The WLAN/ WCDMA Blind Multimode Wireless Receiving System

Dr. Sattar B. Sadkhan.
Seines College, University of Babylon/Babylon.
Email**:** drengsattar@yahoo.com.
Dr. Hanan A. R. Akkar.
Electrical Engineering Department, University of Technology/Baghdad
Wafaa M. R. Shakir.
Technical Institute, Foundation of Technical Education/Baghdad

Received on: 21/9/2011 & Accepted on: 6/9/2012

ABSTRACT

This paper proposes a new multimode wireless receiving system based on Blind Source Separation (BSS) for Orthogonal Frequency Division Multiplexing (OFDM) signal (based on Wireless Local Area Network (WLAN)) and the Wideband Code Division Multiple Access (WCDMA) signal (based on 3G cellular system). The proposed system applied the Independent Component Analysis (ICA) algorithms (adopting Fast-ICA and JADE algorithms) for blind estimating of the received signals. The processes of estimation, detection of the signals and equalization of the channel effects are done as blind methods at the same time. A performance comparison of the adopting algorithms had been done and the simulation results show that the multimode receiving system based on Fast-ICA algorithm had a gain of (7 dB) over JADE algorithm for a (10^{-4} BER) of 30 users WCDMA blindly signal detection.

Keywords: Blind Multimode System, WLAN, WCDMA, ICA, BSS.

المستقبلة اللاسلكية متعددة الأنماط العمياء لنظامي WLAN/ WCDMA

الخلاصة

يقدم هذا العمل نظام استقبال لاسلكى جديد متعدد الأنماط على أساس الفصل الأعمى لمصادر الإشارة المستلمة لفصل واستنتاج نوعين من أشارات الاتصالات الحديثة، إشارة OFDM حسب نظام (WLAN) وإشارة WCDMA حسب نظام (٣G). يستخدم النظام المقترح خوارزميات التحليل المستقل للعناصر (خوارزمية الـ Fast-ICA والـ JADE) لغرض تخمين الإشارة المستلمة بصورة عمياء. وتتم عمليات تخمين وكشف الإشارات وكشف وإلغاء تأثير قناة الإرسال في نفس الوقت بشكل أعمى تماما وتوضح نتائج المحاكاة التي تم إجراؤها إن نظام الاستقبال متعدد الأنماط بالاعتماد على خوارزميةFast-ICA ,يحقق ربح بقيمة **(** 7 dB) لنسبة خطأ مقدارها (10^{-4}) نسبة إلى خوارزمية JADE.

INTRODUCTION

The multitude of wireless communication system types and the convergence of different type of communication networks will continue to be a challenge for the mobile terminal implementations. In future, different types of networks will be employed which increases the transceiver complexity even further. For example, users might want to browse the internet through the Wireless Local Area Network (WLAN), while making a voice call through a cellular network [1].

Moreover, the mobile terminals should be able to detect the available Networks and to select the appropriate connection based on the desired application. Multimode wireless systems require that users are equipped with mobile terminals that can operate in several wireless networks [1].

The multimode wireless systems are aim to solve the network coverage insufficiency during the wireless network transition, holding the user during the wireless network transition and providing legacy service which the subscriber is familiar with. Where, in most countries or regions, only limited communication modes exist, the multimode terminal is capable of solving the problem of different communication modes when the user is traveling in different regions. The multimode terminals are providing differentiated service and improving user satisfaction. Often different modes provide diverse data rate, communication services, and fees. The classical approach to design multimode systems by integrating separate modules, each module covering one standard in ordered to support multiple modes will give prohibitively large and rigid solutions for future multimode mobile devices [2].

Several systems for multimode wireless communication systems had been proposed; the design of a programmable baseband receiver platform for the Wideband Code Division Multiple Access (WCDMA) and the Orthogonal Frequency Division Multiplexing (OFDM) mobile terminals is presented in [3]. The platform is composed of a core processor type Reduced Instruction Set Computer (RISC) and set of coprocessors, the coprocessor provides the functions needed to implement the WCDMA and OFDM receiver algorithms, the (RISC) processor is used to initiate the coprocessor functions and to implement channel estimation and equalization tasks [3]. An adaptive multimode wireless communication system that are implementing on dynamically reconfigurable hardware is presented in [4], the digital baseband processing of a High Performance LAN (HiperLAN/2) system based on OFDM receiver and the Universal Mobile Telecommunications System (UMTS) based on WCDMA receiver were mapped on of the processor type MONTIUM [4].

A design for digital front end of the multi-mode wireless receiver is proposed in [5]. The proposed design can handle the Global System for Mobile Communications (GSM) /Enhanced Data Rates for GSM Evolution (EDGE), Code Division Multiple Access 2000 (CDMA2000), UMTS standards operation by sharing digital signal processing stages for all operation modes and adapting them for minimum power consumption with respect to the channel selection requirements. Another design of the multi-mode receiver subsystem for onboard wireless communication in an airplane is proposed in [6]. The subsystem can provide several different communication systems including WLAN, Worldwide Interoperability for Microwave Access WiMAX, WCDMA, CDMA2000 communication systems and can be achived a maximum channel bandwidth up to 20MHz, the main characteristics of subsystem is miniature size and low cost.

A design for the multistandard based on sigma-delta method for Analogue to Digital Converter (ADC) stage is proposed in [7]. The proposed design can handle

the GSM, WCDMA and WLAN standards, achieving low power consumption by making the unused stages inactive.

