OFDM Based Doppler Spread Estimation in MIMO Channel

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Abstract— In the current technological development the radio frequency front-end architectures used in radar and digital communication technology are becoming more and more similar. OFDM has been applied for various wireless communication systems in the last decade. Because of its tremendous success in digital video broadcasting (DVB) and wireless local area networks (WLANs), it is now considered for broadband wireless systems for both fixed and mobile applications such as wireless metropolitan area networks (WMANs), mobile broadband wireless access (MBWA) and proposed fourth generation (4G) cellular systems. We presented an architecture of OFDM with the help of 32-QAM and 128-IFFT/FFT which can easily reduce the Bit Error Rate(BER) n improves the performance of Signal-to-Noise Ratio. Reduction in BER found to be satisfactory when compared with previous work. In our results it can be seen that as Signal-to-Noise Ratio increases the Bit Error Rate (BER) decreases. Channel estimation has been more effectively done using the approach implemented in the dissertation.

Keywords— ***OFDM, Doppler Estimation.***

I. INTRODUCTION

In the current technological development the radio frequency front-end architectures used in radar and digital communication technology are becoming more and more similar. In both applications more and more functions that have traditionally been accomplished by hardware components are now being replaced by digital signal processing algorithms. Moreover, today's digital communication systems use frequencies in the microwave range for transmission, which are close to the frequency ranges traditionally used for radar applications. This technological advancement opens the possibility for the implementation of joint radar and communication systems that are able to support both applications on one single platform while utilizing a common transmit signal. A typical application area for such systems would be in the intelligent transportation networks, which require the ability of inter-vehicle communication as well as reliable environment sensing.

OFDM has been applied for various wireless communication systems in the last decade. Because of its tremendous success in digital video broadcasting (DVB) and wireless local area networks (WLANs), it is now considered for broadband wireless systems for both fixed and mobile applications such as wireless metropolitan area networks (WMANs), mobile broadband wireless access (MBWA) and proposed fourth generation (4G) cellular systems [1]. Those systems however, should be capable of working efficiently in wide range of operating conditions, such as large range of mobile subscriber station (MSS) speeds, different carrier frequencies in licensed and licensed-exempt bands, various delay spreads, asymmetric traffic loads in downlink and uplink and wide dynamic signal- to-noise ratio (SNR) ranges.

The aforementioned reasons motivated the use of adaptive algorithms in new generation wireless communication systems. Adaptation aims to optimize wireless mobile radio systems performance, enhance its capacity and utilize available resources in an efficient manner. However, adaptation requires a form of accurate parameter measurements. One key parameter in adaptation of mobile radio systems is the maximum Doppler spread. It provides information about the fading rate of the channel. Knowing Doppler spread in mobile communication systems can improve detection and help to optimize transmission at the physical layer as well as higher levels of the protocol stack [2]. Specifically, knowing Doppler spread can decrease unnecessary handoffs, adjust interleaving lengths to reduce reception delays, update rate of power control algorithms, etc. In addition, in OFDM systems, if the channel varies considerably within one OFDM symbol because of high MSS mobility, orthogonality between subcarriers is lost, leading to inter-carrier interference (ICI) [3]. Doppler information can help in selection of appropriate transmission profiles that are immune to ICI and hence the overall system performance will be improved.

II. BACKGROUND AND LITERATURE SURVEY

Various methods based on the auto-correlation function (ACF) have been used to estimate the Doppler spread f_d in single carrier systems [4]. In OFDM systems, the autocorrelation between the repeated parts of the symbol due to cyclic prefix (CP) is exploited in [5] to estimate the Doppler spread.

However, adaptive OFDM systems employ a form of variable CP size selection according to the delay spread of the channel. The part of the CP that is undisturbed by the multipath channel may be small especially when the environment causes large delay spread. This will degrade estimation greatly. Moreover, the results presented shows that the algorithm is biased at low and medium Doppler values, and gives good estimates at very high velocities which is less likely to occur. The scheme is also sensitive to SNR variations. In OFDM systems, channel estimates are often obtained in frequency domain. By obtaining the ACF of a certain subcarrier over several symbols, f_d can also be estimated [6]. However, every subcarrier will have noise perturbation due to additive white Gaussian noise (AWGN) and ICI. In this paper, we overcome this bias by performing inverse fast Fourier transform (IFFT) to the channel estimates and then using the few obtained channel taps to get f_d .

