KALMAN Filter with STTC Technique for the Reduction in Bit Error Rate in MIMO-OFDM

Madan Pal Singh
Er.Satnam Singh Dub
Sri Sai College of Engineering and Technology, Pathankot, Punjab, India

Abstract: -The ODFM is the orthogonal division frequency multiplexing which is used to transmit the data at high rate. The bit error rate is the major issue of OFDM due to dynamic nature of the network. The space-time trellis coded is the extra codes which reduce bit rate error over the multipath fading channel. This research work is based on wireless channel to reduce bit error rate using space-time trellis codes. In this research work, the bit error rate is reduced over the wireless channels using space time trellis codes and KALMAN filters. The simulation of the proposed modal is performed in MATLAB and results shows that bit error rate is reduced in the network

KEYWORDS: -ODFM, Trellis Codes, KALAM

I.INTRODUCTION

A spectrally efficient digital modulation mechanism in which multiple carriers are present that are mutually orthogonal to each other over particular time is known as Orthogonal Frequency Division Multiplexing(OFDM) system. A sub-carrier is known as a carrier in which a pair of sine wave as well as cosine wave is involved. There are several closely spaced modulated carriers present within an OFDM signal. On either side, the sidebands are spread in case when modulation of any form is applied to the carrier. In order to demodulate the complete data successfully, it is important for the receiver to receive the complete signal [1]. There is a need to space the signals close to each other for transmission such that a filter can separate them easily in previous signal systems. Amongst traditional signals, there is a need to involve a guard band. However, in OFDM systems this is not required. Even though there is an overlap of the sidebands from each carrier, there is no interference involved within the signals that are received here since they are orthogonal with respect to each other. The carrier spacing that is equal to reciprocal of the symbol period is used here. A propagation medium whose characterization is done through the wave phenomena is known as a mobile radio channel. The propagation phenomena can be can be described in proper manner with the help of exact information of geometric dimensions as well as electromagnetic properties of the physical scenarios. Thus, realistic and accurate channel models are derived through this study [2]. However, there are huge mathematical efforts required in order to perform this process in order to minimize which the important features of mobile radio channel are only emphasized on. Thus, the mobile radio channels are introduced that include simple model parameters such that the data of real-world applications can be measured. For performing wireless signal transmission, the most commonly used phenomenon is multipath fading. Reflections, refraction as well diffraction are imposed when a radio channel is used to transmit a signal. There is change is the communication scenario mostly when cellular phones are involved within urban and suburban regions [3]. Due to this reason, there is increment in complexities as well as uncertainties of channel response. There are different types of fading found within the channels. There is either small scale or large-scale fading. Further, the classification of small scale fading as flat fading and frequency selective fading is done on the basis of multipath time delay occurring here. The flat fading occurs when bandwidth of signal is less than bandwidth of channel and delay spread is less in comparison to relative symbol period. However, frequency selective fading occurs in case when bandwidth of the signal is greater than that of channel and delay spread is also greater in comparison to relative symbol period. The small-scale fading can be classified into fast fading and slow fading on the basis of Doppler spread [4]. In case when the coherence time of channel is more with respect to the delay constraint of channel, slow fading occurs. Across the time period involved, the amplitude and phase change caused by channel is considered to be approximately constant. In case when a large obstruction is found in between the transmitter and receiver within the path of main signal, the events generated can cause slow fading. Within a channel, when coherence time is less than delay constraint, fast fading occurs. Across the period of utilization, there is difference in the amplitude and phase change involved within the channel. In order to enhance the robustness of communication within a fast-fading channel, the benefits of variations within the channel conditions along with time diversity are included.