A CMOS process design of wideband wireless receiver is proposed in [8] based on Software Defined Radio (SDR). The proposed design for wideband RF front-end includes a low noise amplifier (LNA), a mixer; intermediate frequency amplifier and a variable gain amplifier can cover the frequency range from 100MHz to 2GHz. Another design for dual input-channel multi-mode wireless receiver platform based on Software Defined Radio (SDR) is presented in [9]. The receiver platform compatible with the GSM, WCDMA, and Wireless Fidelity (Wi-Fi) standards can detect and identify the surrounding base stations and access points.

Despite this literatures, none of previous work is adopting the blind methods for estimating the transmitting signals without using the training signals. In this paper a new multimode wireless receiving system based on Blind Source Separation (BSS) for estimating the OFDM and WCDMA signals without any modification in transmission side or using the training signals is proposed.

Blind Source Separation and Independent Component Analysis

The Blind Source Separation gives a solution for unsolvable problem: assuming that some unknown mixing of unknown variables, using only the observed data, the aim of BSS, generates the observed data is to find both the mixing structure and the original components (signals) of the mixture [10]. In communications, blind methods have a wider application. Given that available bandwidth is both finite and scarce, and the need for higher data rates is incessant, blind methods offer promising solutions that require no training data. This provides a means to increase the data rate by allowing transmission of user data in place of training data [11].

Independent component analysis (ICA) is a popular method for solving the BSS problem. By assuming that the unknown variables are statistically independent, ICA tries to estimate both the mixing matrix and the original sources. The ICA needs to examine mixtures from several independent observations (mixing signals) from multiple received antennas [12]. Let S be the original source of signals, A be the mixing matrix, and X be the mixed signals, then

$$X = AS \qquad \dots (1)$$

The object of blind signal separation is to recover the original signals S from the mixed signals X by estimating the separation matrix W. The estimated signal Y is

$$Y = W X = W(AS) = (WA)S \qquad \dots (2)$$

By observing the above equation, it is apparent that the condition $WA = I$ (or ideally $W = A^{-1}$) must stand (in order the estimating signals equal to the original signals). There are many ICA algorithms proposed to find W adopting different types of measurements. One of the popular algorithms is Fast-ICA, which use the following update rules [13]:

$$W^{+} = E[g(Y^{T}Y)] - E[g'(Y^{T}Y)]W \qquad \dots (3)$$

Where $g(u) = tanh(a.u)$, $W = W^{+}/\| W^{+} \|$

JADE (Joint Approximate Diagonalization of Eigenmatrices) is another famous ICA algorithm [14], JADE algorithm uses the second order cumulate (covariance matrix) for decorrelated the data and diagonalization of the eigenmatic of the fourth-order cumulate (kurtosis matrices) for making the data as independent as possible.

The Proposed Multimode Transceiver System Model

The multimode wireless terminals are proposed for providing the capability of receiving signals corresponding to different transmission modes and different signals of different standard, these signals typically different by coding, modulation schemes and frame format. The benefits of the proposed multimode receiving system based on the (WLAN) (adopting the OFDM signaling system) and the 3G cellular mobile communication system (adopting the WCDMA signaling system), is the strength of the two system types i.e., combining the high mobility, the wide coverage ranges form the cellular mobile communication system and a high data throughput from the WLAN system.

This paper considers the issue of designing multimode wireless system based on BSS principle. The aim of this work is to designing the multimode receiving system based on BSS which adopting the ICA algorithms for blind separation, equalization, detection simultaneously the OFDM signal system and WCDMA signal and this will make our receiver the first multimode receiving system adopting blind methods.

The proposed model of the multimode wireless system is shown in Figure (1) and (2). The transmission part is shown in Figure (1) including two transmission systems, OFDM and WCDMA transmitter, while the receiving system is shown in Figure (2) which including the proposed ICA receiver for estimating the original signals form the observation mixtures of signals based on ICA algorithms and the two branches of receiver, the OFDM and WCDMA receivers.

The proposed multimode receiving system does not contain any stages of estimation and equalization the channel effects that exist usually in conventional receiving system. The proposed ICA receiver received the observed mixture of transmitted signal after they propagated through the wireless channel through a dual antenna system (since, the ICA receiver needs to observed mixture of signals form different receiving antennas). The proposed ICA receiver estimates the mixing matrix, which is equivalent to the channel effects, and the separation matrix that is the inverse of the mixing matrix, so the ICA receiver is practically equalized the effects of channel blindly.

The OFDM transmitter is shown in Figure (1). The input data stream is first converted from serial to parallel, and then mapped into any kind of digital modulation according to the constellation map. The output is then pass through the *N*-points Inverse Fast Fourier Transform (IFFT) to generate the OFDM symbol. The output data from the *N*-points IFFT is then converted from parallel to serial and a cyclic prefix is added. The data are sent to the receiver over the channel after being converted to a frame structure (serial data stream). The channel consists of a Rayleigh fading with Additive White Gaussian Noise (AWGN) effects. The frame structure consists of modulated data only without using the pilot signal, thus increasing the spectral efficiency of the transmitted signal. At the receiver the inverse operation is employed, the cyclic prefix is removed and a serial to parallel conversion is achieved

for the signal. The *N*-points Fast Fourier Transform (FFT) is used to convert the signal from time to frequency domain. The signal is then de-mapped and converted back to serial output stream.
The IFFT output sequence of an OFDM symbol could be expressed as [15]

$$x_n(t) = \frac{1}{N}\sum_{i=0}^{N-1} X_i \, e^{2pjni/N} \qquad \dots (4)$$

(n = 0,1,2, …,N-1), where N is the subcarrier number and X_i is a symbol. Following the frequency to time domain conversion, the signal is extended, and the cyclic prefix is added:

$$S_n(t) = \begin{cases} x_n(t+T-T_{CP}) & 0 \le t < T_{CP} \\ x_n(t-T_{CP}) & T_{CP} < t < T_t \\ 0 & otherwise \end{cases} \qquad \dots (5)$$

Where $T_t = T + T_{CP}$ is the total OFDM symbol duration, T is the useful OFDM symbol duration and T_{CP} is the cyclic prefix duration, where each OFDM symbol is preceded by a cyclic prefix. This is an exact copy of the last T_{CP} seconds of the signal that represents the current OFDM symbol.

