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ICI Suppression Analysis Testbed in OFDM Signals

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Abstract: The relentless drive towards the development of faster vehicles on the ground has led to an increased demand for robust systems that can counteract the challenges inherent in the dynamic channel conditions. Orthogonal frequency division multiplexing (OFDM) is one of the leading modulation schemes in this space. However, the risk then becomes interference between carriers due to the presence of Doppler spread. This paper characterizes the ICI in OFDM signals and surveys various techniques to lessen or eliminate the ICI. Signals with OFDM are simulated in GNU Radio to get a frequency domain view of the signals at the transmitter and receiver end for the ICI caused due to Doppler spread. Also discussed are the various ICI suppression methods, their performance and how the ICI signal matches the estimated ICI. The research also touches on aspects of hardware deployment, and opening.

Keywords: Spectral efficiency, Doppler spread, OFDM, Intercarrier Interface.

I. INTRODUCTION

As the modern era witnessed the rapid growth of high-speed ground modes of transportation such as trains as well as automobiles, the urgency for tough communication systems that can offer connectivity, which hardly experiences any fluctuations even in the most likely shifting scenarios, is increasingly being felt. For these systems, orthogonal frequency division multiplexing (OFDM) is one of the elegant modulation techniques, which is very effective in combating multipath fading and provides a high spectral efficiency. Yet, the most dominant problem that encounters OFDM in these situations is caused by the Doppler spread i.e. Intercarrier Interference (ICI). Inter-carrier interference arises as the transmitter and receiver have a relative motion which results in a frequency offset between the subcarriers thereby leading to overlapping of the OFDM symbols and distortion. High-speed scenarios (e.g., trains or vehicles in motion); the Doppler In this case the Doppler effect worsens it even further, thus creating a very serious problem as far as signal quality is concerned. This research is going to study the effect of ICI in the high-speed ground vehicle environment for the OFDM signals and come up with different methods of reducing it. Features of the unsimulated system include simulating OFDM signals, creating ICI, applying ICI suppression measures, and analyzing possible hardware implementation. The remaining part of this research study will discuss the theoretical frameworks of OFDM and ICI, comparable literature analysis,

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methodological framework of this research, findings and discussions, and conclusion in terms of future research prospects addressing the challenges of ICI for high-speed OFDM systems this research aims at providing solutions for communication problems in modern transport systems.

II. SPECTRAL EFFICIENCY

Spectrum efficiency can be defined as the capacity to transmit or the amount of data that can be transmitted through a particular spectrum or bandwidth with low probabilities of transmission errors. Also referred to as system efficiency or bandwidth utilization; it holds that the spectral efficiency of a cellular network equals the highest number of bits of data that can be transmitted to a given number of users within a defined second while at the same time being able to meet a certain quality of service. Spectral efficiency in wireless communications can influence the speed depending on the number of users connected to it at a given time. That is why, in this case, the data transfer rate strongly correlates with such parameters as the transmission device's bandwidth and the transmitted signal, or the signal-to-noise power ratio. The other consequence is that the elevation in the signal-to-noise ratio also enhances spectral efficiency and channel capacity. In other words, it requires higher traffic to occupy the available operations spectrum.

III. DOPPLER SPREAD

The full form of 'API' stands for Application Programming Interface. APIs can be described as the standardized interfaces provided and developed by the Twitter organization as means for users to glean allowed information from the social platform in an automated manner. Through API request a user is able to directly request for a contact to Twitter's server and then obtain data as may be required such as for instance. A Tweet in terms of the Twitter profile, in our case a particular person posting his or her message. However, this implies that if the user wants to access the data in any form through application program interfaces, or API, then the user has to be authenticated by Twitter [5]. As going by this kind of prompting, before one can even use API, he/she must undergo various procedures to create a developer's account.

OFDM

The Orthogoal frequency division multiplexing OFDM is a Modulation that is used in Telecommunications Technology areas for Wireless Communications Technology such as Wi-Fi, 4G LTE, and Wireless Digital Television.

The total available BW is divided into large n

umbers of small subchannels that are orthogonal and with very little BW's. The various subchannels then involve normal digital modulation techniques which can include QAM or PSK depending on the level of complexity. These benefits take place due to the utilization of

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all the sub-channels simultaneously, hence making it possible for OFDM to transmit high data rates with reasonable immunity to fading and interferences.

Some of the benefits of OFDM include: it provides good results where there are multiple signals and/or signal selection in the network is favorable for high-speed data communication in wireless channels. It often entails an error correction coding to improve the dependability of services.