Some referred literature papers are discussed below:

A) Tevfik Y¨ucek, Ramy M. A. Tannious, and H¨useyin Arslan, “Doppler Spread Estimation for Wireless OFDM Systems”, IEEE/Sarnoff Symposium on Advances in Wired and Wireless Communication, 2005

Author present a method for estimating the Doppler spread in mobile orthogonal frequency division multiplexing (OFDM) systems. The estimation is based on finding the autocorrelation function of time domain channel estimates over several OFDM symbols. In OFDM systems channel estimation is popularly performed in frequency domain. Channel frequency response estimates are affected by noise and inter-carrier interference (ICI). As a result, Doppler estimates based on frequency domain channel estimates will be affected significantly. Author show that use of channel estimates in time domain can greatly improve the performance of Doppler estimates. The channel impulse response (CIR) can be obtained by taking IDFT of the channel frequency response (CFR). Consequently the proposed method will reduce processing time and memory usage. Computer simulations support our claim for a broad range of Doppler spread and signal-to-noise ratio (SNR) values in Rayleigh fading channels [7].

B) Yoke Leen Sit, Christian Sturm, and Thomas Zwick, “Doppler Estimation in an OFDM Joint Radar and Communication System”, Proceedings of the 6th German Microwave Conference, IEEE 2011

This paper propose a processing algorithm that allows for estimating the velocity of multiple reflecting objects with standard OFDM communication signals is discussed. This algorithm does not require any specific coding of the transmit data. The technique can be used in combination with a range estimation algorithm in order to implement active radar sensing functions into a communication system for vehicular applications. This scheme operates regardless of the transmitted signal information and coding by processing the symbols that compose the OFDM symbols directly instead of processing the baseband signals. Therefore the algorithm can be applied in combination with the transmission of arbitrary user data and is able to resolve multiple reflecting objects with a high dynamic range and low sidelobe levels [8].

C) J.Tao, J. Wu, and C. Xiao, “Doppler Spread Estimation for Broadband Wireless OFDM Systems Over Rician Fading Channels”, Int J Wireless Inf Networks (2009)

In this paper, Author present a new Doppler spread estimation algorithm for broadband wireless orthogonal frequency division multiplexing (OFDM) systems with fast time-varying and frequency-selective Rayleigh or Rician fading channels. The new algorithm is developed by analyzing the statistical properties of the power of the received OFDM signal in the time domain, thus it is not affected by the influence of frequency-domain inter-carrier interference (ICI) introduced by channel variation within one OFDM symbol. The operation of the algorithm doesn’t require the knowledge of fading channel coefficients, transmitted data, or signal-to-noise ratio (SNR) at the receiver. It is robust against additive noise, and can provide accurate Doppler spread estimation with SNR as low as 0 dB. Moreover, unlike existing algorithms, the proposed algorithm takes into account the inter-tap correlation of the discrete-time channel representation, as is the case in practical systems. Simulation results demonstrate that this new algorithm can accurately estimate a wide range of Doppler spread with low estimation latency and high computational efficiency [9].

D) A. Doukas, G. Kalivas, “Doppler Spread Estimation in Frequency Selective Rayleigh Channels for OFDM Systems ”, IEEE 2011

In this paper, Author present a method for estimating the Doppler spread (DS) in Wireless Local Area Networks (WLAN) using Orthogonal Frequency

Division Multiplexing (OFDM). DS gives a measure of the fading rate of the wireless channel, which can be used to adjust the channel estimation rate and create specifically designed channels estimators to combat Inter-Carrier Interference (ICI) induced due to loss of orthogonality that DS imposes on OFDM systems. The estimation is based on the autocorrelation function of time domain channel estimates over two OFDM symbols and since that most of the receiver algorithms require knowledge if the receiver moves or not we divide the operation region into two modes: still mode(S-mode) and moving mode (M-mode). The estimation accuracy, examined in environments with different PDPs, including channel sparsity, using several constellation schemes is quite accurate from low SNR values of 5 dB [10].

E) Y. Choi, O..C.Ozdural, H. Liu, and S.Alamouti, "A Maximum Likelihood Doppler Frequency Estimator for OFDM Systems", IEEE International Conference on Communications, 2006. ICC '06.

This paper derives a maximum likelihood Doppler frequency estimator for orthogonal frequency division multiplexing (OFDM) systems in time-varying multipath channels.