The WCDMA transmitter is shown in Figure (1). The input data stream U_n of the nth user is first modulated according to the specific type of modulation introduced by the system. The output is then spreading by multiplied with the spreading code sequence; using the Walsh code sequence. The output data from spreading process is passing through the pulse shaping filter then transmitted through the wireless channel. At the receiver the inverse operations are employing, the received signal (after separating the WCDMA signal using ICA receiver) will through the pulse shaping filter, despreading by correlation with the same code sequence which is used in transmitter, then digitally demodulation to retrieved the original data stream of the user.

Considering a WCDMA system with N users, the baseband signal is given by

$$S(t) = \sum_i \sum_{n=1}^{N} U_n^i C_n^i (t - iT_c) \qquad \dots (6)$$

N is the number of users in the system, U_n^i is the ith bit transmitted for the nth user, C_n^i is the spreading code sequence of the nth user, T_c is the chip time. Then, $S(t)$ is fed through the pulse shaping filter. The pulse shaping reduces the intersymbol interference effects and the spectral bandwidth of baseband signals, so

$$c(t) = S(t) * g(t) \qquad \dots (7)$$

where $g(t)$ is the impulse response of the pulse shaping filter, which should be chosen so that its has zero-crossings at multiples of the chip period. A filter is fulfilling this

property is the raised cosine pulse shaping filter. The impulse response of the raised cosine pulse-shaping filter [16]

$$g(t)=\left(\frac{\sin(p\ t/T_c)}{p\ t/T_c}\right)\left(\frac{\cos(ap\ t/T_c)}{(1-(2a\ t/T_c)^2)}\right) \qquad \dots (8)$$

For the proposed multimode system the chip rate is R_c=4.096 MHz, the chip duration $T_c=\frac{1}{4.096MHz}=0.244ms$,the value of Roll-off factor a is 0.22 [17].

The receiving system consists of the proposed ICA receiver, which received the observation signals through a dual antenna system, and the successive stages of the OFDM and WCDMA detection systems. The ICA receiver perform a blindly signals separation process for the observation signals adopted one of the ICA algorithms, then the ICA receiver defining the separated signals by minimizing the Euclidean distance between the receiving and separating signals for solving the order ambiguity inherent in ICA algorithms. The separating signals then delivering through its own branch of the receiving system for completing the detection processes of both signals. The observation mixture signals model $x_k(t)$ is defining as follows:

$$x_k(t)=AS_k(t)+n(t) \qquad \dots (9)$$

where k= 1, 2 is the antenna index, t is the time index, $n(t)$ is AWGN and $S(t)$ is the matrix of OFDM and WCDMA signals, $S_k(t)=\begin{bmatrix} s(t) \\ c(t) \end{bmatrix}$ while A representing the coefficient of Rayleigh fading channel, $A=\begin{bmatrix} a_1 & b_1 \\ a_2 & b_2 \end{bmatrix}$. The specification of the transmitting WCDMA based on 3G cellular system and OFDM signal based on IEEE 802.11a system are as illustration in Table (1):

Table (1): The specification of the transmitting WCDMA and OFDM signals.

Simulation parameters / WCDMA signal		**Simulation parameters / OFDM signal**	
Modulation scheme	BPSK	Modulation scheme	BPSK
Spreading factor	32	No. of all subcarriers	52
Frame length	10 ms	No. of data subcarriers	52
Bite rate	128 Kbps	No. of (FFT / IFFT)	64
Chip rate	4.096 Mcps	No.of Cyclic prefix	16
Frequency band	2110-2170 MHz	Frequency band	4200-6200 MHz
Channel bandwidth	5 MHz	Channel bandwidth	20 MHz

SIMULATION RESULTS

The performances of the proposed system are evaluated through a computer simulation using a MATLAB code. The effectiveness and validity of the multimode receiving system is testing first by OFDM symbols estimation process. For the purpose of performance comparison (SNR vs. BER), the proposed ICA receiver of the multimode receiving system adopting two algorithms (Fast-ICA and JADE algorithms). The ICA receiver is working for estimating the OFDM and WCDMA signals form their observation mixtures based on assumption of their mutual statistical independence and equalized the effect of Rayleigh fading channel, which already caused the mixing process of the signals. Then, the OFDM symbols detection process is completing using the successive stages of the OFDM receiving system after identification of OFDM signal from the two estimating signals using the minimization of Euclidean distances between the separating and receiving signals.

Figure (3) shows the performance comparison of the ICA receiver based on Fast-ICA and JADE algorithms for detection the OFDM signal. It is seen that the performance of Fast-ICA and JADE are very close to each other especially at high SNR. At low SNR (SNR less than 1dB), the JADE perform better than Fast-ICA algorithm, while at high SNR (SNR between 6 and 9 dB) the JADE algorithm gives slightly better performance than the Fast-ICA, i.e., for 8 dB the JADE achieves a BER of (2×10^{-4}) while Fast-ICA algorithm achieves a BER of (7×10^{-4}). Both algorithms give a BER of (1×10^{-4}) at SNR of 9 dB. In general, both tested algorithms perform very well for separation the OFDM signal from the received observation signals and the multimode receiving system gives a very good result for detection the desired OFDM signal.

