ISSN 1991- 8690 الترقيم الدولي ٨٦٩٠ - ١٩٩١
Website: http://jsci.utq.edu.iq Email:utjsci@utq.edu.iq

Simulation of MC-DS-CDMA-System Based on: Wavelet and Slantlet Transforms over Wireless Channel

Ahmed Abdel Hadi Fadhel
University of Thi Qar - College of Engineering

Abstract

In this paper two proposed schemes for improving the performance form the Bit Error Rate (BER) view point were proposed for Multicarrier-Direct-Sequence-Code Division Multiple Access (MC-DS-CDMA) system in wireless channel. The conventional MC-DS-CDMA-system is based on Fast Fourier Transform (FFT). One of the proposed systems was based on Wavelet transform (WT). The other system was based on Slantlet transform (SLT). Simulation is done in three different types of channels. Simulation results show that the two proposed systems outperform the conventional system. Also the MC-DS-CDMA-system which is based on SLT achieves the same performance with less filter lengths than the MC-DS-CDMA-system based on WT.

Introduction:

CDMA is a multiplexing technique where a number of users simultaneously and asynchronously access a channel by modulating and spread their information-bearing signals with preassigned signature sequences [1]. The enormous growth of wireless services (cellular telephones, wireless LAN's ...) during the last decade gives rise to the need for a bandwidth efficient modulation technique that can reliably transmit high data rates. As multicarrier (MC) techniques combine good bandwidth efficiency with an immunity to channel dispersion, these techniques have received considerable attention. To be able to support multiple users, the Multicarrier transmission technique can be combined with CDMA scheme. Different combinations of the multicarrier transmission technique and CDMA are investigated in the context of high-rate communication over dispersive channels. Two techniques that make use of carriers satisfying the orthogonality condition with minimum frequency separation are multicarrier CDMA (MC-CDMA) and MC-DS-CDMA In the MC-CDMA technique, the original data stream is first multiplied with the spreading sequence and then modulated on the orthogonal carriers, as the chips belonging to the same symbol are modulated on different carriers, the spreading is done in the frequency domain.

• In the MC-DS-CDMA technique, the serial to-parallel converted data stream is multiplied with the spreading sequence and then the chips belonging to the same symbol modulate the same carrier, the spreading is done in the time domain. Both MC-CDMA and MC-DS-CDMA have been considered for mobile radio communication [2-6]. The modulator for DS-CDMA is shown in Figure 1 [7].

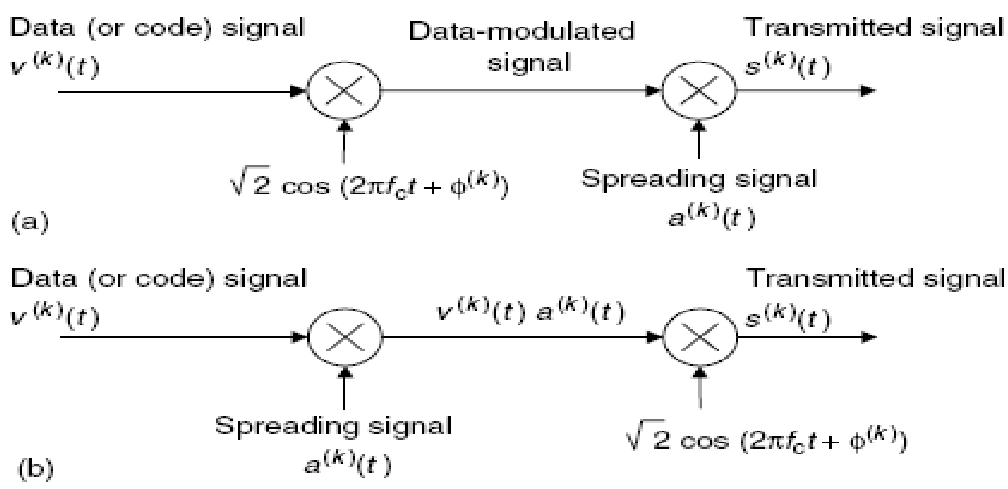


Figure 1: BPSK modulator for the k^{th} user in the DS-CDMA system.

