Abstract— This work presenting a blind wireless receiving system based on the Blind Source Separation (BSS) for blind estimation, and detection the digital Binary Phase Shift Keying (BPSK) signals over quasi-stationary fading channel. The estimation process is performed based the received observation signals only, without prior information about the original signals or about the propagation channel. Conventional methods estimate these signals by taking into account the prior information about the signals and about the propagation channel, this is usually done using the training sequences, which usually costs a bandwidth.

Index Terms—Blind Wireless Receiver; Blind Source Separation; Independent Component Analysis

I- INTRODUCTION

Today, the world is overwhelmed with portable devices like handheld computers, mobile telephones and portable navigation systems. These devices will eventually be integrated into multi-mode devices that can receive a wide variety of signals corresponding to different systems and perform all kinds of functions in one single system, providing rich information to the user.

The multi-mode wireless systems enables the user to download communication and application software by wireless and then can easily access new services without purchasing additional new equipment, even if the communication system is modified or newly introduced. The multi-mode wireless systems are proposed for providing the capability of receiving signals corresponding to different transmission modes, these signals typically different by coding, modulation schemes and signals frame format. In the multi-mode environment, the users are equipped with mobile terminals that can operate in multiple wireless standards [1].

One type of the multi-mode terminals comes as a necessity dictated by the differences in standards in different geographical regions [1]-[2]. The other type of multi-mode terminal is an economically stated reason, by integrating the old and new standards of the same family of the communication systems in the same terminals [3]. The third direction is relates to the implementation of complementary communication standards, to take advantages from the complementary communications systems [4].

The concept of Blind Source Separation (BSS) is commonly used to recover the sources of signals that have been mixed in some manner without (or with as little as possible) prior information of either the mixing process or the source of signals. There are several reasons for applying the BSS in communication systems, including the increasing the system capacity by eliminating or reducing training sequences [5]-[6].

For time varying wireless channels, the transmission of training sequences has to be performed periodically, which has a detrimental effect on spectral efficiency. For example, in the GSM system around 20% of the symbols are training symbols [6]. Hence, by using the blind methods, the training overhead can be eliminated, data symbols can be sent during this period instead of training sequences. One popular method of blind signal separation is Independent Component Analysis (ICA). ICA separated signals based on the assumption that the sources of signals are independent to each other; fortunately, this condition is usually satisfied in communications systems [7], since the different signals are generated independently and differ from each other by coding, modulation schemes, ..., hence, they are (typically) independent.

During the process of signal separation, mixing matrix and separation matrix are estimated.
The mixing matrix, which describes how signals are mixed together and how noise involved, is equivalent to the channel matrix. That means after the signal separation process, the information about channel condition are available. As a result, the function of channel estimation can all be done through blind signal separation.

The ICA needs to examine mixtures from several independent observations (mixing signals) from multiple received antennas. Let S be the source signals, A be the mixing matrix, and X be the mixed signals, then

$$X = AS$$

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

$$Y = WX = W(AS) = (WA)S$$

By observing the above equation, it is apparent that the condition $WA = I$ must stand. There are many ICA algorithms proposed to find W adopting different types of measurements. One of the popular algorithm is Fast-ICA, which use the following update rules [6]

$$W^t = E[g(Y^TY)] - E[g'(Y^TY)]W$$

where $g(u)$ is a non linear function. JADE (Joint Approximate Diagonalization of Eigenmatrices) is another famous ICA algorithm [7]. 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 Flowchart of Fast-ICA and JADE algorithm is shown in Appendix A.

II- THE PROPOSED BLIND RECEIVING SYSTEM BASED ON ICA

In this section, the blind receiving system will be designed based on BSS which adopting the ICA receiver as the first stage of receiving system. The ICA receiver estimates the received communication signals simultaneously even the signals are occupying the same frequency band, or have different or the same digital modulation schemes. These signals are mixed while they are propagating over the multipath fading channel.