In the same time, the ICA receiver adopting the Fast-ICA and JADE algorithms is used for estimating the WCDMA signal forms the received mixtures of signals. The despreading and demodulation processes are completing using the successive stages of WCDMA detector.

The performance comparison of the ICA receiver based on Fast-ICA and JADE algorithm for different number of users (k=10, 20, 30) are shown in Figures (4), (5) and (6). Figure (4) shows that the JADE had quite clearly better separation capability than Fast-ICA for all rang of SNR. At SNR of 2 dB JADE performs a BER of (2×10^{-3}) for 10 users while Fast-ICA had a BER of (3×10^{-2}), at SNR of 3 dB both algorithms had a performance of (2×10^{-4}) and the Fast-ICA had a zero BER at SNR > 4 dB ,while JADE had a zero BER at SNR > 3 dB.

For 20 users WCDMA signal detection, Figure (5) shows that JADE performs better when SNR is low, while Fast-ICA performs better when SNR is high. At SNR of 4 dB Fast-ICA performs a BER of (2×10^{-1}) while JADE had a BER of (8×10^{-3}), at SNR of 7 dB Fast-ICA performs a BER of (6×10^{-4}) while JADE had a BER of (2×10^{-3}) and the Fast-ICA had a zero BER at SNR > 8 dB ,while JADE had a zero BER at SNR > 7 dB.

For 30 users WCDMA signal detection, Figure (6) shows that JADE performs better, when SNR is low, while Fast-ICA performs better when SNR is high. At SNR of 4 dB Fast-ICA performs a BER of (9×10^{-2}) while JADE had a BER of (3×10^{-2}), at SNR of 8 dB Fast-ICA performs a BER of (4×10^{-4}). While JADE had a BER of (1×10^{-3}) and the Fast-ICA had a zero BER at SNR > 9 dB, while JADE had a zero BER at SNR > 16 dB. So, it is clear that the Fast-ICA had an improvements

performance when number of users is increasing, while JADE had a degradation performance when number of users is increasing. Fast-ICA had a gain of (7 dB) over JADE algorithm for a (10^{-4}) BER for 30 users WCDMA. The flowcharts of the proposed multimode system are shown in Figures (7) and (8).

CONCLUSIONS

This paper considers the issue of designing multimode wireless system based on BSS principle. The multimode receiving system based on ICA algorithms used for blind separation, detection the OFDM signal based on WLAN system and WCDMA signal based on 3G mobile systems. The advantages of this technique include there is no need for channel equalization stage, i.e., no training sequence is required, all frame length of signals are using for data. The ICA algorithms are utilized to the OFDM and WCDMA blind separation and detection simultaneously for multimode wireless receiving system.

REFERENCES

[1]. Zhang, X., "Recent Advances and Future Trends of the Multimode Wireless Terminal", IEEE International Conference on Portable Information Devices, Orlando, USA, May, 2007.

[2]. Nilsson, A., Design of Programmable Multi-standard Baseband Processors, Ph.D Thesis, Linköping University, Linköping, Sweden, 2007.

[3]. Harju, L., Nurmi J., "A Programmable Baseband Receiver Platform for WCDMA/OFDM Mobile Terminals", IEEE Wireless Communications and Networking Conference (WCNC'05), New Orleans, LA, USA, March, 2005.

[4]. Rauwerda, G., Multi-standard Adaptive Wireless Communication Receivers, Ph.D Thesis, University of Twente, Enschede, Netherlands, 2007.

[5]. Hueber, G., """"Concept for an Adaptive Digital Front-End for Multi-Mode Wireless Receivers", IEEE International Symposium on Circuits and Systems, Washington, USA, May, 2008.

[6]. Wang, Y., "Multi-mode/Multi-band Receiver for Onboard Ultra Broadband Communication System", International Conference on Microwave and Millimeter Wave Technology (ICMMT), Chengdu, China, May, 2010.

[7]. Jose, B. R., Mathew, J. & Mythili P., "A Multi-Mode Sigma-Delta ADC for GSM/WCDMA/WLAN Applications", Journal of Signal Processing Systems, Springer Science and Business Media, Vol. 62, No. 2 , November, 2011.

[8]. Peng, Y., "A 100MHz - 2GHz Wireless Receiver in 40-nm CMOS for Software-Defined Radio", International Conference of Electron Devices and Solid-State Circuits (EDSSC), Tianjin, China, November, 2011.

[9]. Zhong, Y., "A Dual Input-Channel Software Defined Receiver Platform for GSM WCDMA and Wi-Fi", International Conference on Wireless Communications and Signal Processing (WCSP), Nanjing, China, November, 2011.

[10]. Hyv¨arinen A., Karhunen J., Oja. E., *Independent Component Analysis*, John Wiley, New York, 2001.

[11]. Raju, K., Blind Source Separation for Interference Cancellation CDMA Systems, Ph.D Thesis, Helsinki University of Technology, Espoo, Finland, 2006.

[12]. Lee C., Wolf W., "Blind Signal Separation for Cognitive Radio, Journal Signal Processing System", Springer Science and Business Media, USA, 19 August, 2009.

[13]. Hyvärinen, A. and Oja E., "A Fast Fixed-Point Algorithm for Independent Component Analysis", Neural Computation, No. 9, Vol. 7, pp. 1483-1492, 1997.
[14]. Cardoso, J.F. and Souloumiac A., "Blind beamforming for non Gaussian signals", IEE Proceedings-F, No. 140, Vol. 6, pp.362–370, 1993.
[15] Engels, M., Wireless OFDM Systems: How to make them work? , The Springer International Series in Engineering and Computer Science, 2002
[16]. Couch, L., Digital and Analog Communication Systems, Prentice-Hall PTR, 1997.
[17]. Adachi, F., Sawahashi M. and Suda H., "Wideband DS-CDMA for next generation mobile communications systems" , IEEE Communications Magazine, Vol. 36, No. 9, pp. 56-69, September 1998.

