement.

For moderate impulsive interference power and infrequent occurrence, OFDM systems can cope relatively well with the interference, as it is spread among several sub-carriers of an OFDM symbol. However, for frequent occurrence or high interference power, such interference significantly affects the performance of the system [7] and interference mitigation techniques are required. A common approach to mitigate the impact of impulsive interference is to apply a memory less blanking nonlinearity (BN) at the receiver input prior to the conventional OFDM demodulator [8], [9], which blanks all samples of the received signal with amplitude exceeding a predefined threshold. Although BN does cancel the impulsive interference, it also affects the useful OFDM signal, which is a significant drawback of this scheme [10]; also the whole received signal is typically discarded during the blanking interval, despite only a fraction of the transmission bandwidth might be affected by the interference. Another critical issue when applying the BN to an OFDM-based system is the detection of interference impulses. It is well known that OFDM signals have a relatively high peak-to-average power ratio. This makes a differentiation of interference impulses from OFDM signal peaks challenging.

III. PROPOSED WORK

A. Impulsive Noise Model

Impulsive noise is the common impairment in communication systems, which caused by many different sources, such as car ignitions, high voltage cables, hair dryers, vacuums cleaner and microwave ovens [11], thus the impulsive noise models were analyzed depending on different several sources as literature in last twenty years [12]-[13]. It is complicated to accurately model impulsive noise interference, but model of impulsive noise from any sources has two common properties:

1. The time arrival of an impulsive noise is unpredictable, but it arrives with probability.
2. The amplitude of impulsive noise is much higher than the background noise and it has short period.

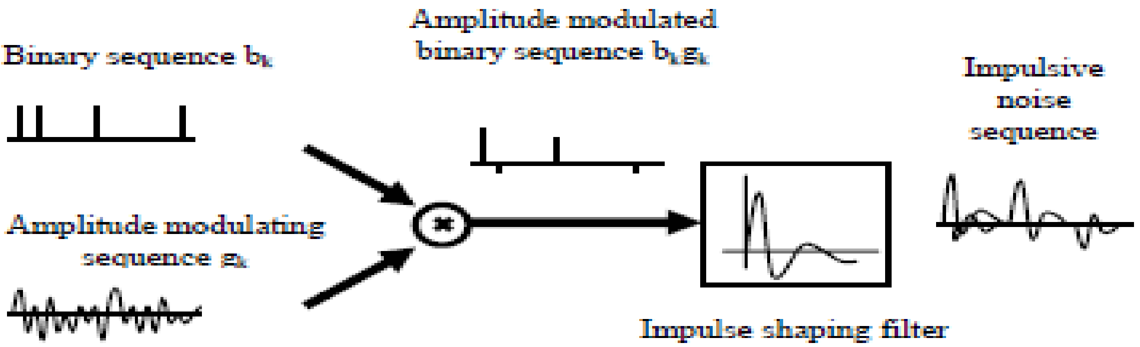


Figure 1. The Bernoulli-Gaussian model of Impulsive Noise.

B. Algorithm

We introduce an iterative algorithm which exploits the nature of the impulsive noise and drastically increases the performance of some OFDM transmission schemes. In [14] a related algorithm was proposed to reduce the influence of clipping noise introduced by hard limiting the peaks of an OFDM-transmission. This algorithm is not suited for correcting impulsive noise errors. The major difference between the two algorithms is that we approach the problem from a different perspective: we do not try to give a good estimate for the transmitted sequence *S*, but we try to find a good estimate for the noise vector *N* given in the received sequence *R*. This leads us to modify the decision rules.

