International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 3 Issue 3ǁ March 2014 ǁ PP.06-14

Improvement of OFDM Performance Using Single Carrier Via Magnitude Keyed Modulation For Wireless Communication

Ayappasamy.K[1], Sheela Bernardine Josy. T[2], Rajalakshmi. S[3] , Benazer Begum. B[4]

[1,] *Assistant professor, Department of Electronics and Communication Engineering,*
[2,3,4,] *Students, (Bachelor of Technology) Department of Electronics and Communication Engineering,*
Dr. S.J.S. Paul Memorial College of Engineering and Technology, Puducherry - 605 502, India

ABSTRACT : *Orthogonal Frequency Division Multiplexing (OFDM) is one of the multiple accessing techniques like TDMA, FDMA, and CDMA etc which is found to be the most suitable technology for the upcoming generations. But compared to OFDM system, Single Carrier OFDM (SC-OFDM) has been proved to be a much better technique as it has an excellent bit error rate (BER) performance, as well as low peak to average power ratio (PAPR). Even though SC-OFDM system has the advantages mentioned above, still it suffers from Inter Carrier Interference like other multi-carrier transmission techniques, resulting in signal performance degradation in high mobility environments. Existing techniques for OFDM like PSK, QAM can be directly applied in SC-OFDM for performance improvement but the throughput of the overall system gets decreased. In this project, we introduce the newly developed Modulation scheme called as the Magnitude Keyed Modulation combined with SC-OFDM system that improves the overall system performance by providing immunity to ICI, maintaining a low PAPR and improvement in Bit Error Rate performance. Simulation results shows that the SC-OFDM technique along with MKM modulation can be well suited for Wireless Communications.*

KEYWORDS: *Orthogonal Frequency Division Multiplexing (OFDM), Carrier Frequency Estimation, Intercarrier Interference cancellation, Peak to Average Power, Bit Error Rate.*

I. INTRODUCTION

ORTHOGONAL FREQUENCY-DIVISION MULTIPLEXING (OFDM) is a method of encoding digital data on multiple carrier frequencies. It has developed into a popular scheme for wideband digital communication. It is essentially a Frequency-Division Multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme such as Quadrature amplitude modulation or Phase-shift Keying at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate Inter Symbol Interference (ISI).However for a high speed communication there may occur degradation in BER performance, introduction of ICI and increased PAPR. To overcome these effects we move on to a newly proposed technique called SC-OFDM due to its better performance in multipath fading channels and lower Peak to Average Power Ratio (PAPR).The ICI effect on SC-OFDM is concentrated entirely on the phase offset and not on the magnitude. Magnitude-Keyed Modulation (MKM) for SC-OFDM is a technique in which this modulation scheme carries digital data only on the signal magnitude, providing SC-OFDM immunity to ICI. Compared to ICI cancellation schemes or CFO estimation schemes that exist today, the proposed modulation technique is totally immune to the ICI. Additionally, it has low complexity and is easy to be implemented. The lower PAPR property of SC-OFDM system is also maintained for the proposed system. Hence, the proposed SC-OFDM system leads to the improvement of OFDM performance.

II. INTRODUCTION TO SC-OFDM

Single-carrier OFDM (**SC-OFDM**) is a technique that uses a single carrier spread with a unique code to the users. SC-OFDM is an attractive alternative to OFDM, especially in the uplink communications where lower Peak-to-Average Power Ratio (PAPR) greatly benefits the mobile terminal in terms of transmitted power efficiency and reduced cost of the power amplifier. The distinguishing feature of SC-OFDM is that it leads to a single-carrier transmit signal, in contrast to OFDM which is a multi-carrier transmission scheme. It combines benefits of multi-carrier transmission with single carrier transmission using a cyclic prefix and frequency domain processing.

