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To Study and Design of Sc-Ofdm System using Mkm for Ici Immune High Speed Wireless Communication

KEYWORDS Intercarrier interference, single carrier OFDM, Magnitude keyed modulation.

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ABSTRACT *Orthogonal Frequency Division Multiplexing (OFDM) has been considered as a strong candidate for next generation wireless communication systems. Compared to traditional OFDM, Single Carrier OFDM (SC-OFDM) has demonstrated excellent bit error rate (BER) performance, as well as low peak to average power ratio (PAPR). Similar to other multi-carrier transmission technologies, SC-OFDM suffers significant performance degradation resulting from intercarrier interference (ICI) in high mobility environments. Existing techniques for OFDM can be directly adopted in SC-OFDM to improve performance, however, this improved performance comes at costs such as decreased throughput. In this paper, we analyze the effect of ICI on an SC-OFDM system and propose a novel modulation scheme. The proposed Magnitude- Keyed Modulation (MKM) modulation provides SC-OFDM system immunity to ICI and with an easy implementation it significantly outperforms OFDM, SC-OFDM and MC-CDMA systems with Phase Shift Keying (PSK) modulation and Quadrature Amplitude Modulation (QAM) in severe ICI environment. Analysis also illustrates the proposed SC-OFDM system with MKM modulation maintains low PAPR compared to traditional OFDM and SC-OFDM systems with PSK and QAM modulations. Simulation results for different modulation schemes in various ICI environments confirm the effectiveness of the proposed system.*

I. INTRODUCTION

ORTHOGONAL Frequency Division Multiplexing (OFDM) and other multi-carrier transmissiontechnologies such as Multi-Carrier Code Division Multiple Access (MC-CDMA) have been considered strong candidates for next generation high-data-rate wireless communication systems because of their good BER performance and high spectrum efficiency [1]. It is highly desired to adopt multi-carrier transmission in aerial vehicle communication to improve the spectrum efficiency. In multi-carrier transmission technology such as OFDM, it is crucial to maintain orthogonality among all the subcarriers. Otherwise, intercarrier interference (ICI) will occur and lead to significant performance degradation. On the other hand, the Single Carrier Orthogonal Frequency Division Multiplexing (SC-OFDM) [14] technique has received a lot of attention as an alternative transmission technique to the conventional OFDM due to its better performance in multipath fading channels and lower peak to average power ratio (PAPR). In this paper We propose a novel modulation scheme called Magnitude-Keyed Modulation (MKM) for SC-OFDM. As the name suggests, this new modulation scheme carries digital data only on the signal magnitude. Hence, MKM provides SC-OFDM with immunity to ICI, i.e., the BER performance of an SC-OFDM system with MKM does not depend on the ICI. Given the MKM is a noncoherent modulation scheme, the proposed SC-OFDM with MKM modulation performs slightly worse than SC-OFDM (or OFDM or MC-CDMA) with PSK (or QAM) modulation when there is no ICI. However, the performance of SC-OFDM (or OFDM or MC-CDMA) with PSK (or QAM) modulation has obvious degradation in severe ICI environment or with high modulation schemes, and the new system significantly outperforms them.

II. SYSTEM MODEL

A. OFDM System

In the OFDM transmitter, after a constellation mapping for the appropriate modulation, (QAM, PSK, etc.), data symbols are converted from serial to parallel. Assuming there are *N* subcarriers in the OFDM system, each OFDM block contains a set of *N* symbols (x0, x1, ..., x_{N-1}), assigned to *N* subcarriers using an *N*-point IFFT.

Accounting for all *N* symbols, the composite complex OFDM signal is given by

$$S(t)=\sum_{k=0}^{N-1} x_k\, e^{j2pik\Delta ft}\, e^{j2\pi fct}\, p(t) \qquad (1)$$

where x_k is the k^{th} data symbol; Δf is the spacing between subcarriers; and *p*(*t*) is a rectangular pulse shape with time limit spanning one OFDM symbol, $0 \le t \le T$. To ensure orthogonality among subcarriers, we have $\Delta f = 1/T = 1/NT_b$ where T_b is the data symbol period.

the received OFDM signal

$$r(t)= \sum_{k=0}^{N-1} \alpha_k\, x_k\, e^{j2pi(k+\varepsilon)\Delta f(t+\Delta t)}\, e^{j2\pi fc(t+\Delta t)} p(t+\Delta t)+n(t) \qquad (2)$$

where *n*(*t*) is additive white Gaussian noise (AWGN), α_k is the complex fading gain on the k^{th} subcarrier, Δt represents the time delay and f_0 is the CFO. Here we denote the normalized carrier frequency offset (NCFO) as $\alpha = f_0 / \Delta f$

The OFDM demodulator detects each symbol by decomposing *r*(*t*) in (2) onto *N* orthogonal subcarriers (via application of an FFT), where perfect timing estimation is assumed.