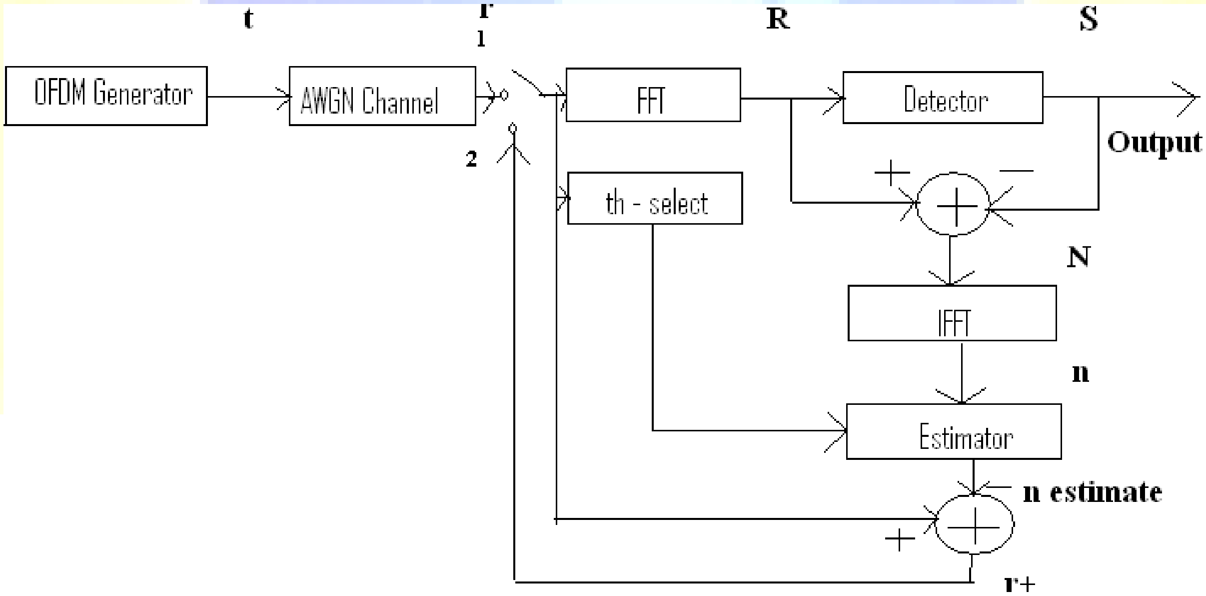


Figure 2. An OFDM system with proposed looping algorithm.

The proposed algorithm is described as follows:

$r = t + n$

```
$r^{(0)} = r$
$l=0$
repeat until stop-criterion valid
    $T = thselect(r^{(l)})$
    $R^{(l)} = Fr^{(l)}$
    $S^{(l)} = detect(R^{(l)})$
    $N^{(l)} = R-S^{(l)}$
    $n^{(l)} = F^{-1}N^{(l)}$
    $n^{estimate} = estimate(n^{(l)})$
    $r^{(l+1)} = r-n^{estimate}$
    $l=l+1$
end repeat
$R^{(l)} = Fr^{(l)}$
$S_f = detect(R^{(l)})$
```

We use the notation given in the figure above in this section and additionally use superscript letters to denote the number of iteration we are in. The return value of the algorithm is S_f (final signal) as an estimate for the sequence *S* that was sent.

In the following we discuss the different elements of the algorithm:

1) *Stop-criterion:* The algorithm is terminated in two conditions, (1) if $S^{(l)} = S^{(l+1)}$ is valid for the first time, any further iteration does not change result of the algorithm, (2) loop is also terminated, if a maximum number of iterations are exceeded.

2) *Detect-operator:* This operator investigates each carrier independently in frequency domain and maps each given $R_i^{(l)}$ on a signal point in the QAM-constellation. We use the same detector as in the Gaussian noise case and therefore choose the signal-point $S_i^{(l)}$ with the minimum Euclidean distance to the given value $R_i^{(l)}$.

3) *Estimation-operator:* There are several options for the determination of $n^{estimate}$. Minimizing the quadratic errors for the estimation or performing a MAP-estimate has two possibilities leading to more general algorithms. In those cases the estimators have to be adaptive to the current values of $n^{(l)}$ and l and the statistical properties of $n^{(l)}$ have to be known. The algorithm

then gets highly sensitive to errors in those assumptions. As we use the following, adaptive estimation-operator:

estimate $(n^{(l)}) = \{ 0$ for $n^{(l)} < T$

$\{n^{(l)}$ for $n^{(l)} > = T$

with some threshold T. And we are finding value of T by the function:

T= thselect (r,’heursure’)

this gives the adaptive value of T.

