Multiple Transmissions of OFDM Signals using Index Modulation

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Abstract— The Index modulation thought has attracted appreciable research interests within the past few years. The primary one, termed OFDM with hybrid in-phase/quadrature index modulation (OFDM HIQ-IM), explores the I- and Q-dimensions put together for index modulation, permitting transmission of additional variety of index modulation bits in every subcarrier cluster. The second, termed linear constellation precoded OFDM-IQ-IM (LP-OFDM IQ-IM), spreads data symbols across two adjacent active subcarriers through linear constellation precoding to increased additional diversity gain. The weight of the signal will be adjusted to the required amount which is needed. This weight updating can be done by using the adaptive algorithm. The adaptive algorithm includes the filtering using adaptive filter and the determination of the Mean Square Error value for the multiple antennas. This will improve the performance of the signal received at the receiver. By maximizing the minimum square Euclidean distance, two completely different realizations of LP-OFDMIQ-IM square measure derived, that result in a revolved and a diamond shaped constellation, severally. The projected OFDM-HIQ-IM and LP-OFDM-IQ-IM, as disclosed by each theoretical analyses and laptop simulations, modify low-complexity detection and exhibit superior error rate performance over the prevailing OFDM-IM schemes.

Key words: OFDM, IM, QSM, LCP

I. INTRODUCTION

INDEX modulation (IM) is a recently-emerging concept, which, as its name suggests, refers to a category of modulation techniques that rely on the index (es) of some medium to modulate information bits, where the medium can be either actual, such as antenna and frequency carrier, or virtual, such as space-time matrix, antenna activation order, and virtual parallel channels [1], [2].

To improve the SE, a natural way is to activate more antennas and use the antenna combination for indexing. Such idea has been realized by the so-termed generalized spatial modulation (GSM), in which multiple active antennas can transmit only one [6] or multiple modulated symbols [7] depending on the configuration of RF chains. Another effective way to improve the SE is to expand the spatial constellation domain to a new dimension by utilizing both in-phase (I-) and quadrature (Q-) components. This scheme, called quadrature spatial modulation (QSM), transmits an additional base-two logarithm of the number of transmit antennas bits without adding any new RF chain [8]. Naturally, by allowing multiple RF chains to transmit multiple modulated symbols, the SE can be further improved with QSM [9]. Besides the aforementioned two schemes, the enhanced spatial modulation (ESM) scheme can also improve the SE by using multiple distinguishable signal constellations [10].

Orthogonal frequency division multiplexing with index modulation (OFDM-IM), which is a modification of OFDM, is a promising frequency-domain IM technique [2]. Similar to GSM, OFDM-IM activates a subset of subcarriers to transmit M-ary modulated symbols and uses the subcarrier activation patterns (SAPs) to convey additional information. This principle originally appeared in 1999 [2], which is motivated by the parallel combinatory spread spectrum concept. As the development of SM, OFDM-IM has been also developed. The first scheme that exploits a similar idea is called subcarrier index modulation OFDM (SIM-OFDM) [2], in which half of the subcarriers are activated according to the incoming information bits and some of the other subcarriers are dedicated to control signaling. Similar to classical OFDM, OFDM-IM is able to exhibit single-symbol decoding complexity when employing the log-likelihood ratio (LLR) [14] or low-complexity maximum-likelihood (ML) [15] detection.

Performance comparison with classical OFDM has been made in the literature for both uncoded and coded scenarios, where the available results show that OFDM-IM enjoys lower bit error rate (BER) [4], higher achievable rate [6], and higher EE [8]. Moreover, since only partial subcarriers are active, OFDM-IM has the potential to suppress the intercarrier interference [9], which usually arises in OFDM systems. OFDM with generalized index modulation (OFDM-GIM) is proposed, where the number of active subcarriers is variable and more SAPs are encoded for indexing.

II. PROPOSED METHOD

In this section, two new schemes to enhance the performance of OFDM-IM with a focus on SE and Diversity gain are proposed respectively. The physical characteristics of the wireless channel present a fundamental technical challenge for reliable communications. This is mainly because of the time varying multipath nature of the channel. Multipath propagation is a result of the propagation of the signal over a number of different paths due to reflections of the signal by mountains, buildings, and other objects. Because of the time variations in the structure of the wireless channel, the nature of the multipath varies with time. This results in signal fading over time. The amplitude variations in the received signal are due to the destructive and constructive addition of multiple signal paths between receiver and transmitter.