The conventional MC system was based on FFT. The MC system that is based on FFT is called Orthogonal Frequency Division Multiplexing (OFDM). OFDM was proposed by Weinstein and Ebert [8]. Most Wireless Local Area Networks (WLAN) use the IEEE802.11b standard, IEEE802.11a and HiperLAN2 are based on OFDM technology because of its high data rate up to 54Mbps and spectral efficiency [9-11]. The block diagram for the conventional and proposed MC-DS-CDMA modulator is shown in Figure 2.

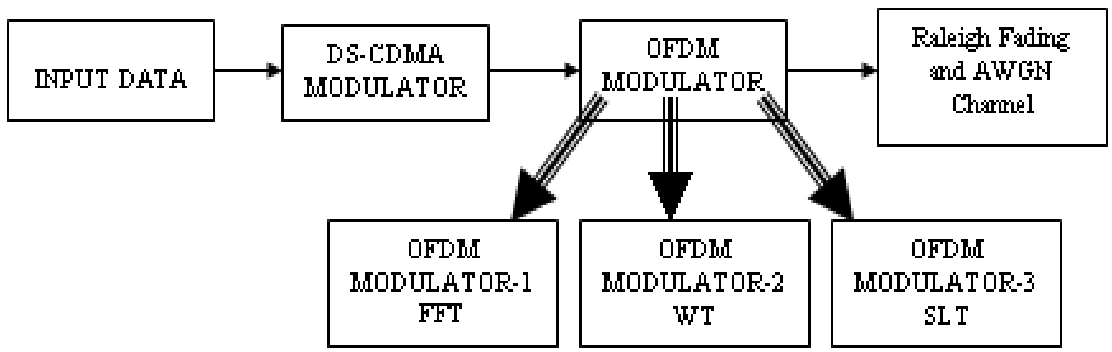


Figure 2: Conventional and proposed MC-DS-CDMA modulators.

System Description

OFDM Modulator based on WT

Modulator-2 depends on Wavelet Transform (WT). Perhaps the easiest way to understand wavelets is to begin with the familiar Fourier transform. Fourier transform techniques may be viewed as a special case of the larger class of wavelets. Consider a signal f(t). Its Fourier transform F(Ω) by definition is given by

$$F(\Omega) = \int_{-\infty}^{\infty} f(t)\ e^{-j\Omega t} dt \qquad (1)$$

$e^{-j\Omega t}$ is called the kernel, or basis of this transform. This kernel defines a set of functions $e^{-j\Omega t}$ by varying Ω. Therefore, generate a set of orthogonal basis functions, which span the frequency domain. In other words, any function f(t) can be expressed by a suitable combination of these basis functions. These basis functions are periodic functions, or waves, which extend over all time from -∞ to ∞ [12].

A system that uses Wavelet Packet-OFDM (WP-OFDM) was proposed by G.R.Hassan [13].The main difference between ordinary OFDM and WP-OFDM is in the OFDM-modulator which uses in the ordinary case (FFT-case) the sine and cosine as a basis functions while for the latter uses the Haar wavelet function as its basis function and it should be mentioned that the Haar function was chosen because of its computational simplicity. Also B.G.Negash and H.Nikookar [14] and H.Zhang, D.Yuan, M.Jiang and D.Wu [15] proposed systems using WT (or sometimes Wavelet Packet Transform (WPT) which is a little bit different from WT) instead of FFT. The terms WT, WPT, and Discrete Wavelet Transform (DWT) are used interchangeably here.