The proposed scheme is a frequency-domain approach that utilizes pilot subcarriers, which are commonly implemented in most practical systems. Time-varying fading causes intercarrier interference (ICI) in OFDM systems. Thus, in the proposed estimator, the effect of ICI is taken into consideration with a proper model for accurate results. The estimator can be implemented using a finite impulse response (FIR) filter bank whose coefficients can be pre-calculated and stored in order to lower the computational complexity. Author evaluate various methods to improve the estimation accuracy and analyze their complexity-performance tradeoffs. They also derive the Cram´er-Rao bound and provide simulation results to quantify the performance of the proposed algorithm [11].

III. METHODOLOGY ADOPTED

Fig. drawn below depicts the setup of such a wi-fi based radar station. It extends a regular access point by a radar subsystem, which consists of a digital radar processing unit and an analog receiver (the latter can be the same as the access point's own receiver if it is full-duplex capable). The radar subsystem is connected to the access point at two positions: first, it has access to any data transmitted by the access point; and second the transmitting and receiving front-ends are synchronized to the same clock.

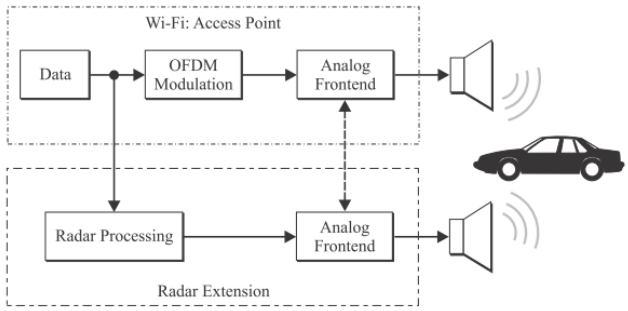


TABLE I
PARAMETERS OF THE OFDM SIGNAL RELEVANT TO THE RADAR PROCESSING

Value	Description
$\Delta f = 20\,\text{MHz}/64 = 312.5\,\text{kHz}$	Sub-carrier spacing
$T = 1/\Delta f = 3.2\,\mu\text{s}$	Symbol duration
$T_G = 1/4 T = 0.8\,\mu\text{s}$	Guard interval duration
$T_O = T + T_G = 4\,\mu\text{s}$	Total OFDM symbol duration
$N = 53$	Total number of carriers (including DC carrier)
$f_C = 5\,\text{GHz}$	Centre frequency

Table written above lists the relevant physical parameters of the OFDM signals used in 802.11a systems.

We will use the matrix representation for signal before transmission. Then at final stage matrix signal is further converted to transmitted signal. The system is configured such that the carrier with index 0 has the lowest frequency; therefore, the sub-carrier with the index k has the frequency

$$f_k = f_0 + k\Delta f.$$

This matrix representation helps a lot when analyzing the effect of OFDM signals in a radar environment. Assume the radar signal is first transmitted, then it is reflected from an object at range r and relative velocity v r and finally received.

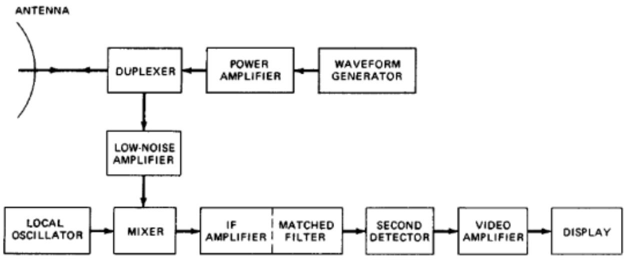
Since the receiver is synchronized with the transmitter, it is able to receive the signal exactly at the same time it is being transmitted. The received signal therefore is delayed by

$$\tau = 2r/c_0$$

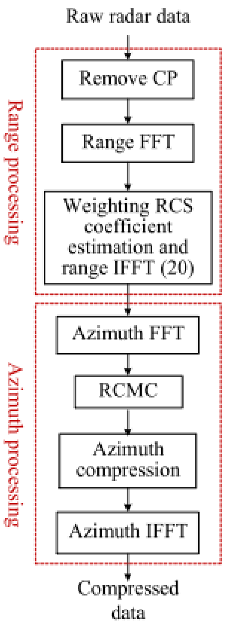
and shifted by a Doppler shift w.r.t. the transmit signal

$$f_D = f_C \frac{v_r}{c_0}.$$

This has two distinct effects on the matrix: the delay causes a phase shift, which depends on the sub-carrier's frequency.