The model for the implementation of the OFDM transmitter is basically consists of the following blocks:

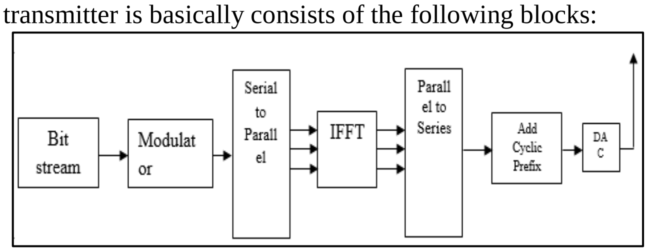

Fig. 2.1: Basic OFDM Transmitter

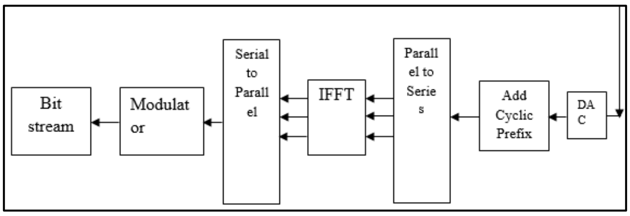

Fig. 2.2: Basic OFDM Receiver

The serial to parallel converter receive the M serial bits to be transmitted, and those bits are divided into N sub-blocks of mn bits each sub-block. Those N sub-blocks will be mapped by the constellation modulator.

The M-QAM encoder converts input data into complex valued constellation points, according to a given constellation, 4-QAM, 16-QAM, 32-QAM and so on. The amount of data transmitted on each subcarrier depends on the constellation. The 4QAM and 16QAM transmit two and four data bits per subcarrier respectively, which constellation to use depends on the quality of the communications channel.

A. Hybrid IQ-OFDM

The first proposed scheme is called OFDM with hybrid in-phase/quadrature index modulation (OFDM-HIQ-IM), which selects the elements from the grid formed jointly by the I- and Q- dimensions for indexing. The idea is motivated from the property that the IM bits have a stronger protection than the ordinary modulation bits and from the deficiency of OFDM-IQ-IM that when the number of SAPs is not equal to an integer power of two, a considerable portion of SAPs have to be discarded due to the independent indexing of I- and Q- components. To solve this problem, OFDM-HIQ-IM only includes those with the equal number of I- and Q- components for indexing, allowing the transmission of one more IM bit in each subcarrier group than OFDM-IQ-IM in most cases.

B. Linear Procoded IQ-OFDM

The second proposed scheme, which is called linear constellation precoded OFDM-IQ-IM (LP-OFDM-IQ-IM), is motivated from the linear constellation precoding (LCP) technique, which was originally proposed for OFDM systems to achieve the maximum diversity gain and includes the CIOD as its special case [41], [42]. To the best of our knowledge, only [43] attempts to employ the LCP to enhance the diversity performance of an IM system, namely SM-OFDM. However, a direct application of this method to OFDM-IM related systems may be not efficient since in those systems, the minimum squared Euclidean distance of the transmitted signal set additionally depends on IM. Specially, in LP-OFDM-IQIM, the subcarrier activation effect is considered in the design and the LCP applies to the I- and Q- components of OFDM-IM signals simultaneously.

C. Adaptive Algorithm

Averages of both the data and the correction terms are obtained to find the updated value of the tap weights of the speech signal. Algorithm that changes its behavior based on the information available at the time it is running. This field includes the families of least mean squares, recursive least mean squares and Kalman filters.

Least mean squares (LMS) algorithms are a class of adaptive filter used to mimic a desired filter by finding the filter coefficients that relate to producing the least mean square of the error signal (difference between the desired and the actual signal). It is a stochastic gradient descent method in that the filter is only adapted based on the error at the current time.

The adaptive filter calculates the output signal y(n) by using the following equation

$$y(n) = y(n) = uT(n) \cdot w(n)$$

where

uT(n) is the filter input vector.

w(n) is the filter coefficients vector.