Space-time trellis codes (STTC): There are multiple antennas employed at the transmitter within the space-time coding. The benefits to be achieved from coding and diversity can be gained with the help of intelligent coding of symbols with respect to space and time. By including multiple antennas at the transmitter, the coding in space is attained [5]. There are roughly any numbers of receive-antennas present within most of the space-time code designs. However, along with these, some other designs are also involved that include extra receive antennas that help in providing receive diversity gain to the systems. However, there is a need to include higher number of processing chains at the receiver end for increasing the receive diversity gain due to which the cost of extra hardware also rises [6]. Within STTC, similar to the utilization of trellis coded modulation (TCM) for single antenna systems, an encoding trellis is utilized. The coding gain of encoding trellis is determined through the structure of trellis as well as the number of states involved. In order to recover the transmitted symbols, a soft Viterbi decoder is used.

II.LITERATURE REVIEW

Neethu V, et.al(2017) proposed a novel technique in order to enhance the overall performance of OFDM systems [7]. The trellis coded orbital angular momentum- quadrature amplitude modulation (OAM-QAM) and enhanced time frequency multiplexing techniques (eTFM) are integrated in order to generate a novel approach. The mapping of trellis coded data to the OAM-QAM constellation points is done and by utilizing viterbi decoder, this data is identified. By ensuring that the bandwidth is not expanded, the coding gain is enhanced here. In comparison to traditional approaches, there is minimization of BER value due to the increase in Euclidean distance. Thus, there is enhancement in performance of results achieved through proposed technique.

Houshou Chen, et.al (2018) proposed a novel algorithm in order to minimize the peak-to-average power ratio (PAPR) within OFDM signals [8]. Within the least trellis of block codes, partial transmit sequence (PTS) is executed here. In order to select the transmitted OFDM signal that has least PAPR, a linear code that includes good minimal trellis is applied. Through correct of error, the side information is then transmitted. As per the simulations performed and results achieved it is seen that the complexity is minimized along with minimization of PAPR through the application of proposed technique.

SametYıldız, et.al (2016) proposed an enhancement maximum-likelihood decoding method in order isolate each of the transmitted signals at the relevant receiver [9]. Here, at the transmitter, a multiplexer is used and at the receiver, a de-multiplexer is used. Enhanced frame error rate (FER) performance is achieved by applying STTC-OFDM as per the experiments conducted. In order to aggregate the system such that the proposed as well as existing methodologies can contrast, the Doppler impact is included here. Enhancements in simulation results show that the proposed mechanism is better in comparison to other already existing approaches.

Ryota Yoshizawa et.al (2016) proposed a novel constellation design in which at the receiver end, the controlling bits as well as information bits can be separated perfectly [10]. For the coded OFDM systems, a simple implementation that includes soft-in soft-out (SISO) decoder is generated here. The performance of proposed system is analyzed in terms of several performance parameters. Further, the practical advantage of this approach in high spectral efficiency system is seen through the comparisons made amongst proposed and several existing approaches.

IlmiawanShubhi, et.al(2013) proposed a sphere decoding mechanism that is used to overload MIMO-OFDM system along with utilization of TCM [11]. The performance degradation of the system is reduced to around 0.7dB at BER=10^{-2} within the Indoor Residential-A channel. Further, enhancements in BER are also achieved within this channel as per the simulation results achieved.

III. NEW STTC-WH-STCC-OFDM SYSTEMS

In order to mitigate ICI [12], the 2x1 STCC-OFDM systems are developed which are majorly inspired from the 2-path transmission mechanism of CC-OFDM scheme [13] [14]. There is backward compatibility of most of the existing OFDM systems with that of STCC-OFDM system. Through the selection of either time division multiplexing (TDM), frequency division multiplexing (FDM) or code division multiplexing (CDM), the multiplexing (MUX) circuit is applied at transmitter and de-multiplexing (DEMUX) circuit at the receiver. Through these steps, the STCC-OFDM systems are designed.

