Modified Conjugate Cancellation Algorithm Forofdm Systems

Mohamed Tayebi[1], Merahi Bouziani[2]
[1]Telecommunications And Signal Processing Lab, Djillaliliabès University, Sidibelabbès, Algeria

Abstract:
The Inter-Carrier Interference Created By The Carrier Frequency Offset Significantly Degrades The Performances Of The Orthogonal Frequency Division Multiplexing Signal. If These Offsets Are Random, Then The Performances Fluctuate With This Shift. In This Letter, We Give Various Reasons For The CFO And Propose A New Technique To Inhibit The Effect Of ICI And Achieve Performance Almost Independent Of Carrier Frequency Offset. This New Technique Is A Variant Of The Method Of Combined Data Using The Conjugate Cancellation Algorithm. When Compared To Other Techniques, It Offers Better Performance In Terms Of Stability And Consistency.

Keywords: Carrier Frequency Offset (CFO), Carrier To Interferences Ratio (CIR), Doppler-Effect, Inter Carriers Interferences (ICI), Orthogonal Frequency Division Multiplexing **(**OFDM).

1. Introduction

The Orthogonal Frequency Division Multiplexing (OFDM), For Its Simplicity Of Implementation Using The Pair FFT/IFFT And Its Innumerable Benefits Such Its High Spectral Efficiency And Robustness Against The Effects Of Multipath Enabled Modern Telecommunications Systems Go A Significant Step Forward And Have Access To New Perspectives [1]. It Has Found Its Place In A Variety Of Broadcast Standards Such As Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB) And In Optical Applications [2]. However, Its Main Drawback Is Its Sensitivity To Carrier Frequency Offset (CFO). This Is Mainly Due To Imperfections Of Local Oscillators And The Doppler-Effect Present In Radio Mobile Channels [3]. The CFO Gives Rise To Inter-Carrier Interference (ICI) That Degrades System Performances [4]-[8]. For A Given Link, The Offset Due To Imperfections Of Local Oscillators Is Constant Where The Doppler-Effect Generates Variable And Random Shifts, Which Not Only Degrade Performances, But Also Let Them, Fluctuate To The Rhythm Of The Doppler-Effect. A Number Of Methods Have Been Proposed To Reduce The Interference, But None Was Interested In The Stability Of Performance. Among The Methods That Do Not Require A Channel Estimation, We Cite The Technique Of ICI Self-Cancellation [9]-[10], The Symmetric Symbol Repetition Scheme (SSR) [7] And The Conjugate Cancellation (CC) [11]. In This Letter, We Propose A New Method Inspired By The Conjugate Cancellation Algorithm [11]. The Results Show Stable Performances Furthermore Being Practically Independent Of The CFO. This Is A Major Advantage In Highly Variable Channel As The Radio Mobile-Channel.

2. Ofdm With Carrier Frequency Offset (Cfo)

In Transmission Using OFDM, Frequency Offset Effects Are Mainly Due To The Imperfections Of Local Oscillators And The Doppler-Effect. The Normalized Values Are Respectively Denoted By ε_o, And ε_d Where:

$$\varepsilon_o = T\Delta f \qquad (1)$$

And

$$\varepsilon_d = T f_p \frac{v}{c} cos\alpha \qquad (2)$$

Where Δf represents The Frequencydifferencebetween The Transmitter And The Receiver, T Is The Symbol Duration, v The Relative Velocity Between The Transmitter And Receiver, f_p The Carrier Frequency, c The Speed Of Light And α The Angle Formed By The Direction Of The Wave And The Velocity Vector. The Influence Of The Doppler-Effect Depends On Several Factors, All May To Vary. What Makes It A Real Problem With Uniformity And Consistency Of Performance When It Varies In Large Proportion.In OFDM Transmission Characterized By A Carrier Frequency Offset, We Denote By $X(k)$ The Transmitted Symbols And Which Is Denoted By $x(n)$, The IFFT Of $X(k)$, It Will Be Expressed By :

$$x(n) = \sum_{k=0}^{N-1} X(k)\,\mathrm{Exp}\left(j2\pi \frac{nk}{N}\right) \qquad (3)$$

The Channel Is Affected By A Carrier Frequency Offset; The Received Signal Is Then Equal To:

$$y(n) = \text{Exp}\left(j2\pi\frac{n\varepsilon}{N}\right)\sum_{k=0}^{N-1} X(k)\,\text{Exp}\left(j2\pi\frac{nk}{N}\right)(4)$$