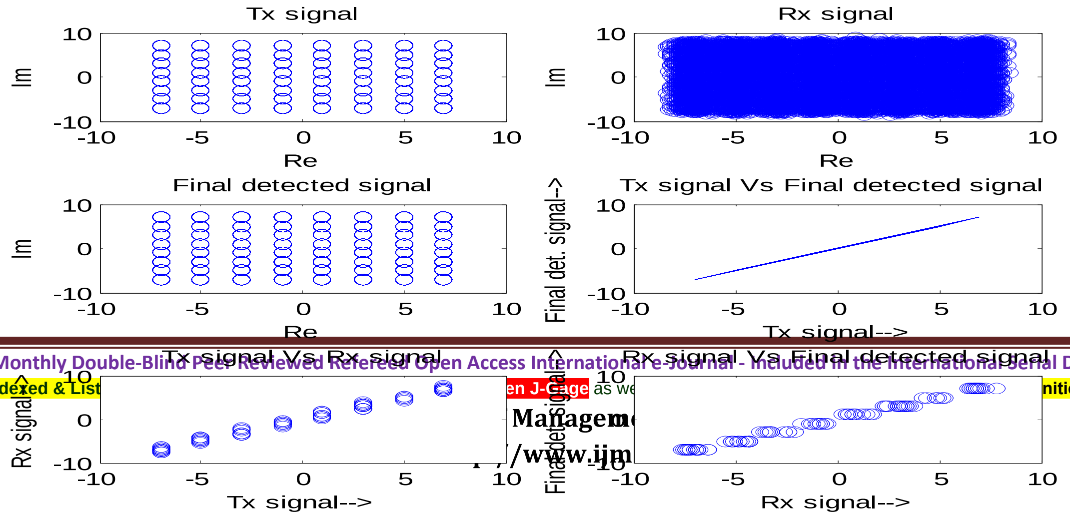
IV. SIMULATION AND RESULT

Here we are working on the MATLAB platform. Here we consider complex symbol alphabets, such as QAM. The QAM-signal consists of alphabet symbols of:

a+ j*b, where a, b = {..., -7 -5 -3 -1 1 3 5 7, ...}.

Here we generate a 64-QAM symbol sequence of 20000 symbols. Then we add some white Gaussian noise to the generated complex symbol streams, so that the SNR is in the range of 0 to 20 dB. The noise vector must be, like the signal (QAM), complex-valued and of equal size as that of signal-vector. Any communication system always includes some noise, which is usually additive. Usually, the noise is assumed to be Gaussian distributed. In symbol detection, we compare the distance of a received noisy sample to all possible symbol values in the used alphabet. The detected symbol (decision) is the one that minimizes the distance.

In the below section of figures, fig. 1 show the transmitted signal, fig. 2 shows the received signal which is corrupted with noise. In fig. 3, finally detected signal is shown which is obtained after applying the proposed algorithm. In fig. 4, a graph is shown between transmitted signal and finally obtained signal, which is almost a straight line. It shows a very less amount of noise in the processed signal. In fig. 5, a graph between transmitted and received noisy signal is shown,



which shows the amount of noise added by the channel in the transmitted signal. In fig. 6, a graph between received noisy signal and finally detected signal is shown, which shows the amount of noise removed by the proposed algorithm.

Figure 3. Different signals of the proposed algorithm.

In the next section of figures, fig. 4 shows that some noise can be observed by repeatedly running the program of algoritm because the signal is generated with the help of random signal, but still this is very small amount of noise, which will not affect the performance of the proposed scheme.