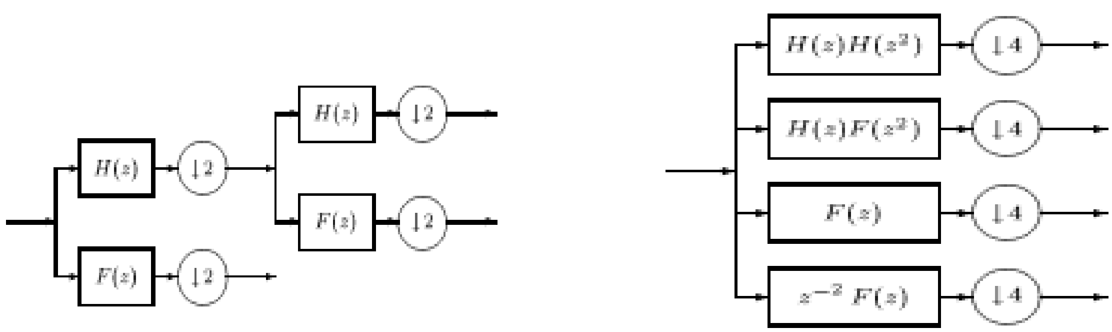
OFDM Modulator based on SLT

The DWT is usually carried out by filterbank iteration for more than one scale (level) of decomposition to obtain higher degree of resolution and therefore each scale use different filters and that leads to difficult implementation.

The Slantlet Transform (SLT) is based on filterbank structure where different filters are used for each scale. Nevertheless, a very simple efficient algorithm based on recursion is available. It is useful to consider first the usual iterated DWT filterbank and an equivalent form, which is shown in Figure 3. The Slantlet filterbank described here is based on the second structure, but it will be occupied by different filters that are not products. With the extra degrees of freedom obtained by giving up the product form, it is possible to design filters of shorter length while satisfying orthogonality and zero moment (vanishing moment) conditions.

For the two channel case, the shortest filters for which the filter is orthogonal and has K zero moments are the well-known filters described by Daubechies. For K=2 zero moments, those filters H(z) and F(z) are of length 4. For this system which is designated D_2, the iterated filters in Figure 3 are of length 10 and 4. Without the constraint that their filters are products, an orthogonal filterbank with K=2 zero moments can be obtained where the filter lengths are 8 and 4, as shown in Figure 4, side by side with the iterated D_2 system. That is a reduction by two samples, which is a difference that grows with the number of stages.

Figure 5 illustrates a three-scale filterbank tree for the DWT and, again an equivalent structure. The three-scale iterated D_2 filterbank tree analyzes signals at three scales with filters of length 4, 10 and 22, as illustrated on the left-hand side of Figure 6. On the other hand, the filterbank shown on the right-hand side of Figure 6 analyzes a signal at three scales with filters of length 4, 8, and 16 [16].



a) Two-Scale filterbank b) Equivalent structure for two-scale filterbank

Figure 3: Two-Scale filterbank and an equivalent structure [16].