A. Solution Methodology

To ensure that all the limitations found in OFDM signals are fully addressed we employ a comprehensive and efficient approach in the project. Thus, our approach concerns the utilization of OFDM signals and motorized systems – the idea which is proclaimed as revolutionary and supposed too vast to eliminate all signal processing modules by 1D-CONV-CNN model developed in LabVIEW and improved during this work. It is expanded to include distinct components: Subcarrier Allocation and Modulation also makes sure that the available bandwidth is divided into multiple number of orthogonal subcarriers by using the DFT algorithm it has an interface where it connects with the LabVIEW receiver code which is very important as it makes it to be dynamic. However, the most severe disadvantage of

Carrier Interference of the transmitted and received signals. There are practical methods for reducing ICI as listed below. OFDM system is the problem of Inter-The above mentioned techniques for ICI elimination uses redundancy namely Frequency domain equalization, Time domain windowing, Pulse shaping, ICI self-cancellation, Maximum likelihood Estimation, Extended Kalman Filtering, Optimized Sinc Power Pulse OSPP etc;The information also spreads the information about the ill effects happening to the distortion techniques that can be minimized by the addition of penalty of reduced and transmission The performance of all the ICI suppression techniques was measured and presented in BER, SINR, and spectral efficiency. Simulation was done to analyze the performance of the techniques in order to minimize the ICI and improve the reliability of OFDM systems in high-speed scenarios. There were also other potential areas for future work and research recognised which include innovation of better and more flexible and dynamic ICI mitigator algorithms, accommodation and enhancement for fabrication into programmable hardware and finally testing and proving the best and efficient ICI mitigator on live experiments.

B. Problem statement

As much as the application of OFDM signals offers benefits in terms of provision of enhanced high speed ground vehicles, they face inter carrier interference due to Doppler spread. It also contains the aims of what has led to this ICI and at least two techniques that may be used to prevent this ICI as well as the development of new schemes in ICI suppression. Specifically, the goals and objectives of this work will involve; Developing a model that can analyse the

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OFDM waveform and come up with reasonable targets for ICI Conduct experiments with the model where the ICI in OFDM waveform will be experimented Conduct trials on this specific hardware for

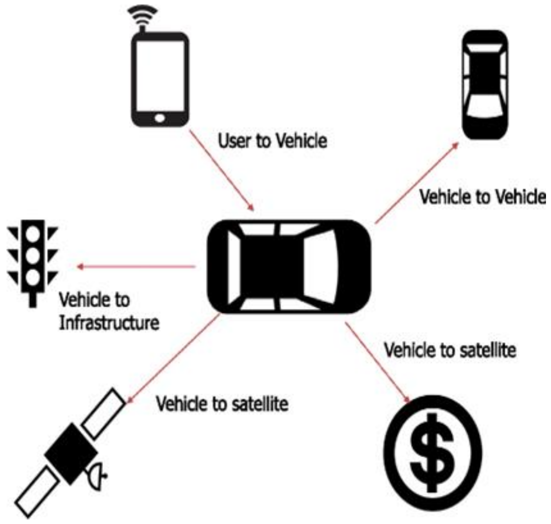

Fig. 01: vehicular spread from OFDM signal

apparatus with low mobility An exploration of existing literature on ICI cancellation techniques, then the formulation of an efficient ICI cancellation technique that can be implemented.

hardware in a low mobility environment Study ICI cancellation technique and propose a novel ICI suppression scheme.

IV. Results and Discussion

The study was the subject of simulations and analysis which showed how the Orthogonal Frequency Division Multiplexing (OFDM) system was affected by intercarrier interference (ICI) in high-speed ground mobile environments and also investigated strategies for mitigating these effects. This chapter outlines major discoveries and discusses their implications Impact on OFDM Signals: Simulations demonstrated that ICI induced by Doppler spread causes distortion and degradation especially when the velocity of vehicles is high or there are large frequency offsets. Representations of OFDM signals in the frequency domain indicated subcarrier overlap with spectral spreading across them leading to greater inter-symbol interference (ISI) which degraded overall signal quality. Techniques for Suppressing ICI Various methods including cyclic prefix (CP) insertion; frequency domain equalization (FDE); ICI self-cancellation (SC);ISI caused by multipath propagation but offered limited suppression of ICI induced by Doppler spread.

FDE in mitigating the effects of static or slowly varying channel conditions, some techniques were effective, however, they did not work well in scenarios with high Doppler spreads.