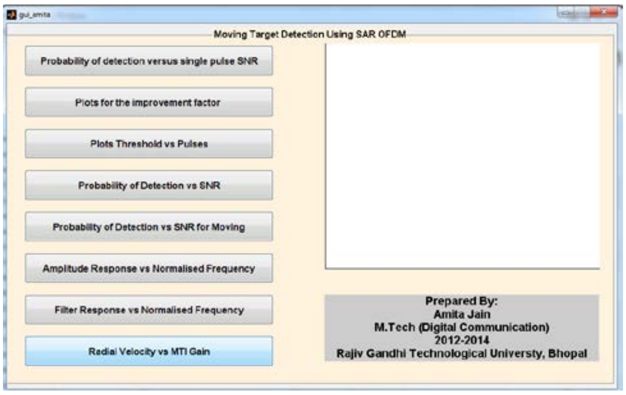


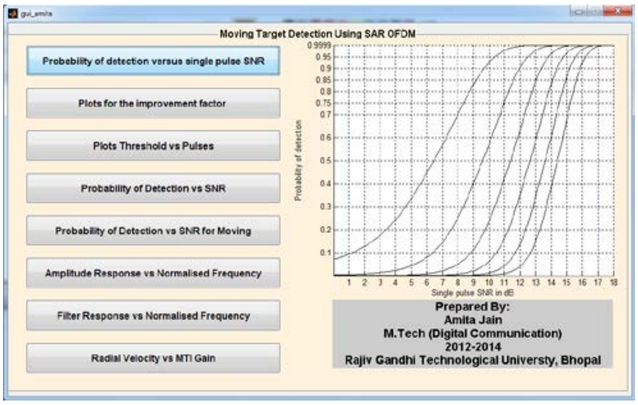
What we have done is "we have compress the raw data before being used for the transmission". The compression process is follow as per chart

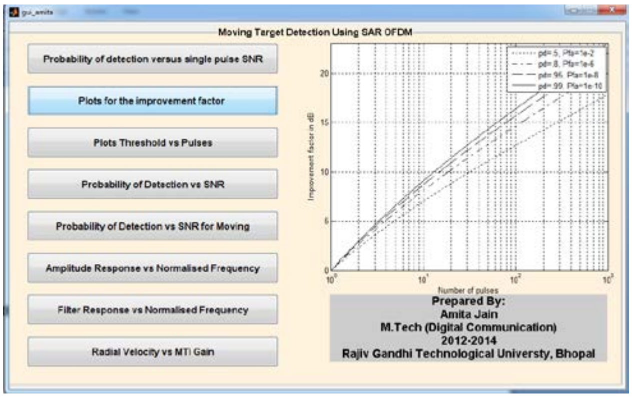


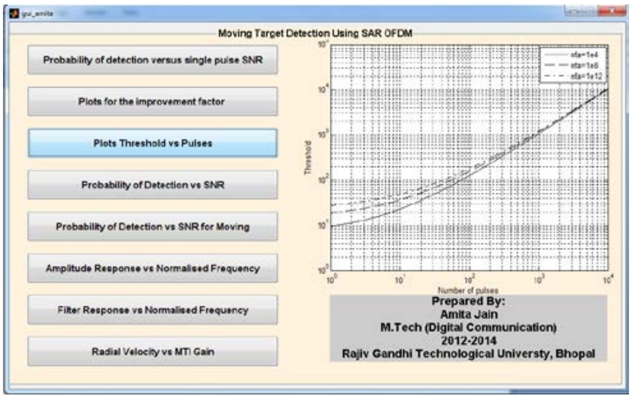
Therefore we have combine the two processes in our work, and the result set follows the above mentioned algorithm.