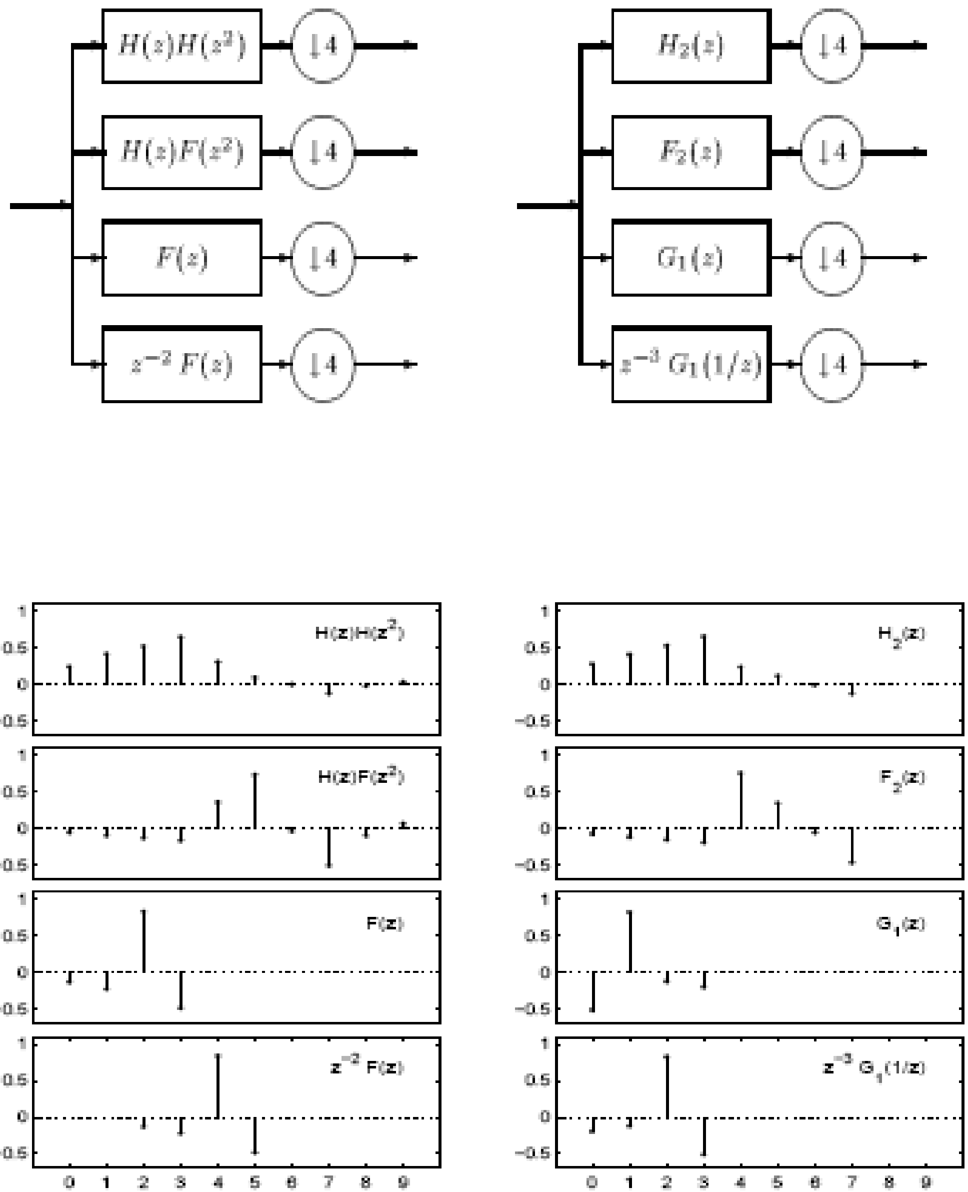
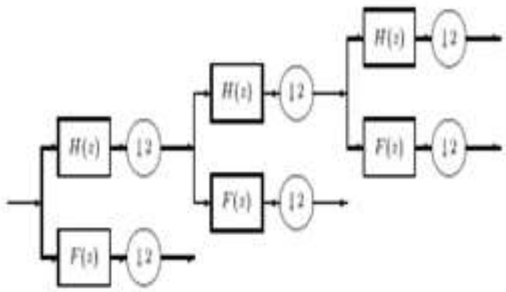
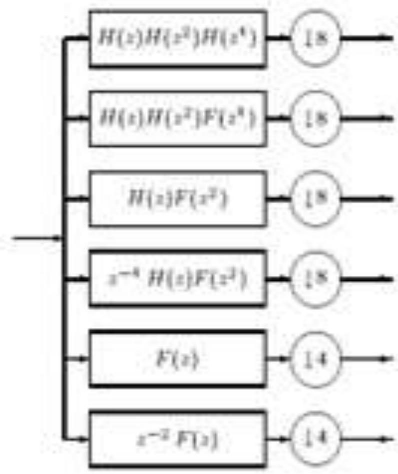