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Through redundancy in OFDM symbols, SC techniques have shown improved performance in canceling ICI but the complexity and computational overhead may be too much for them to handle. TDE methods are able to suppress ICI effectively in situations where there is rapid movement within channels or when there are large numbers of different frequencies present over time; this offers time-domain distortion immunity as well as strong robustness against such kinds of problems occurring at any specific point along said scenario – thus providing an appropriate solution for these particular cases.

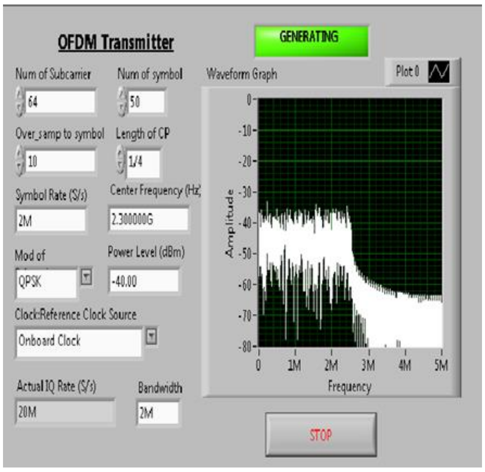

FIG 02: LABVIEW FRONT PANEL OF THE OFDM TRANSMITTER.

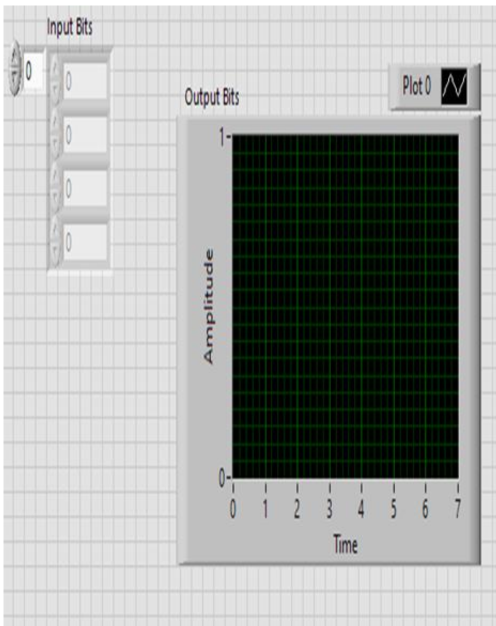

Fig 03: Manchester coding: Output bits: No waveform when input bits are given 0

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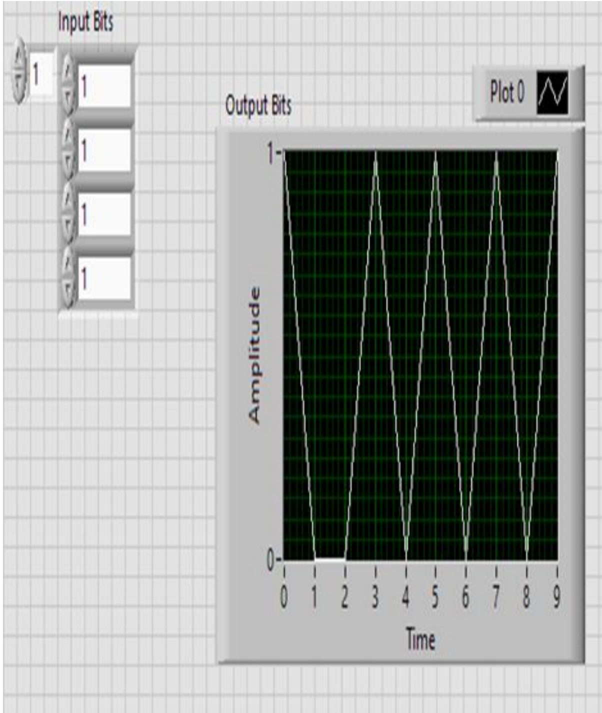

Fig 04: Manchester coding: Output bits: -1 to 1, 2 to 9 when Input bits are given 1