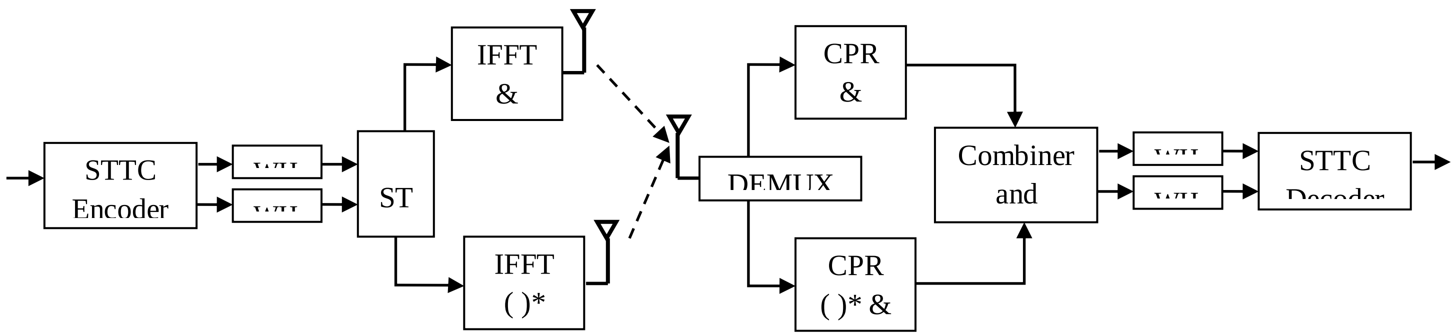

Figure 1: The architecture of a 2x1 STTC-WH-STCC-OFDM System with WHT pre-coders and CC scheme for mitigating ICI

A novel architecture is shown in figure 1.1 above. Here, a novel STTC-WH-STCC-OFDM system is presented by integrating STTC-WH-ST-OFDM and the STCC-OFDM system. At the transmitters end, multiplexing (MUX) circuit is added and at receiver's end, de-multiplexing (DEMUX) circuit is added. A high transmission diversity gain is provided amongst the subcarriers present in OFDM block by the pre-coder WHT. However, within the two blocks, the conjugate data copies are transmitted externally with the help of two-path transmission method. It is also possible to extend the MISO model to MIMO architecture here.

The coded as well as WH transformed symbol vectorsthose are(d_1', d_2') and $(-d_1'^{*}, -d_2'^{*})$are forwarded to the two parallel branches at time slots 1 and 2. IFFT is performed within the upper branch as well as IFFT and conjugate operations ( )* are performed together in lower branch. In order to demodulate the received signal from Tx1, an FFT is employed by upper branch at the receiver baseband [15]. However, a conjugate operator is applied initially and then an FFT is applied for demodulating the received signal from Tx2 at the lower branch. In order to process the upper as well as lower branches separately, the DEMUX is utilized here. At time slots 1 and 2, and Tx1 and Tx2, the four signal vectors that are received are given below:

$$y_{111}' = FFT\left[h_{11} * \left(IFFT(d_1')\right)\right] = H_{11}d_1' \ldots (1)$$

$$y_{121}' = FFT\{\left[h_{12} * \left(IFFT(d_2')\right)^*\right]^*\} = H_{12}d_2' \ldots (2)$$

$$y_{112}' = FFT\left[h_{11} * \left(IFFT(-d_2'^{*})\right)\right] = -H_{11}d_2'^{*} \ldots (3)$$

$$y_{122}' = FFT\{\left[h_{12} * \left(IFFT(d_1'^{*})\right)^*\right]^*\} = H_{12}d_1'^{*} \ldots (4)$$

Further, hard decision variables are achieved through the assumption that across two consecutive time slots, fading is constant and these variables are shown below as:

$$\overline{d_1} = \Psi^{-1}H_{11}^{*}y_{111}' + H_{12}^{*}y_{122}'^{*} = \Psi^{-1}\Psi(|H_{11}|^2 + |H_{12}|^2)d_1 \ldots (5)$$

$$\overline{d_2} = -\Psi^{-1}H_{11}y_{112}'^{*} + H_{12}y_{121}' = \Psi^{-1}\Psi(|H_{11}|^2 + |H_{12}|^2)d_2 \ldots (6)$$