To Recover The Signal, We Apply An FFT To The Signal. The Resulting Signal Is Equal To:

$$Y(k) = \frac{1}{N}\sum_{n=0}^{N-1} y(n)\,\text{Exp}\left(-j2\pi\frac{nk}{N}\right)(5)$$

After Some Manipulations, The Signal Can Be Written [10]:

$$Y(k) = X(k)S(0) + \sum_{\substack{l=0\\ l\neq k}}^{N-1} X(k)S(l-k)(6)$$

Where:

$$S(l-k) = \frac{sin\pi(l-k+\varepsilon)}{Nsin\frac{\pi}{N}(l-k+\varepsilon)}\,exp\,j\pi\left(1-\frac{1}{N}\right)(l-k+\varepsilon)(7)$$

If The Transmitted Signal Is The Instead Of Emitting$x(n)$, We Transmit Its Conjugate:

$$x^*(n) = \left(\sum_{k=0}^{N-1} X(k)\,\text{Exp}\left(j2\pi\frac{nk}{N}\right)\right)^* = \sum_{k=0}^{N-1} X^*(k)\,\text{Exp}\left(-j2\pi\frac{nk}{N}\right)(8)$$

Then, The Received Signal Is Written:

$$y(n) = \text{Exp}\left(j2\pi\frac{n\varepsilon}{N}\right)\sum_{k=0}^{N-1} X^*(k)\,\text{Exp}\left(-j2\pi\frac{nk}{N}\right)(9)$$

Its Conjugate Is Then Equal To:

$$y^*(n) = \text{Exp}\left(-j2\pi\frac{n\varepsilon}{N}\right)\sum_{k=0}^{N-1} X(k)\,\text{Exp}\left(j2\pi\frac{nk}{N}\right)(10)$$

To Recover The Signal, We Apply To A Signal An FFT, The Resulting Signal Is Then Equal To [11]:

$$Y(k) = X(k)S'(0) + \sum_{\substack{l=0\\ l\neq k}}^{N-1} X(k)S'(l-k)(11)$$

Where:

$$S'(l-k) = \frac{sin\pi(l-k-\varepsilon)}{Nsin\frac{\pi}{N}(l-k-\varepsilon)}\,exp\,j\pi\left(1-\frac{1}{N}\right)(l-k-\varepsilon)(12)$$

3. Modified Conjugate Cancellationalgorithm

In Our Proposed Algorithm, We Reconsider The Idea Of Conjugate Cancellation [11], But With A Different Combination, The CIR Obtained Will Be:

$$CIR = \frac{|S(0)-S'(0)|^2}{\sum_{l=1}^{N-1}|S(l)-S'(l)|^2} \qquad (13)$$

Figure 1 Plots The Variations Of The CIR For The Proposed Method And Standard OFDM. Note That The Modified Conjugate Cancellation Algorithm Provides An Improvement Over The Standard OFDM Beyond $\varepsilon = 0.15$. Comparing The Proposed Algorithm To The Existing Ones, We Can Clearly Notice That For The Range $0.01 \leq \varepsilon \leq 0.5$, The CIR Degradation Is About 35 Db For The Standard OFDM, Which In Terms Of Performance Shows That It Is Very Sensitive To The Carrier Frequency Offset, While For The Proposed Method, For The Same Range Of CFO, The Degradation Is Only 2 Db. Furthermore, It Maintains An Average

Value Of The CIR Equal To 10 Db. In An Environment, Where The CFO Is Strongly Variable, The Proposed Algorithm Is Clearly More Appropriate.