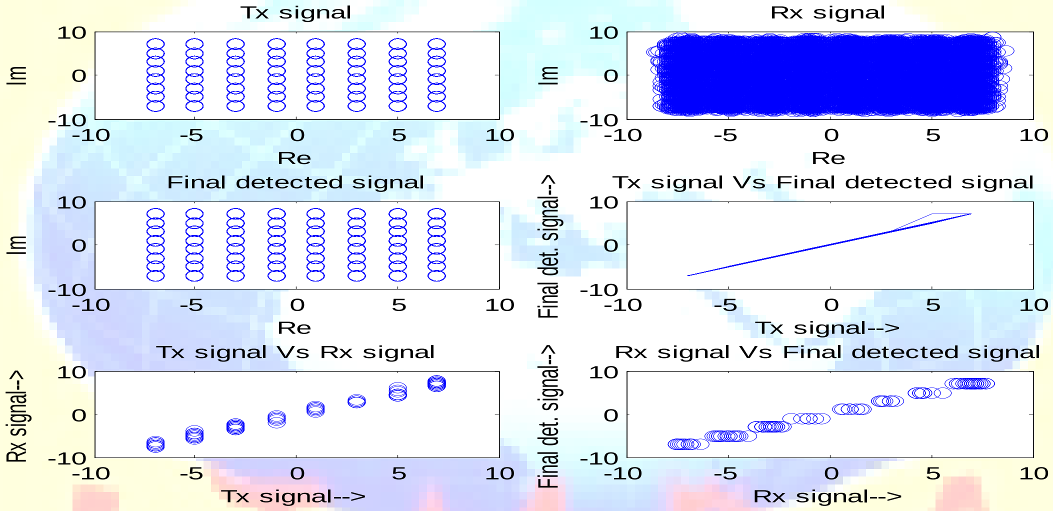


Figure 4. Small amount of noise due to random signal.

Following two figures shows the wave form and constellation form respectively, of the noise added by the channel in the transmitted signal.

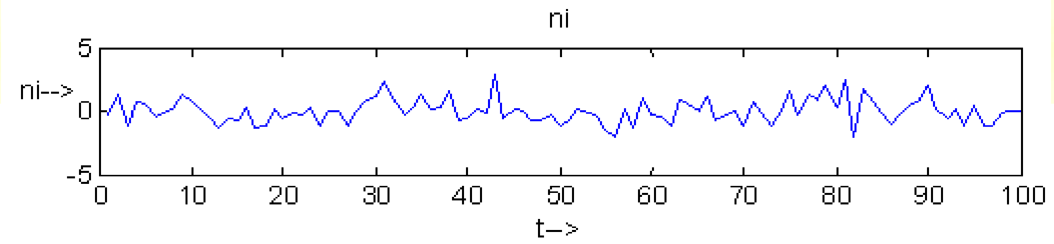


Figure 5. Wave form of noise added by the channel.

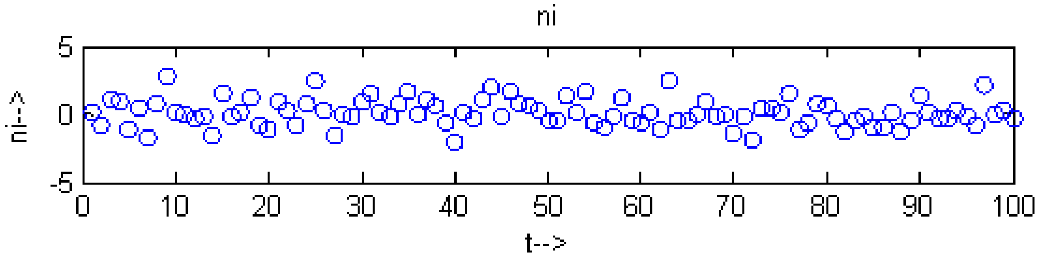


Figure 6. Constellation form of noise added by the channel.

Next two figures show the wave form and constellation form respectively, of the noise which is present in the finally processed signal.

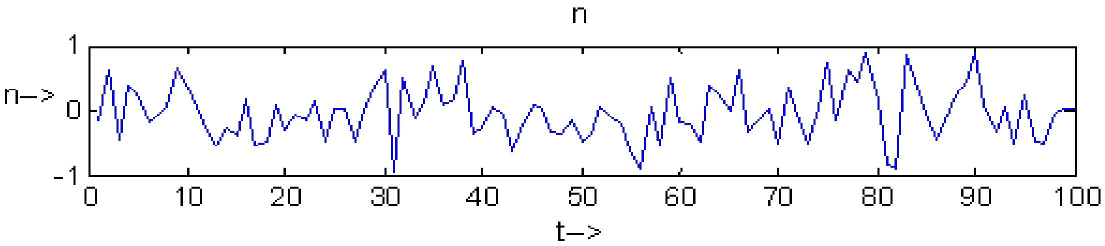


Figure 7. Wave form of noise present in the processed signal.