2.1 SC-OFDM Transmitter

SC-OFDM transmitter is shown in Fig.1. Compared to the conventional OFDM system, the SC-OFDM system distributes each parallel data set to all sub-carriers using a different phase rotated spectral spreading on each symbol as illustrated in the Fig.1.For each user the sequence of bits transmitted is mapped in a complex constellation symbols (BPSK, QPSK or QAM). The different users are assigned different Fourier coefficients. This assignment is carried out in the mapping and demapping blocks. Just like in OFDM, guard intervals (or called cyclic prefix) with cyclic repetition are also introduced.

$$s(t) = \frac{1}{\sqrt{N}}\sum_{i=0}^{N-1}\sum_{k=0}^{N-1} x_k e^{-j\frac{2\pi}{N}ik} e^{j2\pi i\Delta f t} e^{j2\pi f_c t} p(t) \qquad (1)$$

The above equation corresponds to the transmitted SC-OFDM symbol. Here x_k is the k^{th} data symbol,Δf is the spacing between subcarriers and $p(t)$ is the rectangular pulse shape with time limit spanning one OFDM symbol.As shown from the Fig. 1the spreading code set corresponds to the normalized DFT matrix with the k^{th}data symbol being spread to thei^{th}subcarrier employing spreading code,

$$\beta_i^k = \frac{1}{\sqrt{N}}\exp\left(-j\frac{2\pi}{N}ik\right) \qquad (2)$$

The SC-OFDM system can be easily implemented using an MC-CDMA framework by making appropriate changes to the spreading code; Hence, the SC-OFDM system uses the same bandwidth as the conventional OFDM or MC-CDMA system. Similar to an OFDM system, SC-OFDM can also be implemented using FFT and IFFT transforms.

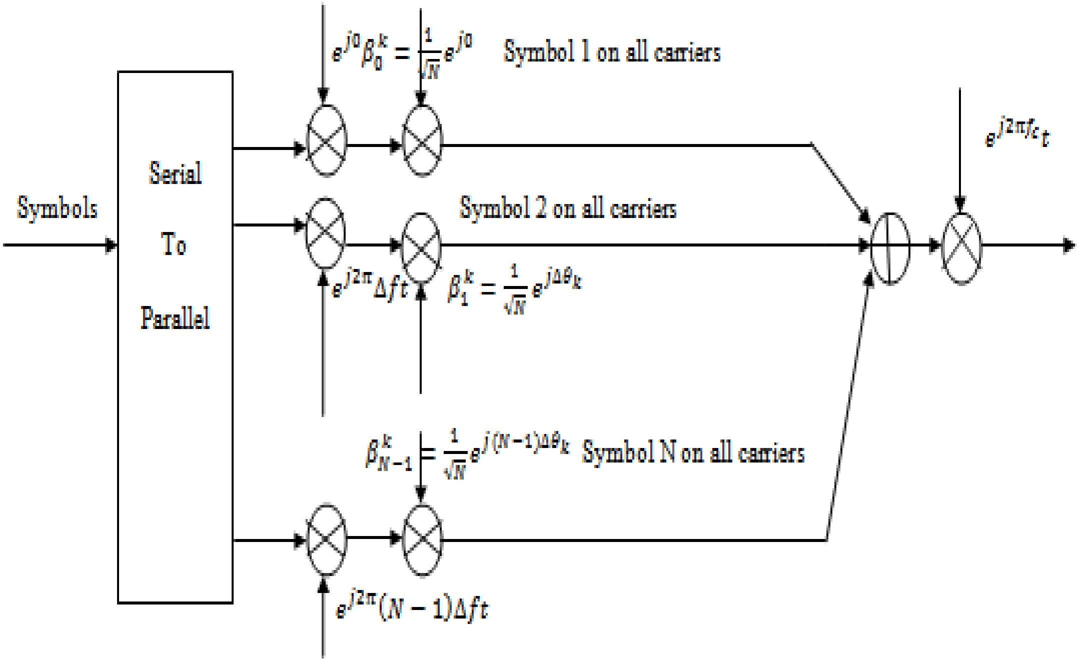

Fig. 1 .SC-OFDM transmitter

2. 2 SC-OFDM Receiver

At the SC-OFDM receiver shown in Fig.2., the SC-OFDM demodulator detects the $\mathbf{k}^{\mathbf{th}}$data symbol by: 1) decomposing the received signal r(t) into N orthogonal subcarriers (via application of an FFT, and perfect timing estimation is assumed), 2) applying the $\mathbf{k}^{\mathbf{th}}$symbol's spreading code, 3) combining the N results with $\{r_0^k, r_1^k, \dots, r_{N-1}^k\}$ an appropriate combining scheme ,denoted by the "Combiner" block in Fig.2. 4) Decision of each symbol will be made based on the result from the "Combiner", denoted by the block "Decision Device". The receiver side includes one demapping block, one IDFT block and one detection block for each user signal to be received.