Figure 4: Comparison of two-scale iterated D_2 filterbank (left-hand side) and two-scale iterated Slantlet filterbank (right-hand side) [16].





a) Three-Scale filterbank b) Equivalent structure for three - scale filterbank

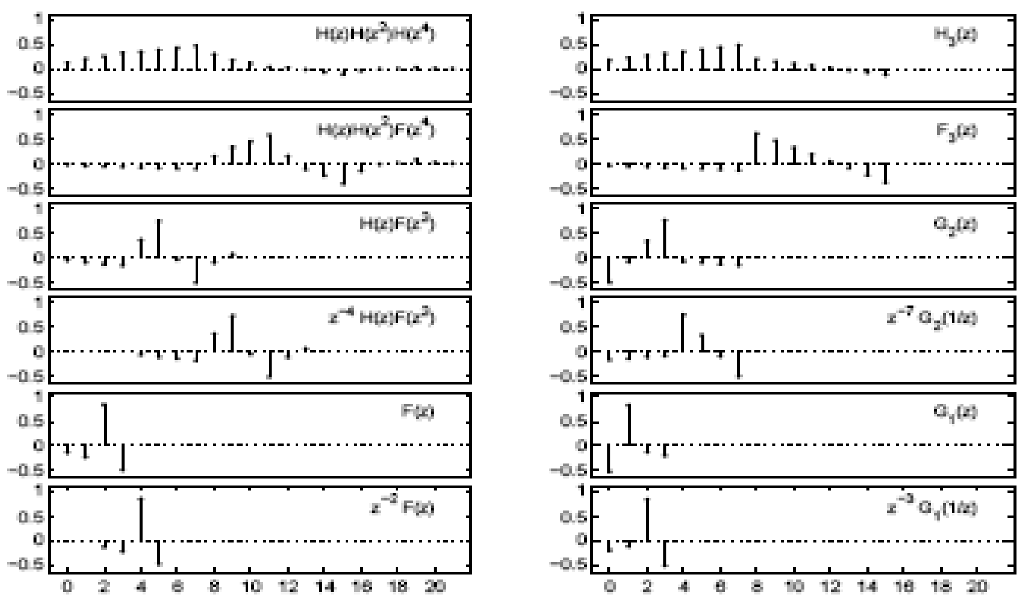


Figure 6: Comparison of three-scale iterated D_2 filterbank (left-hand side) and three-scale iterated Slantlet filterbank (right-hand side) [16].

Simulation Results

The number of subcarriers is equal to the number of FFT points and equals to 64. Three types of channels are used: The additive white Gaussian noise (AWGN) channel, AWGN channel + Raleigh flat fading channel and AWGN channel + Raleigh selective fading channel with two paths. The delay and the attenuation of the second path are 8 samples and -8dB respectively. The Doppler frequency shift was 50 Hz. Three users were taken using Welsh functions with processing gain (PG) =16.

Performance in AWGN channel

As shown in Figure 7 it can be seen that the gain at BER $=10^{-3}$ is about *1*dB when using MC-DS-CDMA based on SLT system over the system uses MC-DS-CDMA based on DWT. The gain of MC-DS-CDMA based on SLT system is *13*dB over the MC-DS-CDMA based on FFT system.

Performance in AWGN channel + Raleigh flat fading channel

As shown in Figure 8 it can be seen that the gain at BER $=10^{-3}$ is about *0* dB when using MC-DS-CDMA based on SLT system over the system uses MC-DS-CDMA based on DWT(the two systems are equivalent). The gain of MC-DS-CDMA based on SLT system is *13*dB over the MC-DS-CDMA based on FFT system.

Performance in AWGN channel + Raleigh selective fading channel

As shown in Figure 9 it can be seen that the gain at BER $=10^{-3}$ is about *3*dB when using MC-DS-CDMA based on SLT system over the system uses MC-DS-CDMA based on DWT(the two systems are equivalent). The gain of MC-DS-CDMA based on SLT system is *14*dB over the MC-DS-CDMA based on FFT system.