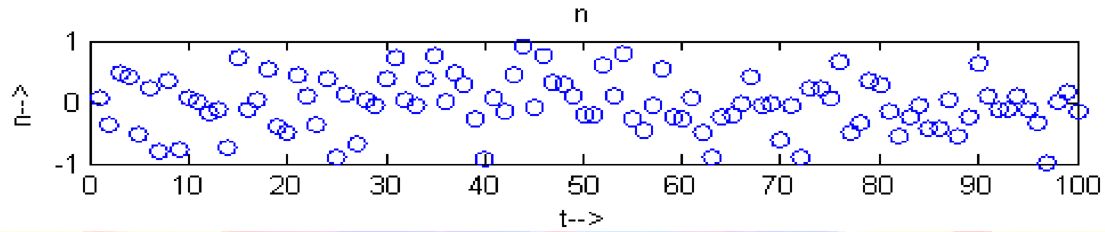


Figure 8. Constellation form of noise present in the processed signal.

Here, we can easily observe that the noise which is present in the final signal is considerably less in amount as compared to the initial noise which is added by the channel, this proves the removal of noise and improvement of signal by the proposed algorithm.

C. Symbol Error Probability (SEP) / Symbol Error Rate (SER):

SEP can be calculated both analytically and using computer simulations. For 64-QAM, the theoretical SEP is of the form:

P = 3.5*Q(d/(2*sigma)) – 3.0625*Q(d/(2*sigma))^2,

where Q(.) is Q-function, d the minimum distance of two constellation points, and sigma^2 is the variance of noise real or imaginary part.

Simulated SEP: From below table, we can observe that with the increasing Signal to Noise (SNR) value, the value of Signal Error Probability (SEP) decreases considerably.

The resultant table is as follows:

TABLE I. SNR VS SEP

S. No.	SNR	Simulated SEP
1.	0	0.9234
2.	1	0.9144
3.	2	0.8988
4.	3	0.8863
5.	4	0.8693
6.	5	0.8504
7.	6	0.8242
8.	7	0.7991
9.	8	0.7617
10.	9	0.7182
11.	1 0	0.6709
12.	11	0.6260
13.	12	0.5634
14.	13	0.4942
15.	14	0.4212
16.	15	0.3458
17.	16	0.2680
18.	17	0.1998
19.	18	0.1347
20.	19	0.0885
21.	20	0.0466

From fig. 9, we can observe the rapid decrease in SEP with increasing SNR, which signifies the noise removal capacity of the proposed algorithm.

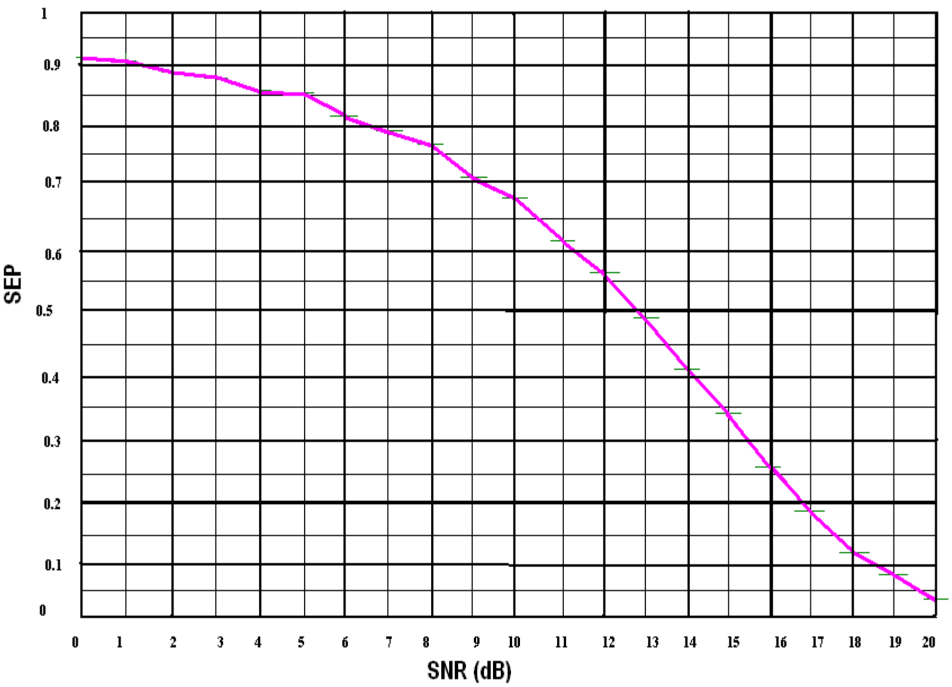


Figure 9. SNR Vs SEP graph.