$$r(t) = \frac{1}{\sqrt{N}} \sum_{i=0}^{N-1} \alpha_i \sum_{k=0}^{N-1} x_k e^{-j\frac{2\pi}{N} ik} e^{j2\pi} (i+\varepsilon)\Delta f (t+\Delta t) e^{j2\pi f_{c(}} t+\Delta t). p(t+\Delta t) + n(t) \qquad (3)$$

The above shown expression denotes the received signal. The SC-OFDM expression includes additional Fourier transform operations due to spreading codes being applied. Thus Single Carrier OFDM uses simple transmitter and receiver sections where the symbols to be transmitted are available on all carriers with a newly developed spreading code, combined with a phase factor and then transmitted. Similarly at the receiver end, using the same spreading code as used at the transmitter, we recover the transmitted symbols. The illustration given above is being depicted in Fig.2.

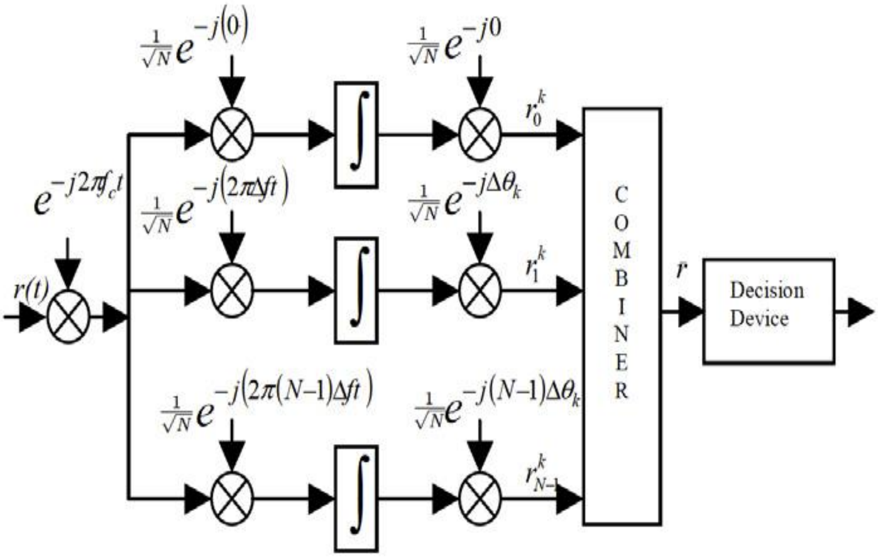

Fig. 2.SC-OFDM Receiver

3. MAGNITUDE KEYED MODULATION

The newly proposed modulation technique is called to be as Magnitude Keyed Modulation. It is a digitally modulated scheme. It is a type of modulation technique using the magnitude to carry symbols.MKM is different from Amplitude Shift Keying (ASK) using antipodal signal pairs given that MKM is a non-coherent modulation scheme and doesn't require phase reference. MKM tends to provide SC-OFDM with immunity to ICI. The proposed modulation scheme does not need to sacrifice the data via employing training sequence or self cancellationcoding; meanwhile it is totally immune to ICI. Additionally, the proposed system has low complexity and is easy to be implemented. Meanwhile the lower PAPR property of SC-OFDM is also maintained for the newly proposed system. Hence the proposed SC-OFDM system with the Magnitude Keyed Modulation scheme is an ideal candidate for high speed wireless communications.

3.1 Problems Solved by the Proposed Technique

The proposed type of modulation namely Magnitude Keyed Modulation along with the Single carrier OFDM scheme has various advantages relating to the previously developed modulation techniques. The Intercarrier interference is being reduced. The Peak to Average Ratio is also being reduced. The combined scheme provides an excellent Bit error rate performance when comparing to the other existing schemes. The calculations of the PAPR performance analysis and the Inter Carrier Interference are discussed below.