Here, the hard-detected signal vector is represented by $\bar{d}_j, j = 1,2$. Through the receiver antenna Rx1 this signal is obtained and then through Tx antenna j it is transmitted. With the help of CC, the channel impact to subcarriers is compensated after the IWHT and coherent combiner and detector. For novel STTC-WHSTCC-OFDM system, the new decoder algorithms are generated through equations (5) and (6). Thus, by concerning on each subcarrier, the hard-detected signal vectors enter the ML decoding algorithm.

$$\hat{\bar{b}} = arg_Q \min\left(\sum_{k=0}^{N-1}\left|\bar{d}_1^k - Q_{11k}\right|^2 + \sum_{k=0}^{N-1}\left|\bar{d}_2^k - Q_{12k}\right|^2\right) \ldots (7)$$

Here, the kth element of hard detection vector is denoted by $\bar{d}_1^k$. With respect to the receiver antenna Rx1 and thetransmit antenna Tx "j", this hard detection vector is represented as $\bar{d}_j, j = 1,2$. Using two decision vectors which are $\overline{d_1}$ and $\overline{d_2}$ and including all possible code words that are Q_{11k} and Q_{12k} respectively, the two squared Euclidean distances are calculated separately [15]. Equation (7) shows the computation of final soft detected data bit vector that is denoted by $\hat{\bar{b}}$. The STTC, pre-coderWHT, and conjugate cancellation are combined with each other in this mechanism and it is seen that there is enhancement in the performance of BER in terms of MUX and DEMUX operations at Tx and Rx, respectively, in comparison to other previously studied approaches.

IV. KALMAN FILTER

Filtering is a very common factor required within the radio communication systems as there is lot of noise present within them. For removing this noise from the electromagnetic signals, an effective filtering algorithm is applied. One of these techniques is the Kalman filtering technique which basically involves a set of mathematical equations. Here the state of process is estimation which further reduces the mean square error of the system. On the streams of noisy input data provided, this method is applied which further produces optimal results. With respect to various aspects, the filter is very efficient. The predictions provided from past, present and future states are considered within this filter.

The Kalman filter maintains the estimates of the state:

$$\hat{\mathbf{x}}(k|k) \;\; - \text{estimate of } \mathbf{x}(k) \text{ given measurements } z(k),\ z(k-1),\ldots$$

$$\hat{\mathbf{x}}(k+1|k) \; - \text{estimate of } \mathbf{x}(k+1) \text{ given measurements } z(k),\ z(k-1),\ldots$$

and the error covariance matrix of the state estimate

$$\mathbf{P}(k|k) \;\; - \text{covariance of } \mathbf{x}(k) \text{ given } z(k),\ z(k-1),\ldots$$

$$\mathbf{P}(k+1|k) \; - \text{estimate of } \mathbf{x}(k+1) \text{ given } z(k),\ z(k-1),\ldots$$

The partitioning of Kalman filter can be done in very simple steps with the involvement of physical interpretation within it:

0. Known are $\hat{\mathbf{x}}(k|k), \mathbf{u}(k)$, $\mathbf{P}(k|k)$ and the new measurement $\mathbf{z}(k+1)$.

$$\left.\begin{array}{l} \text{1. State Prediction } \; \hat{\mathbf{x}}(k+1|k) = \mathbf{F}(k)\hat{\mathbf{x}}(k|k) + \mathbf{G}(k)\mathbf{u}(k) \\ \text{2. Measurement Prediction: } \; \hat{\mathbf{z}}(k+1|k) = \mathbf{H}(k)\hat{\mathbf{x}}(k+1|k) \end{array}\right\} \textit{Time update}$$

$$\left.\begin{array}{l} \text{3. Measurement Residual: } \; \mathbf{v}(k+1) = \mathbf{z}(k+1) - \hat{\mathbf{z}}(k+1|k) \\ \text{4. Updated State Estimate: } \; \hat{\mathbf{x}}(k+1|k+1) = \hat{\mathbf{x}}(k+1|k) + \mathbf{W}(k+1)\mathbf{v}(k+1) \end{array}\right\} \textit{measurement update}$$

where $\mathbf{W}(k+1)$ is called the Kalman Gain defined next in the state covariance estimation.