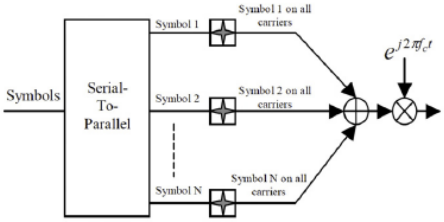
Now denoting $x = \{x_0, x_1, \ldots, x_{N-1}\}$ as the transmitted symbol vector, $y = \{y_0, y_1, \ldots, y_{N-1}\}$ as the received signal vector,

$n = \{n_0, n_1, \ldots, n_{N-1}\}$ as the noise vector, and $H = diag\{\alpha_0, \alpha_1, \ldots, \alpha_{N-1}\}$ as the channel fading gain matrix, we have

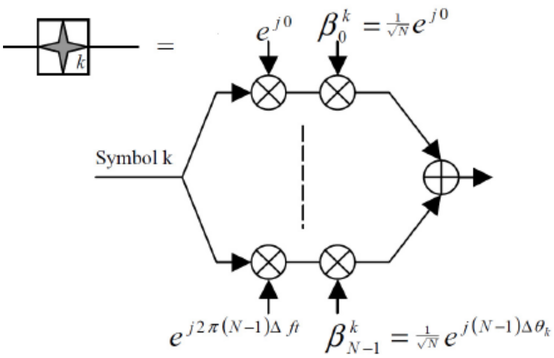
$$y = xHS + n, \qquad (3)$$

where S is the ICI coefficient matrix having dimension $N \times N$ with p^{th}-row and q^{th}-column elements given by $S_{p,q} = S(p-q)$. The resultant matrix form of S is:

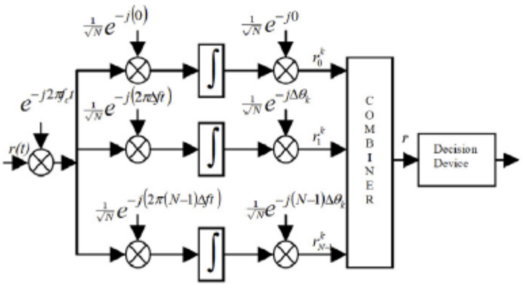
$$\mathbf{S} = \begin{bmatrix} S(0) & S(-1) & \ldots & S(1-N) \\ S(1) & S(0) & \ldots & S(2-N) \\ \vdots & \vdots & \ddots & \vdots \\ S(N-1) & S(N-2) & \cdots & S(0) \end{bmatrix}$$



Fig(a): SC-OFDM Spread Symbol Combining



Fig(b): SC-OFDM Symbol Spectral Spreading



Fig(c): SC-OFDM receiver.

B. Single Carrier OFDM System

Conceptual representations of the SC-OFDM transmitter and receiver are shown in Fig. 1 and Fig. 2 [20], respectively. Compared to a conventional OFDM system, the SC-OFDM system distributes each parallel data set to all sub-carriers using different phase-rotated spectral spreading on each symbol [14], as illustrated in Fig. 1(b). The spreading code set corresponds to the normalized DFT matrix with the k^{th} data symbol being spread to the i^{th} sub-carrier employing spreading

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

Accounting for β^{ι}_{κ}

and a block of N total data symbols, the transmitted SC-OFDM symbol corresponds to

S(t)= 1/

The SC-OFDM system can be easily implemented using an MC-CDMA framework by making appropriate changes to the spreading code. Specifically, SC-OFDM system can be

implemented as a fully loaded MC-CDMA system with new spreading code β^{i}_{k} , for example, transmitting N symbols using N subcarriers can be implemented as an MC-CDMA system with N users (each symbol can be viewed as an user in MC CDMA system) using spreading code $\beta k\ i$. 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.The received SC-OFDM signal $r(t)$ for the transmitted signal in (9) is given by

$$\mathrm{r(t)=} \quad 1/ \quad \sqrt{N}$$
$$\sum_{i=0}^{N-1} \alpha\, i \sum_{k=0}^{N-1} x_k\ e^{-\frac{j2\pi}{N}ik}\ e^{j2\pi(i+\varepsilon)k\Delta f(t+\Delta t)} e^{j2\pi fc(}$$
$$\Delta t) + n(t)$$