3.1.1 PAPR Performance Analysis

Peak to Average Power Ratio (PAPR) is defined as the ratio between the Peak Power of the signal to the Average Power of the signal. It is a measurement of the waveform calculated from the peak amplitude of the waveform divided by the value of waveform. There were many PAPR reduction techniques being proposed by the earlier papers. Here we present the reduction technique employing the SC- OFDM with MKM.Since an important benefit of an SC-OFDM system is a much lower PAPR when compared with conventional OFDM, it is necessary to analyze the PAPR performance for SCOFDM with MKM. This is done using one particular definition of discrete PAPR of an OFDM symbol: the maximum amplitude squared divided by the mean power of discrete symbols in the time domain.For an OFDM system with BPSK modulation, when the signal in time domain converges to one peak (e.g., in frequency domain$x_k = (-1)^k$ the worst PAPR is obtained and equals N. However, for single carrier systems such as SC-OFDM with MPSK (BPSK, QPSK, etc.) modulation, the maximum amplitude squared equals to the mean power in the time domain and therefore PAPR= 1 << N. Unlike SC-OFDM with MPSK modulation, the SC-OFDM system with MKM cannot retain the PAPR= 1 feature since the magnitude (amplitude) varies for different symbols in time domain. However, as shown next, the SC-OFDM system with MKM has a much lower PAPR than an OFDM system with either PSK or MKM. To compare the PAPR for different systems, we analyze the Cumulative Distribution Function (CDF) of the PAPR given by

$$P(\mathrm{PAPR} \leq z) = \mathrm{CDF}(z) \qquad (4)$$

When comparing the PAPR for a given modulation order, SC-OFDM with MKM always results in a lower PAPR relative to the corresponding OFDM system using either PSK or MKM.

3. 1. 2 Intercarrier Interference

Inter carrier Interference is the type of Interference occurring in the transmitted OFDM symbols due to the overlapping of one carrier with another causing a serious degradation in the transmitted signal. To reduce this problem various techniques have been employed namely introducing the cyclic prefix i.e. guard interval in order to differentiate one carrier from another. However, it causes some other problems like reduction in spectral efficiency. Hence, various ICI cancellation methods have been adopted from the earlier stages.

InterCarrierInterference Cancellation Techniques

ICI self cancellation schemes used polynomial coding, windowing technique, data conjugate method. However, these schemes mitigate ICI at the cost of reduced data rate. Hence, considerable effort has been spent to improve ICI cancellation performance by estimating both the integer and fractional CFO components. These existing CFO estimation schemes can be classified as either data aided or blind estimators. While data aided estimators provide better estimation performance, they also reduce the effective data rate. Hence, the blind estimators have received a lot of attention due to system power and high bandwidth efficiencies. The blind estimator utilizes an estimation algorithm based on maximum likelihood criteria to estimate the CFO. However, existing blind CFO estimators has inherent drawbacks and efficient performance requires: 1) a constant modulus (CM) constellation, 2) a large number of OFDM blocks, and/or 3)knowledge of the channel order. To address these drawbacks, we propose a high accuracy blind CFO estimator for OFDM systems. It is made possible with the combined Single Carrier OFDM with the Magnitude Keyed Modulation technique in which the Inter Carrier Interference has been reduced drastically.

ICI Coefficient Analysis

To provide an initial understanding, how the ICI coefficient impacts system performance, we first focus our attention on an AWGN channel. In this case, the channel gain fading matrix **H** becomes an identity matrix **I**. For the analysis we must determine the ICI power. This can be done using the Carrier to-Interference Power Ratio (CIR), defined as:

$$\mathrm{CIR} = \frac{\text{Desired Signal Power}}{\text{ICI power}} \qquad (5)$$

However, when there is no ICI present, e.g., ε→0, the CIR approaches infinity. As an alternative approach, the ICI power can be estimated using the Interference-to-Carrier Power Ratio (ICR), defined as:

$$\mathrm{ICR} = \frac{1}{\mathrm{CIR}} = \frac{\text{ICI power}}{\text{Desired Signal Power}} \qquad (6)$$

The expression in (11) implies that the ICR becomes smaller as the desired signal power to ICI power ratio increases. It is evident that ICR is system dependent. It is evident that ICR of SC-OFDM is zero for all values, meaning the desired signal component is unaffected by ICI. Given the CIR of SC-OFDM is much lower than that of the OFDM system. It is noted that the ICI effect on SC-OFDM data symbols is simply a (different) phase offset on each and every data symbol.