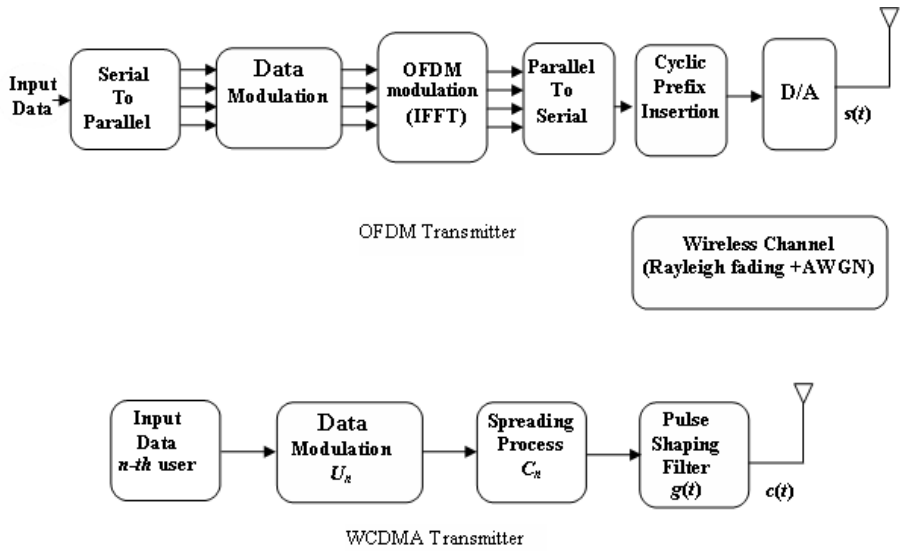


Figure (1): The OFDM and WCDMA Transmitter Models.

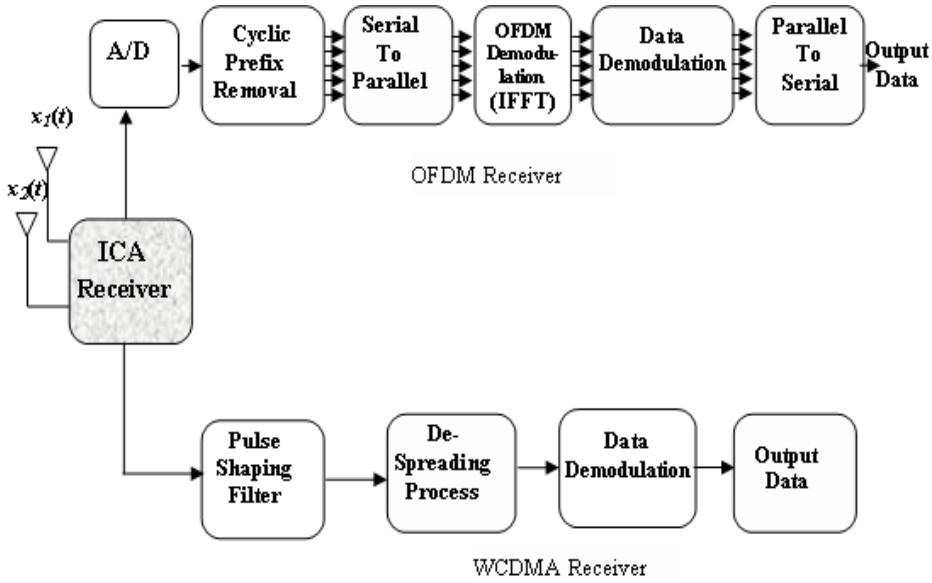


Figure (2): The Proposed Multimode Receiving Model.

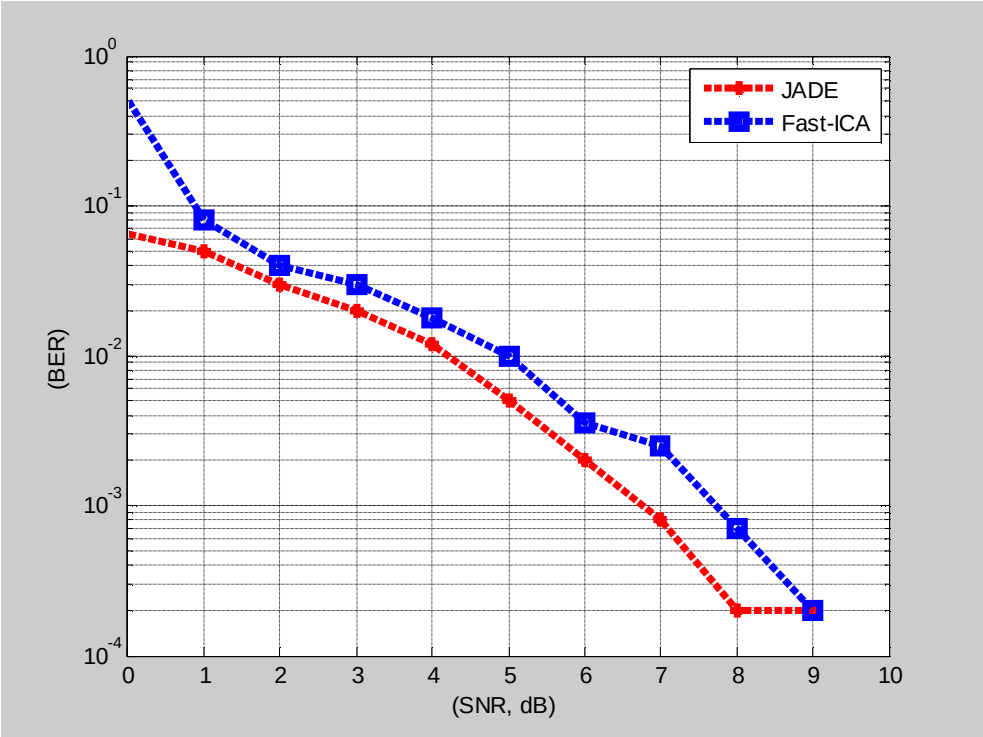


Figure (3): Performance of the Proposed System for Detection the OFDM Signal.