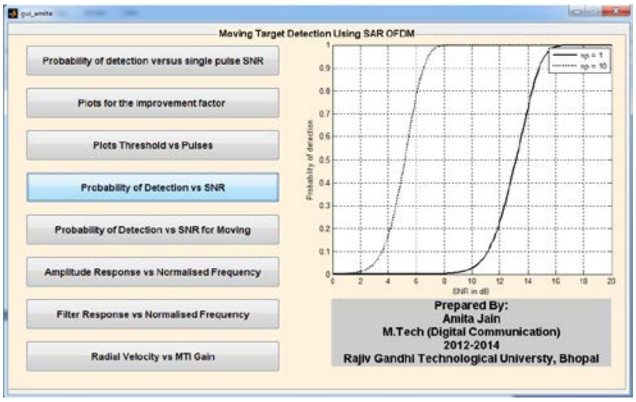
IV. RESULTS

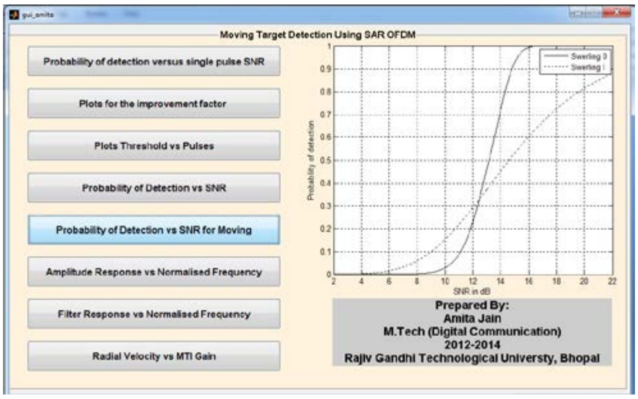


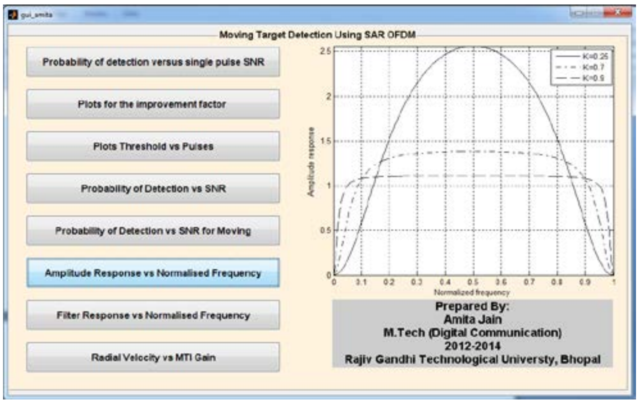


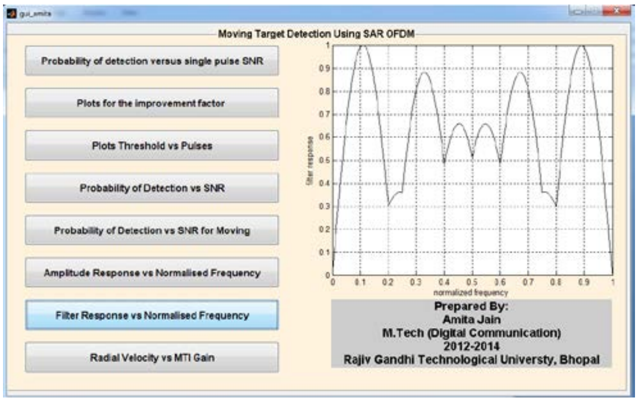


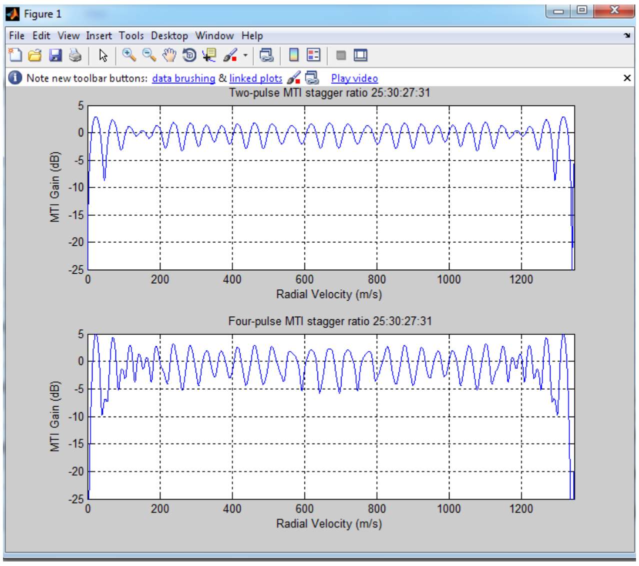












V. CONCLUSION

We presented an architecture of OFDM with the help of 32-QAM and 128-IFFT/FFT which can easily reduce the Bit Error Rate(BER) n improves the performance of Signal-to-Noise Ratio. The use of OFDM for Doppler Estimation in MIMO channel is presented.

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