In case there are vk, wk and x0 Gaussian vectors given, the random vectors initialized here are xk, xk+1, Yk+1. The Gaussian is propagated with the help of Kalman filter as per the discussions made earlier.

V. SIMULATION PARAMETERS

In order to perform all the simulations, the COST207 6-ray typical urban (TU) frequency-selective mobile channels are applied. There is 220 symbols/second of symbol rate involved and $T_s=2^{-20}$ sec of sampling period used. Along with two Tx and 1 Rx antennas, both QPSK 4-state and 16-state STTC are selected. The computation of channel responses h_{11} and h_{12}, that they are known at the receiver and also stay constants for two OFDM block periods are the assumptions made here. 256 is the selectedOFDM block size which is denoted as N. In the form of CP, one quarter of N samples is utilized. Within this simulation, to the range of 100 Hz to 200 Hz a maximum Doppler f_D is spread. Similarly, to the range of 0.024 to 0.048, the maximum Doppler spread to subcarrier frequency spacing radio $\varepsilon_D = f_D N T_s$ is applied.

.....

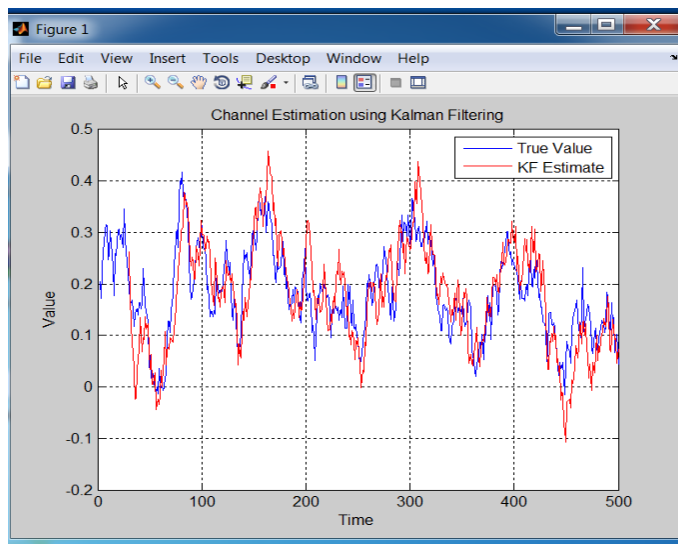

Figure 2:Channel Estimation Using Kalman Filtering

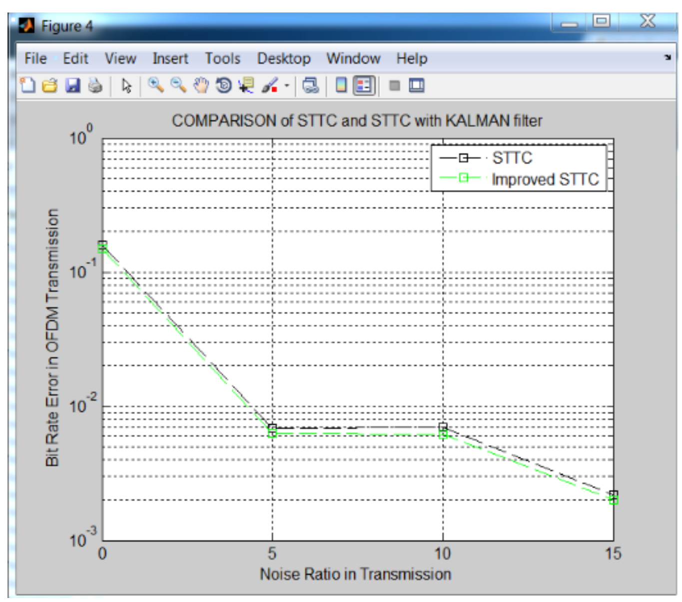

Figure 3: Comparison between MIMO-OFDM and with KALMAN filter

As shown in figure 1, the noise ratio is represented with black line and green line shows noise ratio with the utilization of KALMAN Filter. There is reduction in noise ration and bit error with the utilization of Kalman filter in comparison to the genuine MIMO-ODFM systems