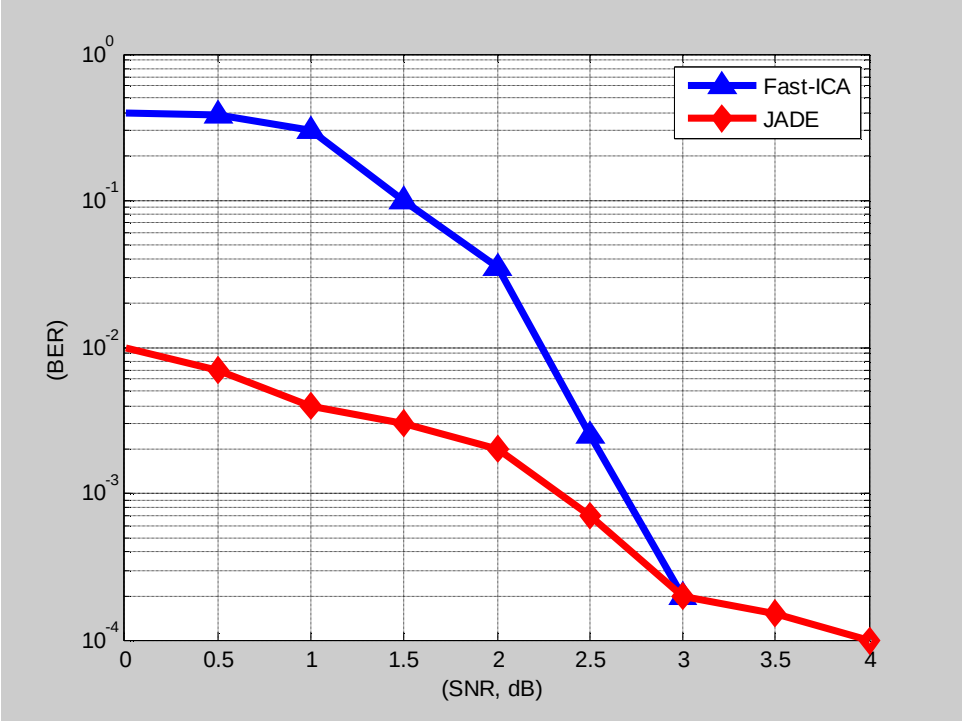


Figure (4): Performance of the Proposed System for Detection the WCDMA Signal (10 Users).

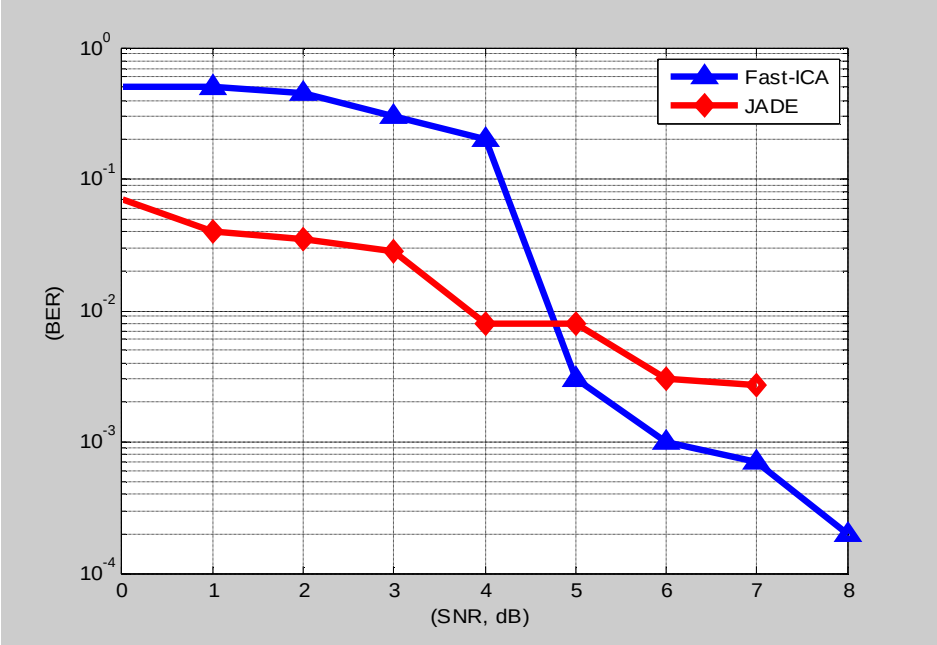


Figure (5): Performance of the Proposed System for Detection the WCDMA Signal (20 Users).