At the SC-OFDM receiver shown in Fig. 2, the SC-OFDM demodulator detects the *kth* 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)

IV. ICI COEFFICIENT ANALYSIS

To provide an initial understanding how the ICI coefficient impacts system performance, we first focus our attention 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 Carrierto- Interference Power Ratio (CIR), defined as [4], [31]:

CIR =Desired Signal Power/ICI Power

However, when there is no ICI present, e.g., ε → 0, the CIR approaches infinity which cannot be shown in a figure. As an alternative approach, the ICI power can be estimated using the Interference-to-Carrier Power Ratio (ICR), defined as:

$ICR = CIR^{-1}$

ICR becomes smaller as the desired signal power to ICI power ratio increases. It is evident that ICR is system dependent and thus critical for us to consider several possible cases.

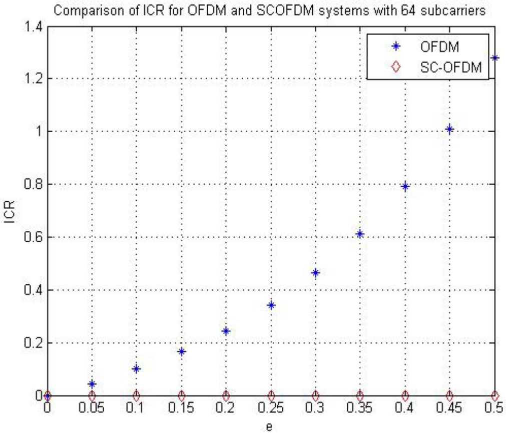


Fig. 4. ICR comparison for OFDM and SC-OFDM systems using *N* = 16 subcarriers with ICI present.

Results in Fig. 4 show ICR versus ε for OFDM and SCOFDM systems using *N* = 16 subcarriers over an AWGN channel with ICI present. It is evident that ICR of SC-OFDM is zero for all ε values, meaning the desired signal component

used for data estimation is unaffected by ICI.

A.Analysis of SC-OFDM Performance with ICI Present

Due to the perfect ICR performance of the SC-OFDM system, we next consider its performance with ICI present. Using the ICI coefficient matrix in (26) with **H** = **I** for the

AWGN channel, we revisit the expression in (16) and rewrite the received SC-OFDM signal vector as

$$\mathbf{Y=yFSF^H +nF^H =xFF^H \psi FF^H + nF^H} ,$$

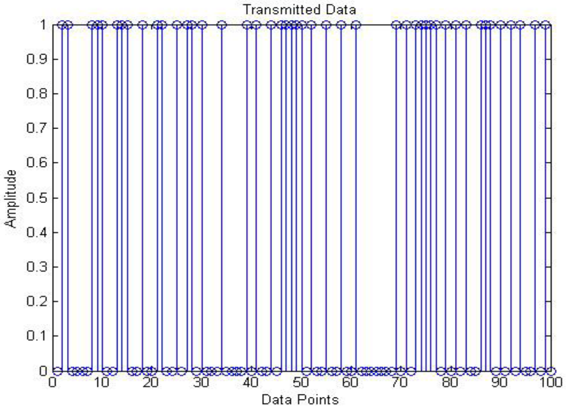
Recalling that $|\psi k| = 1$ for all *k*, it is noted that the ICI effect on SC-OFDM data symbols _x is simply a (different) phase offset on each and every data symbol x_k. Compared with an OFDM system under similar ICI conditions, SC-OFDM

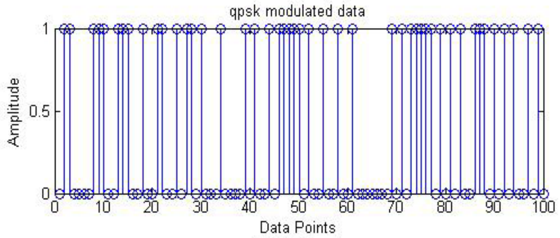
provides significantly better performance. This is due to the received OFDM signal vectors in (27) being a combination of subcarrier data symbols and shifted responses thereof, while the subcarrier data symbols in the SC-OFDM signal vector given by (28) only experience a phase offset–this is why we observe zero ICR for all ε and realize the benefit of SCOFDM.