VI. CONCLUSION

In this work, it is concluded MIMO-OFDM is the dynamic network in which bit error rate is very high. The space –trellis codes are applied on the fading channel. The wireless fading channel has very high bit error rate. In this research work, the space-time trellis codes and KALMAN filter is applied to reduce bit rate error. The simulation of proposed modal is Implemented in MATLAB and results shows upto 20 percent improvement in the results

References

[1] A. Dammann, Stef. Kaiser, "Transmit/Receive-Antenna Diversity Techniques for OFDM Systems", Institute of Communications and Navigation, German aerospace center, P.O. Box 1116, D-82230 2002.

[2] S. Rohilla, D. Kumar, Patidar, N. Kumar, Soni, "Comparative Analysis of Maximum Ratio Combining and Equal Gain Combining Diversity Technique for WCDMA", International Journal of Engineering Inventions, 2278-7461, p-ISSN: 2319-6491 vol. 3, no.1, pp. 72-77, 2013

[3] D.P.Calderon, "Rotated constellation for DVBT2", in Proc. DCIS, Volume 13, Issue6, pp. 187–191, 2009

[4] D. P. Calderon, V. B. Lecuyer, Ana Cinta Oria, and Jose GarciavDoblado, "Diversity Technique for OFDM Systems: Enhanced Time Frequency Multiplexing", IEEE transactions on broadcasting, vol.62, no. 3, pp. 769-775, 2016

[5] Chao ZHANG, "Trellis Coded OAM-QAM Union Modulation with Single-Point Receiver", IEEE communications letters, vol.74, no. 13, pp. 543-550, 2016

[6] C. Zhang and L. Ma, "Trellis coded orbital angular momentum modulation,"IEICE Trans. Fundamentals, vol. E99-A, no. 8, pp. 564-571, 2016.

[7] Neethu V, Ismayil Siyad C, "Performance Analysis of Diversity Techniques for OFDM system using Trellis Coded OAM-QAM union modulation", International Conference on Intelligent Computing and Control (I2C2), vol.21, no. 6, pp. 321-328, 2017

[8] Houshou Chen, and Kuo-Chen Chung, "A Low Complexity PTS Technique Using Minimal Trellis in OFDM Systems", 2018, IEEE Transactionson Vehicular Technology, vol. 67, no. 1, pp. 213-220, 2018

[9] SametYıldız, Hen-Geul Yeh, "The Performance Analysis of Space-Time Trellis Coded MIMO-OFDM Systems", IEEE, vol. 27, no. 9, pp. 243-252, 2016

[10] Ryota Yoshizawa and Hideki Ochiai, "Trellis-Assisted Constellation Subset Selection for PAPR Reduction of OFDM Signals", IEEE, vol. 5, no. 11, pp. 847-854, 2016

[11] IlmiawanShubhi, Yukitoshi Sanada, "Trellis Coded Modulation with Pseudo Distance in Overloaded MIMO OFDM With Sphere Decoding", IEEE, vol. 5, no. 19, pp. 196-207, 2013

[12] H. G. Yeh, "Architectures for MIMO-OFDM systems in frequency selective fading channels," IEEE Trans. Circuits and Syst., II, Express Brief. vol. 62, no. 12, pp. 1189-1193, 2015.

[13] H. G. Yeh, Y. K. Chang, and B. Hassibi, "A scheme for canceling intercarrier interference through conjugate transmission for multicarrier communication systems," IEEE Trans. on Wireless Communication, vol. 6, no. 1, pp. 3- 7, 2007.

[14] C. L. Wang, et al., "An adaptive receiver design for OFDM systems using conjugate transmission," IEEE Trans. Commn., vol. 61, no. 2, pp. 599-608, 2013.

[15] Hen-Geul Yeh, SametYıldız, "Space-Time Trellis Coded OFDM Systems in Frequency Selective Mobile Fading Channels", IEEE, vol. 11, no. 5, pp. 365-374, 2016