III. SIMULATION RESULTS

Table. 1 Simulation Parameters used in OFDM and SC-OFDM

Parameters	**Details**
Tool	MATLAB 7
Subcarriers	64
Bandwidth	1 MHz
Modulation techniques	BPSK, MKM
Channel used	AWGN, Rayleigh
Subcarrier spacing	1 KHz
Guard time	800ns
Single frame size	96 bits

Fig. 1. Shows that the BER performance of normal OFDM. The SNR is 14 dB for 10^{-3} BER.

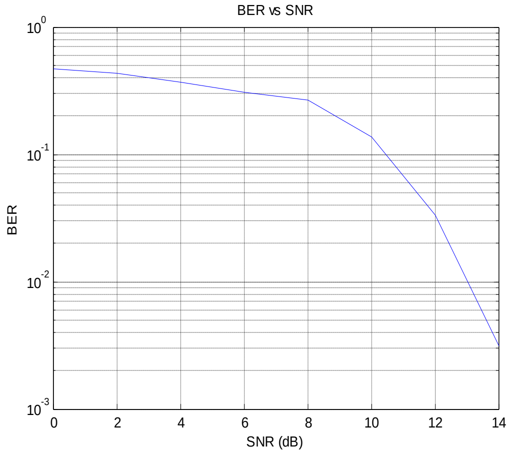

Fig. 1. BER performance of OFDM

Fig. 2. Shows the peak power problem of general OFDM scheme. The peak power alters the Q point of transistor and decreases the overall system performance.

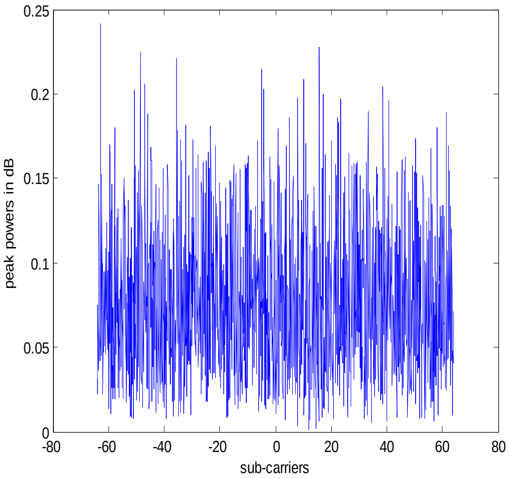

Fig. 2. Peak powers in OFDM

The Peak power problems in the conventional system are reduced by using MKM –SC OFDM technique is shown in Fig. 3. In this, the original sequences are affected by high peak sequences for 120 subcarrier is controlled by MKM SC OFDM is described.

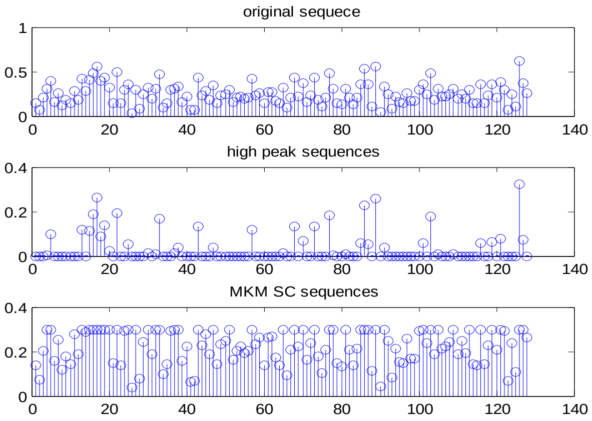

Fig. 3. Peak power reduction using single carrier MKM OFDM.

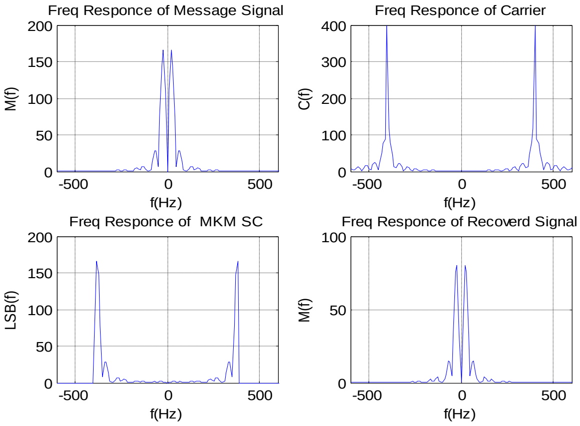

Fig. 4. Frequency spectrum of single carrier MKM OFDM

The frequency spectrum of message signals and the carrier signal of single carrier MKM OFDM is shown in Fig. 4.