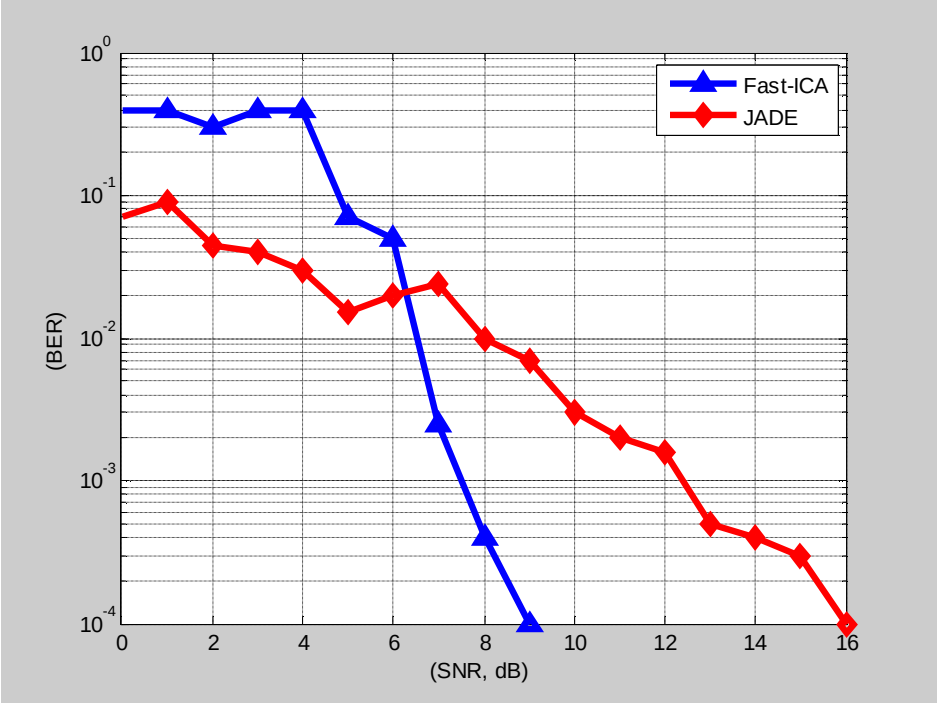


Figure (6): Performance of the Proposed System for Detection the WCDMA Signal (30 Users).

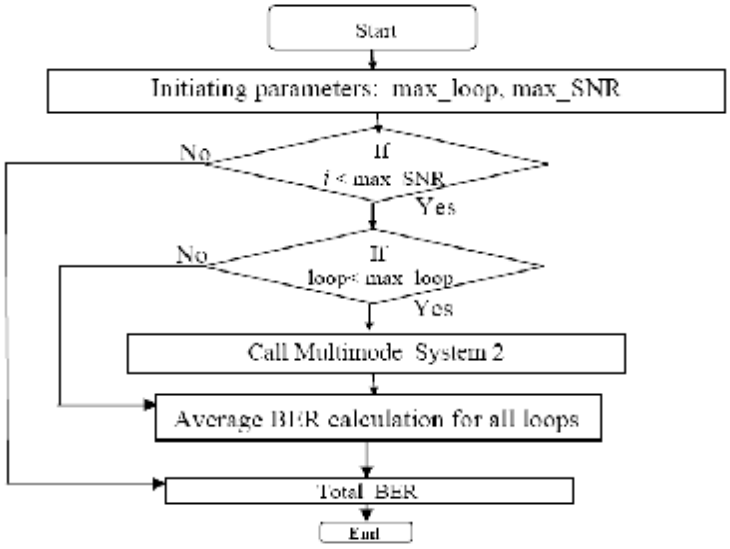
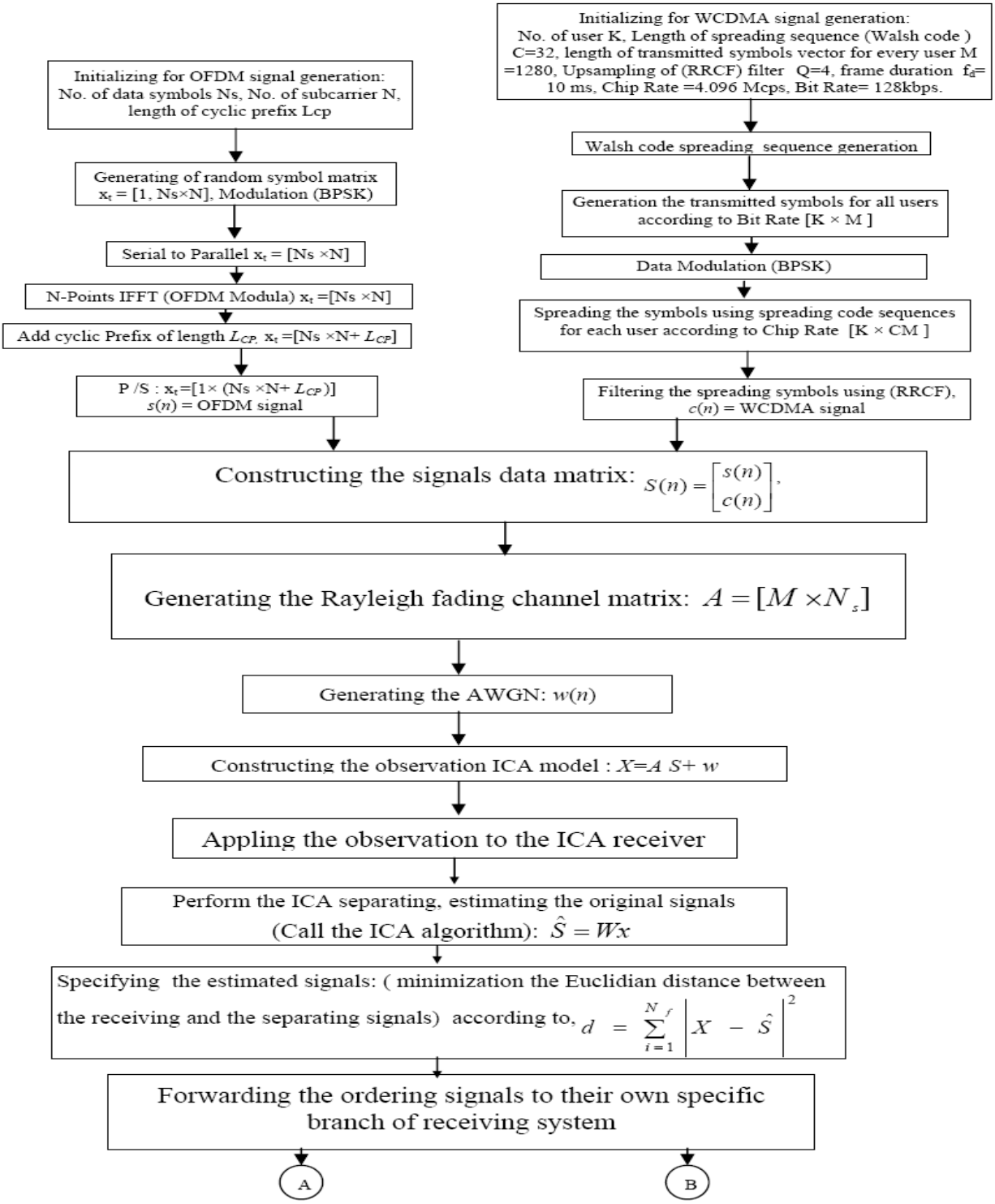