The transmitting signals could be any type of communication signals. The BPSK signals types are proposed as the signals of transmission systems. Figure (1) illustrates the proposed ICA blind system. The ICA receiver equalizes the effect of the channel blindly during the signals estimation process and does not need an additional training sequence in data stream. Thus, using ICA algorithms for estimating the signals lead to an overall blind detection of the receiving signals. At the transmission side, the $N_s$ independent sources of communication signals. At sample interval $n$, the set of the signals are denoted by the vector $s(n)$

$$s(n) = [s_1(n), ..., s_{N_s}(n)]$$

where $n = 0, 1, 2, ..., N_s$, and $i$ is the index of the original sources of signals, $i = 1, 2, ..., N_s$. These signals will be transmitted over noisy multipath fading channel. At the reception side, the observations mixing signals $x(n)$ deliver to the ICA receiver via the reception antenna system. $x(n)$, can be presented as follows

$$x(n) = [x_1(n), ..., x_M(n)]$$

$j = 1, 2, ..., M$, where $j$ is the index of observation signals, $x_j(n)$ correspond to the observation signals acquired by the multi antenna system. It will be assumed that, the $M$ observations, are mixtures of the $N_s$ communication signals due to multipath fading channel effects. The model of observation $x_j(n)$ signals is defining as following

$$x_j(n) = A s_j(n) + w(n)$$

where, $w(n)$ is AWGN and $s_j(n)$ is the original

$$s_j(n) = [s_{j1}(n), ..., s_{jN}(n)]$$

BPSK signals matrix, the mixing matrix $A$ represents the fading channel matrix. For the quasi-stationary channel type (i.e., the parameters of the wireless channel remain unchanged over the period of the signal processing frame), the model of fading channel as the following

$$A = \begin{bmatrix} a_1 & \cdots & b_1 \\ \vdots & \ddots & \vdots \\ a_n & \cdots & b_n \end{bmatrix}$$
The coefficients of $A$ have a Rayleigh distribution for amplitude and a uniform distribution for phase. The ICA receiver performed a blindly signals separation process for estimating the original signals adopting one of the ICA algorithms and equalized the effects of fading channel by estimating the separation matrix $W$ and applied it to the observation signals. Each estimated signal $\hat{s}_i(n)$ represents one of the original components of transmitted signals, as in the following

$$\hat{s}_i(n) = Wx(n)$$

(8)

An additional step is required for solving the order ambiguity inherent in ICA algorithms. This step is necessary for specifying the order of the ICA estimated signals then passing the ordered signals to their own specific branch of receiving system to complete the blind detection process.

The proposed approach for specifying the order of estimation signals is based on minimization the Euclidean distance between the receiving observation and the estimating signals. The only prior information available for the ICA receiver is the arrangement of the incoming receiving signals, assuming that the first vector of observation matrix is the desired signal and the other vectors are the interference signals for the specific branch of the receiving system. The ICA receiver uses this information to perform the signal type specification, by minimization the Euclidean distance between the receiving observation and the estimating signals according to the following equation,

$$d = \sum_{i=1}^{N_f} ||\hat{b}_i - b_i||$$

(9)

where $N_f$ is the length of the block of data symbols, $\hat{b}_i$ is the estimated signal and $b_i$ is the received signal, $d$ is the Euclidean distance between the received and the estimated signals.

The ICA receiver is then forwarding the estimating signals through their own branch of the blind receiver to complete the detection processes for all signals in the same time. The ICA receiver adopted either Fast-ICA or JADE for blindly estimating the transmitting signals over quasi-stationary fading channel. The specification of the transmitted signals is illustrated in Table (1).

![Fig. 1. The Proposed Blind Receiving System.](image)

**Table (1): The specification of the transmitting the BPSK signals**

<table>
<thead>
<tr>
<th>Simulation parameters / BPSK signals</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulation scheme</td>
<td>BPSK</td>
</tr>
<tr>
<td>Frame length</td>
<td>10 ms</td>
</tr>
<tr>
<td>Bite rate</td>
<td>10-100 Mbps</td>
</tr>
<tr>
<td>Frequency band</td>
<td>4250-5250 MHz</td>
</tr>
<tr>
<td>Channel bandwidth</td>
<td>5 MHz</td>
</tr>
</tbody>
</table>
III- RESULTS AND DISCUSSION

The performance evaluation of the proposed blind receiving system is investigated through the computer simulation for blind estimating and detecting the received observation signals. The transmitting signals include two BPSK signals that transmitted over environment of noisy fading channel.

The ICA receiver performed a blindly signals separation process for estimating the original signals adopting one of the ICA algorithms (Fast-ICA or JADE algorithm) and equalize the effects of fading channel by estimating the separation matrix \( W \) and applied it to the observation signals.