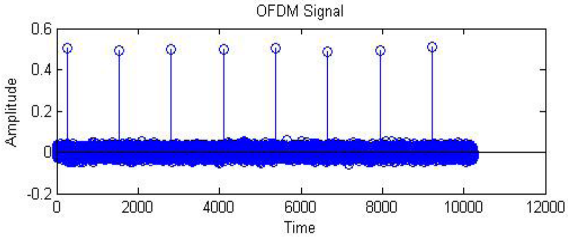
B.MKM FOR SC-OFDM SYSTEMS

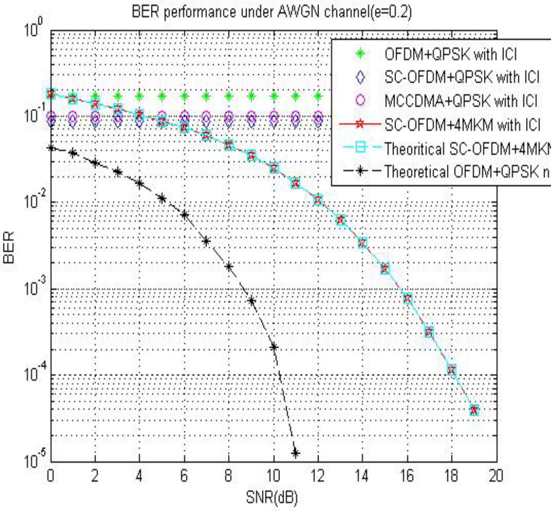
After observing the ICI coefficient property, we find that $\mathbf{FSF^H}$ is a diagonal matrix with each diagonal element having unit magnitude. Hence, the ICI has no effect on the magnitude of each and every SC-OFDM data symbol. Therefore, when there is no noise present (29) shows that $|r_k| = |x_k|$ independent of ε. To fully exploit the inherent ICI immunity in SCOFDM, we introduce a novel digital modulation scheme called Magnitude Keyed Modulation (MKM). Specifically, we will only use the magnitude to carry digital symbols. For example, binary MKM (2MKM) is equivalent to binary On-Off Keying (OOK). Note that MKM is different than Amplitude Shift Keying (ASK) using antipodal signal pairs given that MKM is a non-coherent modulation scheme and doesn't require phase

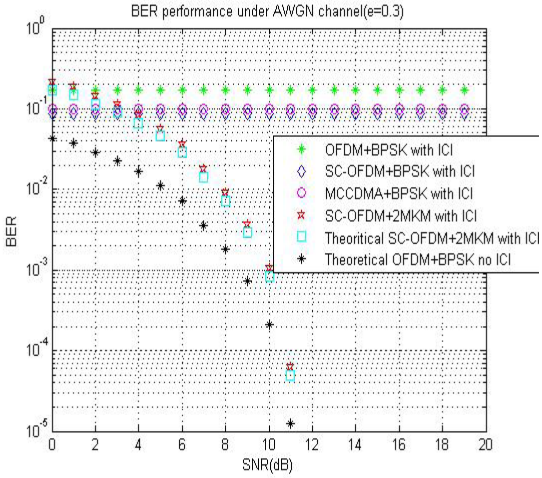
RESULTS











CONCLUSION

In this paper, we analyze the effect of ICI on an SCOFDM receiver and propose a novel modulation scheme called Magnitude-Keyed Modulation (MKM) for use with an SCOFDM system. Taking advantage of unique ICI coefficient matrix properties, we showed that the ICI effect on a received SC-OFDM signal is simply a phase offset on each and every data symbol, while the magnitude of the data symbol is unaffected. Hence, by transmitting digital information only on the SC-OFDM signal magnitude, the authors develop a novel modulation scheme called MKM and apply it to an SCOFDM system. The resultant SC-OFDM system with MKM modulation experiences a boost in ICI immunity and significantly outperforms traditional OFDM, SC-OFDM and MCCDMA systems using Phase Shift Keying (PSK) modulation and Quadrature amplitude modulation (QAM) in severe ICI environments. Simulation results are presented for SC-OFDM with binary, 4-ary, and 8-ary MKM modulations and the performance of each configuration compared with traditional OFDM/SC-OFDM/MC-CDMA using PSK/QAM modulation. Results for both AWGN and multipath fading channels clearly demonstrate that SC-OFDM with MKM is superior–much less BER degradation is observed as normalized carrier frequency offset and normalized Doppler spread increase.

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