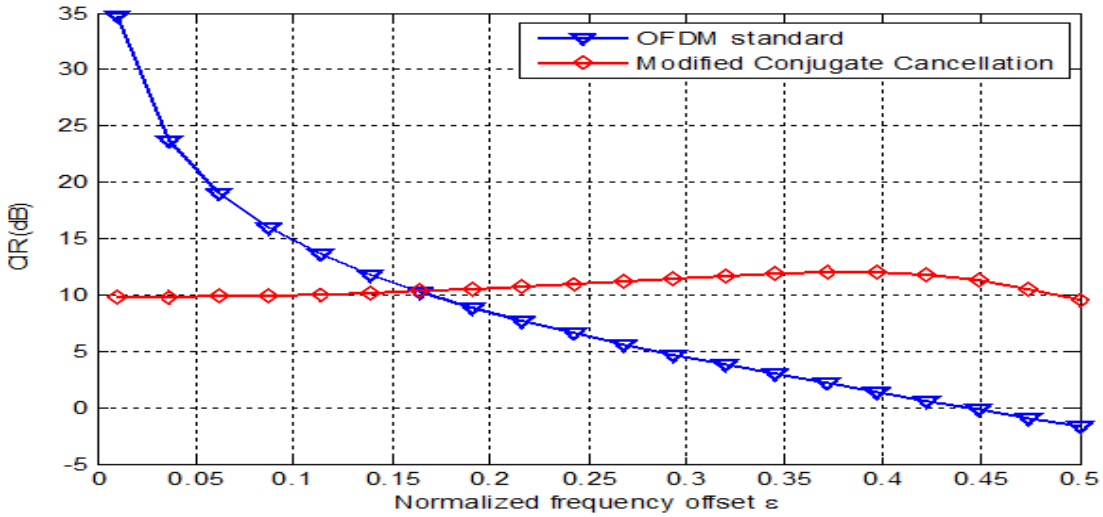

Figure 1: Comparison Of OFDM CIR And CIR With Modified Conjugate Cancellation

4. Conclusion

In This Paper, We Studied The OFDM In A Radio Mobile Channel. We Cited Several Methods To Reduce Inter-Carrier Interference (ICI) Created By The Carrier Frequency Offset (CFO). Compared To Existing Methods, The Proposed Method Has The Advantage Of Being Very Weakly Dependent On The Carrier Frequency Offset, Which Makes It Is Feasible And Attractive Solution For Links To Great Variation In CFO Due To Doppler-Effect.

References

[1] S. Weinstein And P. Ebert, "Data Transmission By Frequency-Division Multiplexing Using The Discrete Fourier Transform," IEEE Trans. Commun, Vol. 19, Pp. 628-634, Oct. 1971.

[2] J.Armstrong,"OFDM For Optical Communications", Journal Of Lightwavetechnology,Vol.27,N°.3,February 1,2009.

[3] M. Russell And G. L. S. Stüber, "Interchannel Interference Analysis Of OFDM In A Mobile Environment," In Proc. VTC'95, Chicago, IL, July 1995, Pp. 820–824.

[4] J. Armstrong, "Analysis Of New And Existing Methods Of Intercarrier Interference Due To Carrier Frequency Offset In OFDM', IEEE Trans. Commun**.,** Vol 47, No.3, Pp. 365-369, Mar. 1999.

[5] K. Sathananthan And C. Tellambura, "Performance Analysis Of An OFDM System With Carrier Frequency Offset And Phase Noise," IEEE Vehicular Technology Conference, VTC 2001 Fall, Atlantic City, NJ, USA, Vol. 4, Pp. 2329-2332, Oct. 7-11, 2001.

[6] K. Sathananthan And C. Tellambura, "Probability Of Error Calculation Of OFDM Systems With Frequency Offset," IEEE Trans. Commun., Vol. 49, No. 11, Pp. 1884-1888, Nov. 2001.

[7] K. Sathananthan, R. M. A. P. Rajatheva, And S. B. Slimane, "Analysis Of OFDM In The Presence Of Frequency Offset And A Method To Reduce Performance Degradation," In Proc. IEEE Globecom, Vol. 1, San Francisco, CA, Nov. 2000, Pp. 72–76.

[8] J. Lee, H. Lou, D. Toumpakaris, And J. Cioffi, "SNR Analysis Of OFDM Systems In The Presence Of Carrier Frequency Offset For Fading Channels" IEEE Transactions On Wireless Communications, Vol. 5, N°. 12, December 2006

[9] Y. Zhao And S.-G.Häggman, "Sensitivity To Doppler Shift And Carrier Frequency Errors In OFDM Systems—The Consequences And Solutions," In Proc. IEEE 46th Vehicular Technology Conf., Atlanta, GA, Apr. 28–May 1, 1996, Pp. 1564–1568.

[10] Y. Zhao And S.-G.Haggman, "Intercarrier Interference Self-Cancellation Scheme For OFDM Mobile Communication Systems," IEEE Trans. Commun., Vol. 49, Pp. 1185–1191, 2001.

[11] H.Yeh, Y. Chang, And B.Hassibi "A Scheme For Cancelling Intercarrier Interference Using Conjugate Transmission In Multicarrier Communication Systems"IEEE Transactionson Wireless Communications, Vol. 6, N°.1, January 2007