V. CONCLUSION

In this paper we analyzed the performance of the OFDM transmission scheme corrupted by impulsive noise. Specifically, the proposed algorithm has demonstrated a superior performance in terms of the achieved decreased signal error probability with increasing signal to noise ratio while preserving a low complexity. Here we described a new iterative algorithm suited for mitigating the influence of the impulsive noise on the OFDM transmission. By implementing the proposed algorithm suited to suppress impulse-like interference we do not try to give a good estimate for the transmitted sequence *S*, but we try to find a good estimate for the noise vector *N* given in the received sequence *R*. This leads us to modify the decision rules. Here we utilize more sophisticated estimation-operators to achieve a faster convergence of the algorithm by the implementation of the adaptive estimators. The algorithm can be potentially used with any type of impulsive interference, yet we expect that it copes particularly well with frequency-selective interference.

REFERENCES

[1] 0. Hooijen: *"A Channel Model for the Low-Voltage Power-Lie Channel; Measurement- and Simulation Results"*, Proc. ISPLC, Essen, 1997

[2] H. Philipps: *"Modeling of Power-Line Communication Channels"*, Proc. ISPCL, Lancaster, 1999

[3] J. Lago-Fernandez and J. Salter, *"Modelling impulsive interference in DVB-T: statistical analysis, test waveforms and receiver performance,"* BBC R. and D. Whitepaper (WHP 80), Apr. 2004.

[4] Y. Wu, *"Performance Comparison of ATSC 8-VSB and DVB-T COFDM Transmission Systems for Digital Television Terrestrial Broadcasting," IEEE Transactions on Consumer Electronic*, Vol. 45, No. 3, August 1999.

[5] S. Brandes, U. Epple, and M. Schnell, *"Compensation of the impact of interference mitigation by pulse blanking in OFDM systems,"* in *Proc. 2009 IEEE Global Telecomm. Conf.*, pp. 1–6.

[6] J. H¨aring and A. J. H. Vinck, *"Iterative decoding of codes over complex number for impulsive noise channels," IEEE Trans. Inf. Theory*, vol. 49, pp. 1251–1260, May 2003.

[7] M. Ghosh, *"Analysis of the effect of impulse noise on multicarrier and single carrier QAM systems," IEEE Trans. Commun.*, vol. 4, pp. 145–147, Feb. 1996.

[8] S. V. Zhidkov, *"Analysis and comparison of several simple impulsive noise mitigation schemes for OFDM receivers," IEEE Trans. Commun.*, vol. 56, pp. 5–9, Jan. 2008.

[9] H. A. Suraweera, C. Chai, J. Shentu, and J. Armstrong, *"Analysis of impulse noise mitigation techniques for digital television systems,"* in *Proc. 2003 Int. OFDM Workshop*, pp. 172–176.

[10] U. Epple, K. Shibli, and M. Schnell, *"Investigation of blanking nonlinearity in OFDM systems,"* in *Proc. 2011 IEEE Int.Commun. Conf.*, pp. 1–5.

[11] H.A. Suraweera and J. Armstrong, *"Noise Bucket Effect for Impulse Noise in OFDM," Electronics Letters*, Vol. 40, No. 18, September 2004.

[12] M. Ghosh, *"Analysis of the Effect of Impulse Noise on Multicarrier and Single Carrier QAM System," IEEE Transactions on Communications*, Vol. 44, No. 2, February 1996

[13] I. Mann, S. McLaughlin, W. Henkel, R. Kirkby, and T. Kessler, *"Impulse Generation with Appropriate Amplitude, Length, Inter-arrival, and Spectral Characteristics," IEEE J. Select Areas Commun.*, Vol. 20, pp. 901-912, June 2002

[14] D. Kim, G. L. Stiiber: *"Clipping Noise Mitigation for OFDM by Decision-Aided Reconstruction"*, IEEE Communications Letters, Vol. 3, No. 1, Jan. 1999