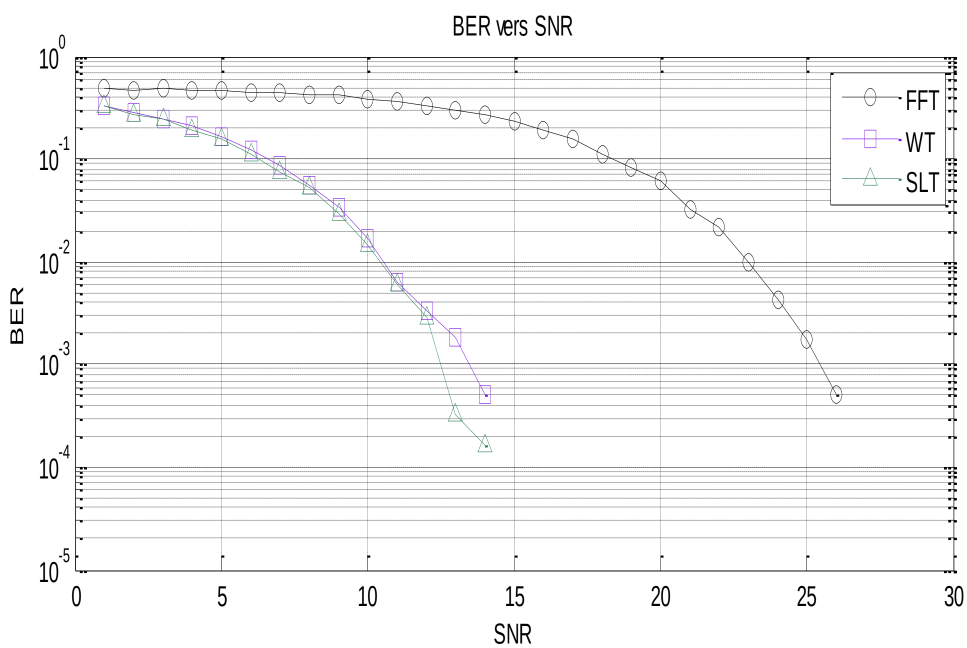


Figure 7: AWGN channel.