Performance comparison of various PAPR reduction methods

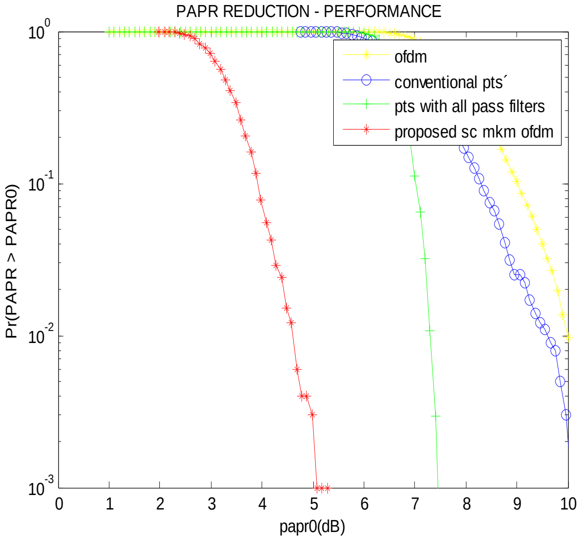

Fig. 5 PAPR reduction performance for various methods

The PAPR reduction performance of different PAPR reduction techniques are shown in Fig. 5. The proposed single carrier magnitude keying modulation OFDM method gives better performance than compared to the other techniques..

BER performance of MKM Modulation using SC-OFDM

Comparing the previous methods of Modulation, the proposed technique of Magnitude Keyed Modulation gives better Bit Error Rate performance as shown from Fig. 6 and Fig.7.The result of proposed method outperforms the existing modulation techniques.

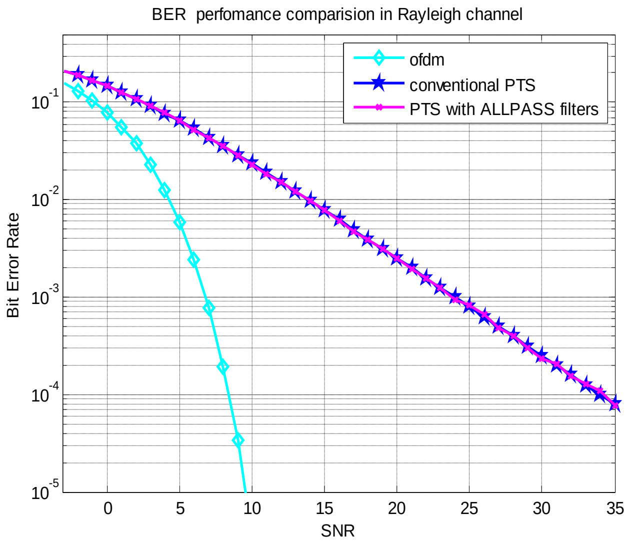

Fig. 6. BER performance for conventional methods

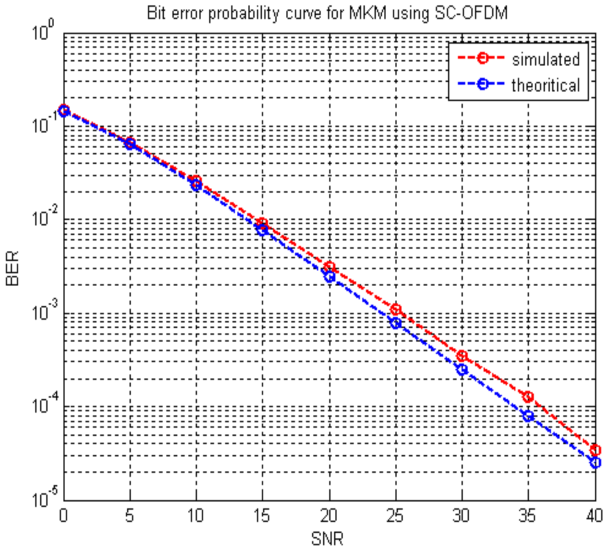

Fig. 7. BER performance of MKM with SC-OFDM.

Performance Comparison

Table. 2. Performance Comparison of Various PAPR reduction techniques.