D. Adaptive Filtering of Signals

An adaptive filter is a system with a linear filter that has a transfer function controlled by variable parameters and a means to adjust those parameters according to an optimization algorithm. Because of the complexity of the optimization algorithms, almost all adaptive filters are digital filters. Adaptive filters are required for some applications because some parameters of the desired processing operation (for instance, the locations of reflective surfaces in a reverberant space) are not known in advance or are changing. The closed loop adaptive filter uses feedback in the form of an error signal to refine its transfer function. Generally speaking, the closed loop adaptive process involves the use of a cost function, which is a criterion for optimum performance of the filter, to feed an algorithm, which determines how to modify filter transfer function to minimize the cost on the next iteration. The most common cost function is the mean square of the error signal.

As the LMS algorithm does not use the exact values of the expectations, the weights would never reach the optimal weights in the absolute sense, but a convergence is possible in mean. That is, even though the weights may change by small amounts, it changes about the optimal weights. However, if the variance, with which the weights change, is large, convergence in mean would be misleading. This problem may occur, if the value of step size is not chosen properly.

If is chosen to be large, the amount with which the weights change depends heavily on the gradient estimate, and so the weights may change by a large value so that gradient which was negative at the first instant may now become positive. And at the second instant, the weight may change in the opposite direction by a large amount because of the negative gradient and would thus keep oscillating with a large variance about the optimal weights.

III. Result and Discussion

The input signal is obtained by giving the input value to the ofdm system. The random value is given as the input value.

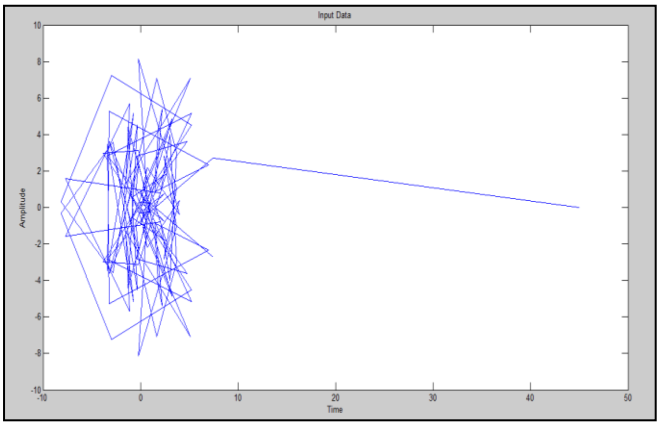

Fig. 3.1: The Input signal

The value that is given as the input to the system will form many waves signals that may be in the form of sine wave or loop wave.

A. *Spectral Efficiency of HIQ-IQ-OFDM*

The spectral efficiency of the Hybrid inphase and quadrature orthogonal frequency division multiplexing are obtained by using the two types of methods used in the ofdm system. The value of the two methods varied due to the usage of the different methods of modulation techniques used before the transmission

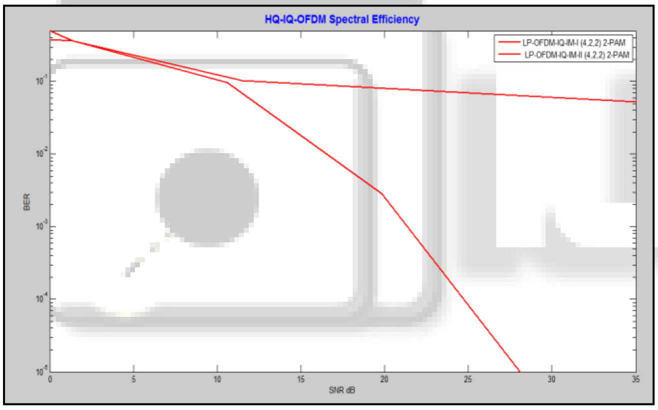

Fig. 3.2: Spectral Efficiency of Hybrid IQ OFDM

The spectral efficiency of the hybrid inphase and quadrature OFDM system produces higher spectral efficiency than the existing system. It also gives increased diversity gain.