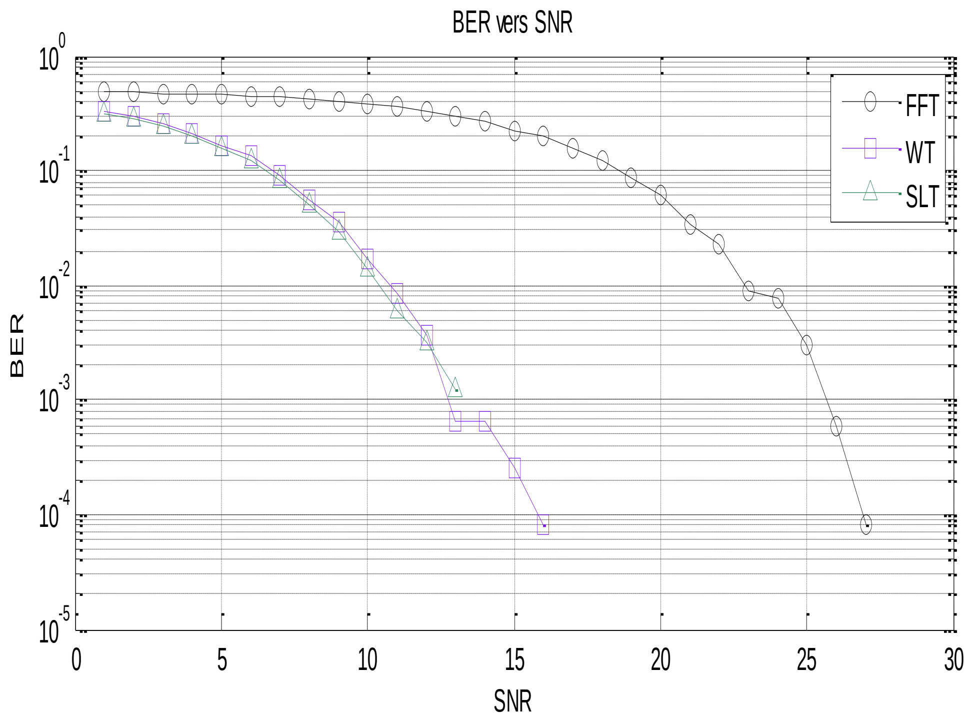


Figure 8: AWGN channel + Raleigh flat fading channel.

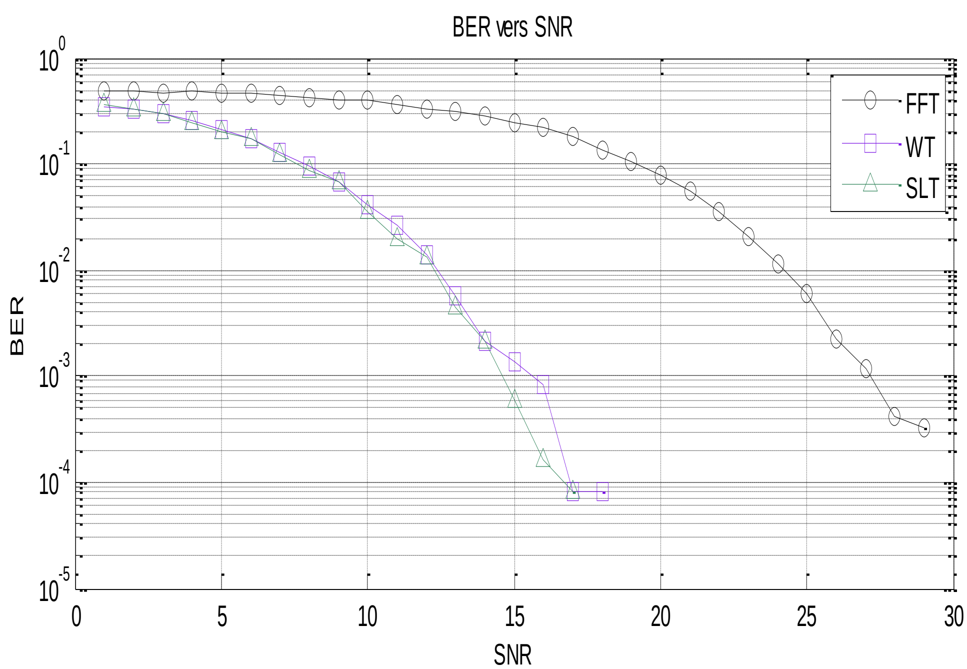


Figure 9: AWGN channel + Raleigh selective fading channel.

Conclusions

In this work a comparison between the performance of MC-DS-CDMA based on FFT system and two proposed systems were realized in three types of channels. The following points can summarize the conclusions drawn from the results obtained:

1- From the BER view: the performance of the proposed systems were better in all three types of channels.

2- From the data rate view: the MC-DS-CDMA based on FFT system uses a cyclic prefix that wastes about 25% of the bandwidth while in the proposed systems there is no cyclic prefix.

3- The MC-DS-CDMA based on DWT system is more complex than MC-DS-CDMA based on SLT system. The BER and the data rate achieved by both systems are comparable in two cases unless in selective fading channel, because different filters are used.

References

1. S. Hara, R. Prasad, 1997, “Overview of Multicarrier CDMA”, IEEE Communications Magazine, 35, (12), 126-133.

2. K. Fazel, L. Papke, 1993, "On the Performance of Convolutionally Sequenced CDMA/OFDM for Mobile Communication System", Proceedings IEEE PIMRC'93, 668-472, Yokohama, Japan.