Figure (7) Flowchart of the Main Program of the Proposed Multimode system.


Initializing for OFDM signal generation: No. of data symbols Ns, No. of subcarrier N, length of cyclic prefix Lcp
Generating of random symbol matrix x_t = [1, Ns×N], Modulation (BPSK)
Serial to Parallel x_t = [Ns ×N]
N-Points IFFT (OFDM Modula) x_t =[Ns ×N]
Add cyclic Prefix of length L_{CP}, x_t =[Ns ×N+ L_{CP}]
P /S : x_t=[1× (Ns ×N+ L_{CP})]
$s(n)$ = OFDM signal
Initializing for WCDMA signal generation: No. of user K, Length of spreading sequence (Walsh code) C=32, length of transmitted symbols vector for every user M =1280, Upsampling of (RRCF) filter Q=4, frame duration f_d= 10 ms, Chip Rate =4.096 Mcps, Bit Rate= 128kbps.
Walsh code spreading sequence generation
Generation the transmitted symbols for all users according to Bit Rate [K × M]
Data Modulation (BPSK)
Spreading the symbols using spreading code sequences for each user according to Chip Rate [K × CM]
Filtering the spreading symbols using (RRCF), $c(n)$ = WCDMA signal
Constructing the signals data matrix: $S(n) = \begin{bmatrix} s(n) \\ c(n) \end{bmatrix}$,
Generating the Rayleigh fading channel matrix: $A = [M \times N_s]$
Generating the AWGN: $w(n)$
Constructing the observation ICA model : X=A S+ w
Appling the observation to the ICA receiver
Perform the ICA separating, estimating the original signals (Call the ICA algorithm): $\hat{S} = Wx$
Specifying the estimated signals: (minimization the Euclidian distance between the receiving and the separating signals) according to, $d = \sum_{i=1}^{N_f} \left| X - \hat{S} \right|^2$
Forwarding the ordering signals to their own specific branch of receiving system
A
B

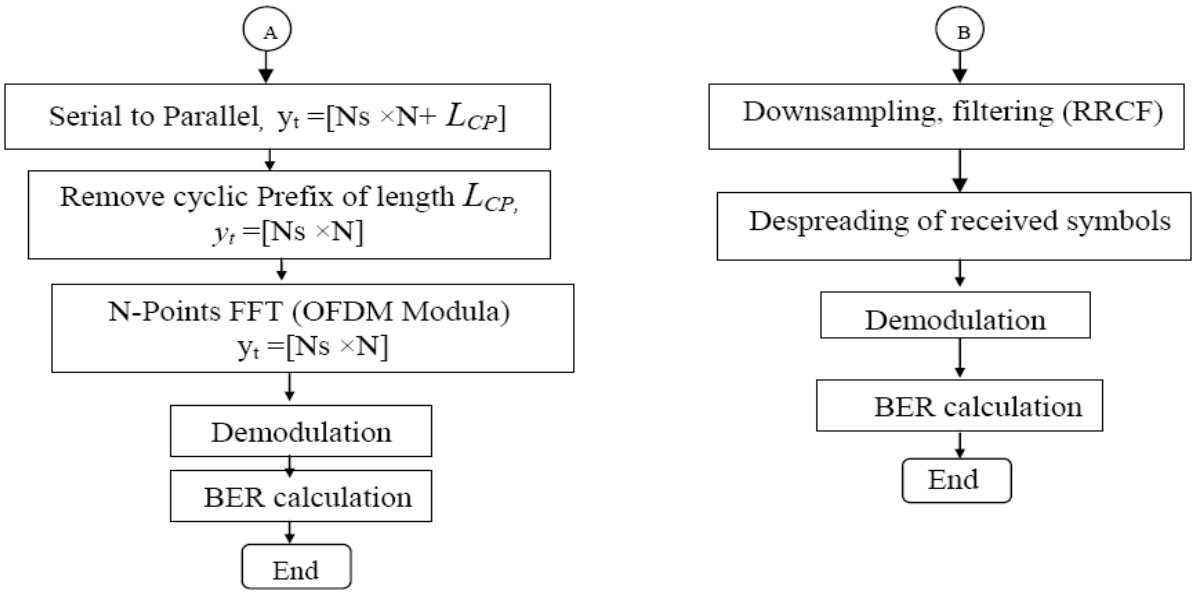


Figure (8) Flowchart of the Sub Program (Multimode_System 2) of the Proposed Multimode system.