B. *Spectral Efficiency of LP-IQ-OFDM*

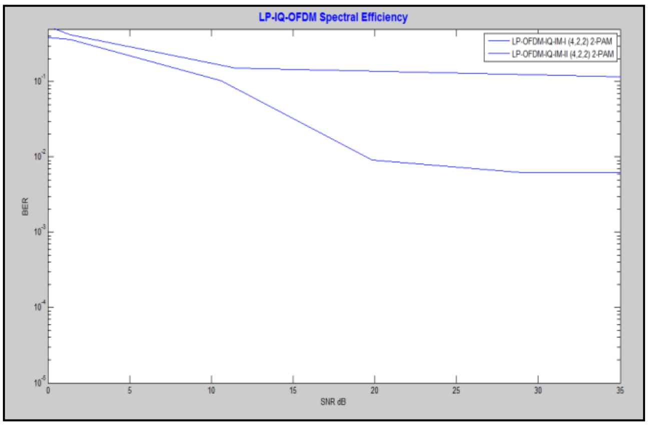

Fig. 3.3: Spectral Efficiency of LP IQ OFDM

The signals are then given to the channel or medium for the transmission of the signal to the receiver. After receiving the signal at the receiver section, the reverse operation will be done. This reverse operation is known as the demodulation technique.

The spectral efficiency of the Linear constellation precoder inphase and quadrature orthogonal frequency division multiplexing are obtained by using the two types of methods used in the ofdm system.

C. *Mean Square Error after Filtering*

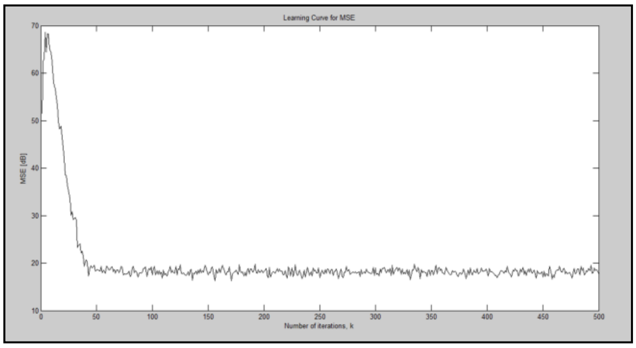

Fig. 3.4: Curve for Mean Square Error

The existing method of the transmission of the ofdm signal has a better performance, efficiency but the value will be decayed when the noise added. The existing system produces lower spectral efficiency and it also produces higher transmission delay and diversity gain.

D. *Output Signal*

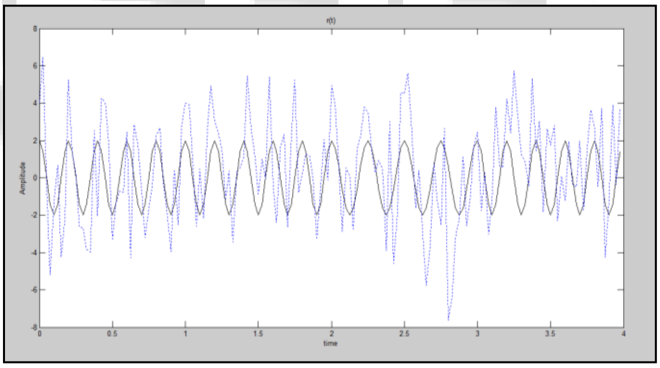

Fig. 3.5: Output signal

The output signal produced by the existing method for various amount of subcarriers are calculated and they are plotted in the graph that is given above figure. The signal r(t) is the updated signal obtained after filtering the received signal. This updated signal will reduces the loss during the transmission of the signal and it also increases the diversity gain value of the signal at the receiver side. The signals that are received by the different receivers and they also have different gain values of the received signal. Antenna diversity, also known as space diversity or spatial diversity is any one of several wireless diversity schemes that uses two or more antennas to improve the quality and reliability of a wireless link.

IV. Conclusion

In this paper, thus LPOFDM- IQ-IM is proposed to enhance the diversity gain and also the straight line BER performance of OFDM-IM systems, severally. The proposed schemes may be more combined to reap each of their benefits. An asymptotically tight edge has been derived and two low-complexity near-optimal detectors have been designed for OFDM-HIQ-IM. LP-OFDM-IQ-IM combines a try of I/Q-symbols linearly, achieving an extra diversity gain over OFDM-IM, OFDM-IQ-IM, and OFDMHIQ- IM. The received signal is filtered using the adaptive filtering algorithm which uses the adaptive filter for the filtering of the signal and it reduces the mean square error value of the signal. The output signal obtained from after the filtering of the signal produces the signal similar to the transmitted signal. Simulations are conducted and results have verified the analysis and also the benefits of LP-OFDM-IQ-IM over classical OFDM similarly as existing OFDM-IM schemes.