The coefficients of \( A \) have a Rayleigh distribution for amplitude and a uniform distribution for phase. All the results are average of 100 independent trials, the mixing matrix \( A \) is generated independently for each run.

Figures (2) and (3) show the performance of the blind receiving system (as SNR vs. BER) for estimating and detection the BPSK signals of frame length consists of \((10^5, 10^6)\) samples for each signal. Figure (2) shows the performance of the Fast-ICA and JADE algorithms for \((10^5)\) frame length of transmitted signals, where the performance of Fast-ICA and JADE are very close to each other. At SNR of 12 dB, JADE had a BER of \((2 \times 10^{-6})\), Fast-ICA had a BER of \((4 \times 10^{-6})\). Both algorithms had a zero BER at SNR of 13 dB.

Figure (3) shows the performance of the Fast-ICA and JADE algorithms for higher frame length signals \((10^6)\) samples, the performance of both algorithms are nearly identical, at SNR of 12 dB, JADE had a BER of \((3 \times 10^{-6})\), Fast-ICA had a BER of \((3 \times 10^{-6})\). Fast-ICA algorithm had a zero BER at SNR of 14 dB, while JADE had a zero BER at SNR of 13 dB.

Fast-ICA and JADE are both block-based ICA algorithms, i.e., the entire received observation signals are used at every iteration in order to optimize the objective function that corresponds to a measure of independence. According to the previous results, the performance of both tested algorithms improve as the number of samples in the signals frame are increasing, because the statistical independence is easier to establish for larger number of samples. Where Fast-ICA algorithm criteria for blind signals separation is based on maximization the kurtosis of the components, while JADE algorithm criteria is based on diagonalization of cumulate matrices for blindly estimating the signals. The previous results prove that both criteria of the Fast-ICA and JADE algorithms can successfully adopted for blindly estimation the BPSK signals for different number of samples in the signals frame lengths over noisy fading channel.
the desired signal is higher than the interference signal for specific detection system. For SIR as performance comparison of the Fast-ICA and JADE algorithms adopting by ICA receiver for estimating the BPSK signals for different number of samples in the signal frame lengths \( N_f \), where \( N_f \) is varied from \( 10^5 \) to \( 10^6 \) samples with step size \( 10^5 \). The resulted average SIR vs. frame length is shown in Figure (4) for SNR of (10 dB), the two algorithms performed closely for range of number of samples of \((10^5 - 8 \times 10^5)\). For higher number of samples Fast-ICA outperformed JADE algorithm. For the range of number of samples of \((10^5 - 8 \times 10^5)\), Fast-ICA and JADE algorithms had a nearly SIR of (26-28 dB). For signal frame length of \((10^6)\) samples, JADE had a SIR of 38 dB, Fast-ICA had 35 dB, i.e., Fast-ICA is superior to JADE for longer signals frame length. This is because Fast-ICA optimization criteria based on kurtosis of the signals components is easier to establish for a large number of samples. The results suggest that, Fast-ICA algorithm has better capability in dealing with quasi-stationary fading channel within longer signals frame lengths.

**Table (2): Average Computation Times Comparison.**

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Time (105 Samples)</th>
<th>Time (106 Samples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JADE</td>
<td>25.453 sec.</td>
<td>190.239 sec.</td>
</tr>
<tr>
<td>FAST-ICA</td>
<td>62.239 sec.</td>
<td>626.812 sec.</td>
</tr>
</tbody>
</table>

### IV- Conclusions

This work considers the issue of designing blind receiver system based on ICA. In communications, the available bandwidth is both finite and scarce, and the need for higher data rates is incessant, the ICA offering 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. The proposed blind receiving system based on ICA algorithms is used for BPSK blind signals detection. The BPSK signals are transmitted over quasi-stationary channel. For BPSK blind signals detection of \((10^5, 10^6)\) samples frame length, the performances of Fast-ICA and JADE algorithms are close to each other.

### APPENDIX A

The Flowcharts of Fast-ICA and JADE algorithm are shown in Figure (5),(6) respectively.

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![Fig. 4. Performance of the blind receiving system in the presence of interferers over quasi-stationary channel.](image)

![Fig. 5. Flowchart of Fast-ICA algorithm.](image)
REFERENCES