3. N. Yee, J-P. Linnartz, G. Fettweis, 1993, "Multicarrier CDMA in Wireless Radio Networks", Proceedings IEEE, PIMRC'93, 109-113, Yokohama, Japan.

4. A. Chouly, A. Brajal, S. Jourdan, 1993, "Orthogonal Multicarrier Techniques Applied to Dircet Sequence Spread Spectrum CDMA techniques ", Proceedings IEEE Globecom'93, 1723-1728, Houston, USA.

5. V.M. DaSilva, E.S. Sousa, 1993, "Performance of Orthogonal CDMA Sequences for Quasi-Synchronous Communication Systems", Proceedings IEEE ICUPC'93, 995-999, Ottawa, Canada.

6. S. Kondo, L. B. Milstein, 1996, "Performance of Multicarrier DS-CDMA Systems", IEEE Transactions on Communications, 44, (2), 238-246.

7. K. SH. Zigangirov, 2004, "Theory of Code Division Multiple Access Communication", Wiley.IEEE Press.

8. S. B. Weinstein and P. M. Ebert, 1971, “Data Transmission by Frequency Multiplexing using the Discrete Fourier Transform”, IEEE Transactions in Communications Technology, 19, (5).

9. B. Crow, I. Widjaja, J .G. Kim, P. Sakai, 1997, "IEEE802.11 Wireless Local Area Networks", IEEE Communications Magazine, 116-126.

10. IEEE standard, 1999, "Part II: Wireless LAN Meduim Access Control (MAC) and Physical Layer (PHY) specifications: High-Speed Physical Layer in the 5GHz Band".

11. ETSI, "Hiperlan/2-Technical Overview", online: http://www.etsi.org/technicalactiv/Hiperlan/hiperlan2tech.htm.

12. A .N. Akansu, M. V. Tazebay, M. J. Medley and P. K. Das, 1997, "Wavelet and Subband Transforms: Fundamentals and Communication Applications", IEEE Communication Magazine, 104-114.

13. G. R Hassan, 2005, "Wavelet-Based OFDM Scheme", M.Sc Thesis, University of Baghdad, Baghdad.

14. B. G. Negash and H. Nikookar, 2001, "Wavelet Based OFDM for Wireless Channels", International Research Center for Telecommunications-Transmission and Radar Faculty of Information Technology and Systems, Delft University of Technology, IEEE Vehicular Technology Conference, 688-691.

15. H. Zhang, D. Yuan, M. Jiang and D. Wu, 2004, "Research of DFT-OFDM and DWT-OFDM on Different Transmission Scenarios", Proceedings of the 2^{nd} International Conference on Information Technology for Application (ICITA).

16. I. W. Selesnick, 1999, "The Slantlet Transform", IEEE Transactions on Signal Processing, 47, (5), 1304-1313.

محاكاة نظام (MC-DS-CDMA) على اساس تحويلات (Wavelet) و (Slantlet) لكل قنوات اللاسلكي

احمد عبد الهادي

كلية الهندسة - جامعة ذي قار

الخلاصة

في هذا البحث تم اقتراح نظامين لتحسين أداء نظام متعدد النواقل متعدد الوصول لقنوات الشفرة MC-DS-CDMA في القناة اللاسلكية من ناحية تقليل معدل الخطأ. النظام الموجود يعتمد على تحويل فورير السريعFFT . أحد النظامين المقترحين يعتمد على تحويل المويجة WT . النظام الأخر يعتمد على تحويل الانحدار SLT. نتائج المحاكاة أخذت من ثلاثة أنواع من قنوات الاتصال. المحاكاة أثبتت أن كلا النظامين المقترحين قد تفوقا على النظام الموجود. كذلك تم ملاحظة أن النظام المعتمد على تحويل الانحدار قد حقق نفس نتائج النظام المعتمد على تحويل المويجة ولكن باستعمال مرشحات ذات طول أقل.