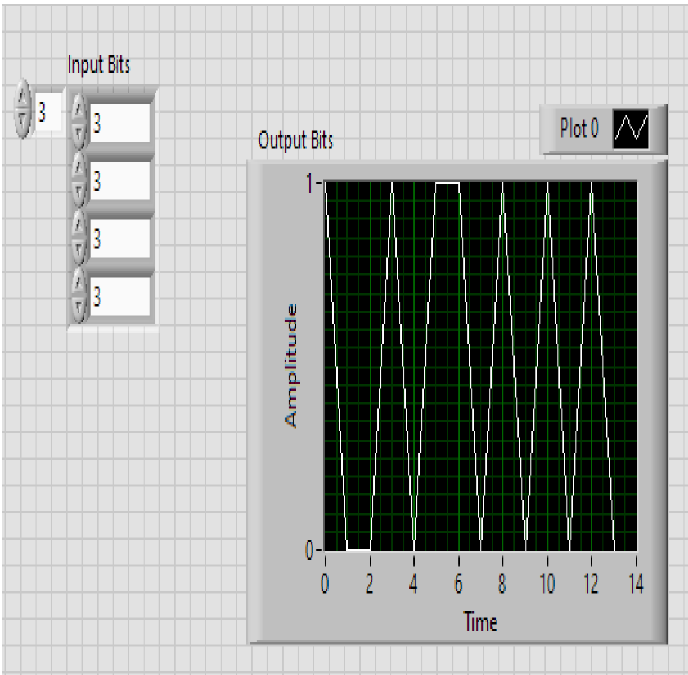

Fig 05: Manchester coding: Output bits: -1 to const. 2, 4 to const. 6.5 to 12.5 when Input bits are given 3

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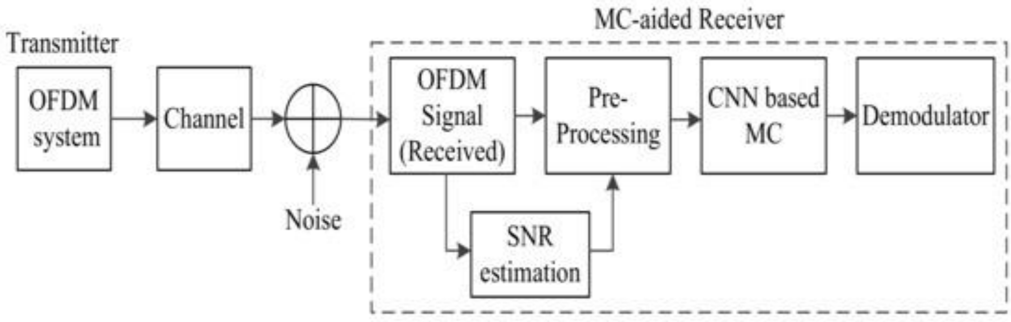

Fig 6. Framework of the proposed CNN-based MC system [12]

V. Conclusion

Summing up, this research shows how intercarrier interference (ICI) affects the reliability and performance of Orthogonal Frequency Division Multiplexing (OFDM) systems in high-speed ground vehicle environments. ICI caused by Doppler spread distorts OFDM signals which results in spectral spreading, inter-symbol interference (ISI) and degradation of signal quality. This means that communication systems operating under such conditions should use strong ICI suppression methods. Additionally, after analyzing different ways to suppress ICI like cyclic prefix insertion or frequency-domain equalization among others, we found out there are trade-offs between complexity, performance and implementation feasibility. Even though there wasn't one "best" method, adaptive strategies such as TDE showed potential at dealing with the changing natures of ICI while keeping communication strong. As we move from simulating things on computers over to making them exist in reality with electronics and circuit boards, it becomes clear that we need ways to deal with how long stuff takes to figure out twice as many things happen every second and using everything we have in a smart way. Doing these things with actual machines and gadgets will help us put them into the real world where they belong and see if they work when cars are driving really fast.

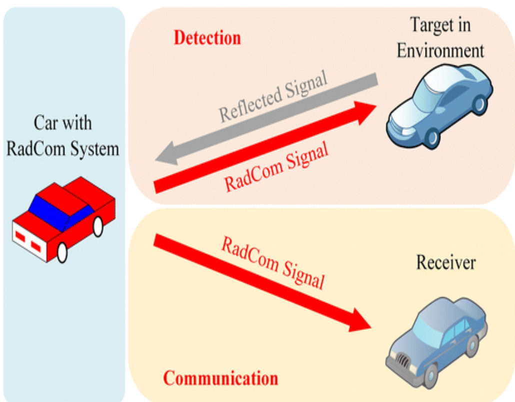

Fig 07 RadCom system in vehicle networking scenario

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The phase noise (PN) effect on orthogonal frequency division multiplexing based multi-node transmission for small cell backhaul is studied [1]. The first part of this paper introduces a method enhancing the contrast of an input image while simultaneously compressing the dynamic range of that one [2]. In this paper, we consider the high-speed railway (HSR) communication bases on the long-term evolution for railway (LTE-R) platform. Since the large Doppler spread is introduced due to the movement of the train, the orthogonality of subcarriers is destroyed resulting in the inter-carrier interference (ICI) [3]. In this paper, a novel CSI estimation method, ParEst, is proposed, which estimates the CSI from multiple transmitting antennas simultaneously [4].

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