TECHNIQUES	PAPR
Conventional OFDM	**12 dB for 10^{-3} ccdf**
Conventional PTS	**10.1 dB for 10^{-3} ccdf**
PTS with all-pass filters	**7.5 dB for 10^{-3} ccdf**

Proposed SC MKM OFDM	**5.1 dB for 10^{-3} ccdf**
BER - OFDM **Conventional PAPR method**	**14 dB for > 10^{-3} SNR** **35 dB for > 10^{-4} SNR**
BER Performance proposed SC –MKM OFDM	**40 dB for > 10^{-4} SNR**

IV. CONCLUSION

Thus the proposed technique called as the Single carrier using Magnitude Keyed modulation OFDM technique provides an excellent Bit error rate performance, reduced Peak to average power ratio and reduced Intercarrier Interference. Hence this proposed method improves the OFDM performance and removes the degradation in the highly mobility environments thereby, paving for an effective wireless communication.

REFERENCES

[1] S. Hara and R. Prasad, Multicarrier Techniques for 4G Mobile Communications, 1st edition. Artech House, 2003.

[2] W. M. Jang, L. Nguyen, and P. Bidarkar, “MAI and ICI of synchronous downlink MC- CDMA with frequency offset,” IEEE Transaction. On Wireless Communication. vol. 5, pp. 693–703, Mar. 2006.

[3] T. R. Wang, J. G. Proakis, E. Masry, and J. R. Zeidler, “Performance degradation of OFDM systems due to Doppler spreading,” IEEE Transaction on. Wireless Communication. vol. 5, pp. 1422–1432, June 2006.

[4] Y. Zhao and S.G. Haggman, “Intercarrier interference self-cancellation scheme for OFDM mobile communication systems,” IEEE Transaction on. Communication. vol. 49, pp. 1185–1191, July 2001.

[5] A. Seyedi and G. Saulnier, “General ICI self-cancellation scheme for OFDM systems,” IEEE Transaction on. Vehicular. Technology. vol. 54, pp. 198–210, Jan.2005.

[6] H.-G. Ryu, Y. Li, and J.-S. Park, “An improved ICI reduction method in OFDM communication system,” IEEE Transaction on. Broadcasting, vol. 51, pp. 395–400, Sept. 2005.

[7] Z. Jianhua, H. Rohling, and Z. Ping, “Analysis of ICI cancellation scheme in OFDM systems with phase noise,” IEEE Transaction on. Broadcasting, vol. 50, pp. 97–106, June 2004.

[8] A. J. Coulson, “Maximum likelihood synchronization for OFDM using a pilot symbol: analysis,” IEEE J. Sel. Areas Communication., vol. 19, pp. 2495– 2503, Dec. 2001

[9] M. Morelli and U. Mengali, “An improved frequency offset estimator for OFDM applications,” IEEE Communication. Letters. vol. 3, pp. 75–77, Mar. 1999.

[10] D. Falconer, S. L. Ariyavisitakul, A. Benyamin-Seeyar, and B. Eidson, “Frequency domain equalization for single-carrier broadband wireless systems,” IEEE Communication. Mag., vol. 40, pp. 58–66, Apr. 2002.

[11] N. Benvenuto and S. Tomasin, “On the comparison between OFDM and single carrier modulation with a DFE using a frequency-domain feed forward filter,” IEEE Transaction on. Communication. vol. 50, pp. 947–955, June 2002.

[12] D. A. Wiegandt, Z. Wu, and C. R. Nassar, “High-throughput, high performance OFDM via pseudo-orthogonal carrier Interferometry spreading codes,” IEEE Transaction on. Communication. vol. 51, pp. 1123–1134, July 2003.

[13] F. Yang, K. H. Li, and K. C. Teh, “A carrier frequency offset estimator with minimum output variance for OFDM systems,” IEEE Communication. Letters. vol. 8, pp. 677–679, Nov. 2004.

[14] X. N. Zeng and A. Ghrayeb, “A blind carrier frequency offset estimation scheme for OFDM systems with constant modulus signaling,” IEEE Transaction on. Communication. vol. 56, pp. 1032–1037, July 2008.

[15] Y. Yao and G. B. Giannakos, “Blind carrier frequency offset estimation in SISO, MIMO, and multiuser OFDM systems,” IEEE Transaction on. Communication. vol. 53, pp. 173–183, Jan. 2005.