International Journal of Electronics Signals and Systems

Volume 3 | Issue 4 Article 2

April 2014

CCI CANCELLATION USING KF IN FADED MIMO CHANNELS

DEBANGI GOSWAMI
Dept of Electronics and Communication Technology, Gauhati University, Guwahati, Assam, India, debangi21@gmail.com

Kandarpa Kumar Sarma
Department of Electronics and Communication Technology, Gauhati University, Guwahati, Assam-781014, kandarpaks@gmail.com

Recommended Citation

GOSWAMI, DEBANGI and Sarma, Kandarpa Kumar (2014) "CCI CANCELLATION USING KF IN FADED MIMO CHANNELS," *International Journal of Electronics Signals and Systems*: Vol. 3 : Iss. 4 , Article 2.
DOI: 10.47893/IJESS.2014.1175
Available at: https://www.interscience.in/ijess/vol3/iss4/2

CCI CANCELLATION USING KF IN FADED MIMO CHANNELS

DEBANGI GOSWAMI[1] & KANDARPA KUMAR SARMA[2]

[1,2]Dept of Electronics and Communication Technology, Gauhati University, Guwahati, Assam, India
E-mail:debangi21@gmail.com, kandarpaks@gmail.com

Abstract- Multi input multi output system (MIMO) has become a viable option to meet the demand of high data rate wireless communication. But MIMO system performance is severely affected by the presence of co-channel interference (CCI). CCI cancellation in MIMO channel therefore is a challenging area of research. This paper provides a Kalman Filter based CCI cancellation approach. In the severely faded Rayleigh channel in coded MIMO set-up, experimental results show that Kalman filter based approach for CCI cancellation provides satisfactory results and can thus prove to be a reliable CCI cancellation technique in future.

Keywords- *Co-channel interference, MIMO, STBC, Rayleigh Fading*

I. INTRODUCTION

In recent years, researchers have found that substantial amount of performance gain of transmitted and receive diversity can be achieved by using multiple antennas. Multiple- Input Multiple-Output (MIMO) system. MIMO technology is a part of many high data rate wireless communication systems. It increases capacity and performance of wireless links. This is generated by the transmit – receive diversity inherent in MIMO technology. Space-time block code (STBC) is a method usually employed into MIMO wireless communication systems to improve the reliability of data transmission using multiple antennas. The use of STBC with diversity gains derived from MIMO set-up provide improved performance in faded wireless channels.

Co-channel interference (CCI) in wireless channel is a degrading phenomenon. It is more so with MIMO systems and the capacity of such systems is limited considerably by the presence of CCI. Therefore, CCI cancellation is challenging area and continues to attract research. The receiver design which could effectively remove the CCI and give a satisfactory receiver performance is a pertinent problem.

Many methods of CCI cancellation in MIMO domain have been proposed. In paper [2], STBC is used to combat CCI. A minimum mean square error (MMSE) and maximum a-posteriori (MAP) receiver design was proposed in [3]. In [6], maximum likelihood (ML) estimate of channel using training sequence are studied assuming temporally and spatially white noise.

In the present work, we study channel estimation and data detection of coded MIMO system with two CCI sources under fading in an interference limited environment using recursive Kalman Filter (KF). We specially use an application specific KF for a coded - MIMO set-up which cancels CCI successfully. The paper is organised as follows. Section II introduces basic theoretical notions regarding the model. Section III describes the system Model. Experimental details and stimulated results are included in Section IV. Section V contains the conclusion of the work.

II. BASIC THEORTICAL NOTIONS

The use of STBC and MIMO has proven to be an effective combination. This section provides a brief description of STBC, CCI, Rayleigh fading and related channel aspects considered for the work.

*A .Rayleigh Multipath Fading Channel***-** The propagation environment for any wireless channel is either indoor or outdoor may be subject to LOS (Line-of-Sight) or Non LOS (NLOS). A probability density function of the signal received in the LOS environment follows the Rician distribution, while that in the NLOS environment follows the Rayleigh distribution. In mobile radio channels, Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal or the envelope of an individual multipath component [1].

*B. Space-Time Block Code (STBC)***-** In general multiple antennas are used to achieve spatial diversity and to achieve time diversity the transmission is repeated n times. Scope of diversity is expanded by using multiple antennas at both the receiver and transmitter. The capacity of multi-antenna systems far exceeds that of a single antenna system and capacity grows at least linearly with the number of transmit antennas as long as number of received antenna is greater than or equal to number of transmit antennas. STC were first introduced by Vahid Tarokh, Nambi Seshadri and Robert Calderbank from *AT*&*T* research labs in 1998 as a novel means of providing transmit diversity for the multiple antennas fading channel. These STCs achieve significant error rate improvements over single-antenna systems. Their original scheme was based on trellis codes but the simpler block codes were utilised by Siavash Alamouti [14], and later Vahid Tarokh, Hamid Jafarkhani and Robert Calderbank [15] to develop STBCs. STC involves the transmission of multiple redundant copies of data to compensate for fading and thermal noise in the hope that some of them may arrive at the receiver in a better state than others

C. Co-channel interference (CCI)- MIMO architectures are useful for combined transmit receive diversity. For its parallel mode of transmission, MIMO system offer high data rate in narrow bandwidth .MIMO system is characterized by multiple antenna elements at the transmitter and receiver, have demonstrated the potential for increased capacity in rich multipath environments.
A MIMO system input-output relationship can be written as

$$x(k) = H(k)s(k) + v(k) \tag{4}$$

where x(k) is M×1 vector with *xi(k),i=1,…,M* ,s(k) is N×1 vector of the input symbols v(k) is an additive noise vector, H(k) is M×N channel matrix with elements *hij(k),1,…,M,j=1,2….,N* denoting the transfer function between the jth transmit and ith receive antenna respectively. Propagation related variations modeled by Rayleigh, ITU pedestrian and vehicular channels and Rician distribution can be included in matrix H.

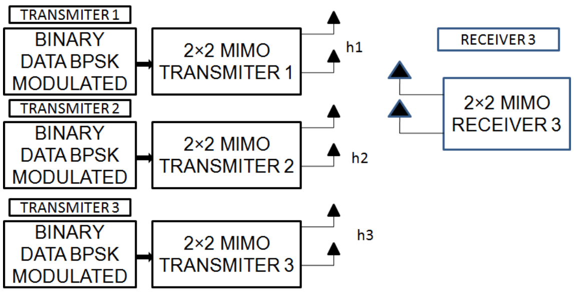

Fig1: A generic MIMO scheme with interferer

Considering the presence of CCI, the expression (4) can be modified as below:

$$x(k) = H(k)s(k) + \sqrt{\frac{P}{L}}\sum_{i=1}^{L} h_i(k)s_i(k) + v(k) \tag{5}$$

where P is constant interference power, L is the number of interferer, hi(k) is the channel vector of the ith interferer and rest of the terms as described with reference to equa (1).A generic set-up depicting a MIMO arrangement with certain no of interferer is shown in Fig 1.

Here propagation taking place through channel **H** while interference signal *si(k)* reach the receiver end through another set of channel taps denoted by $\sum_{i=1}^{L} hi(k)$ .Receiver receives the CCI affected signal.

D. Kalman Filter- In 1960, R.E. Kalman published his famous paper describing a recursive solution to the discrete data linear filtering problem. The Kalman filter is a set of mathematical equations that provides an efficient computational (recursive) means to estimate the state of a process, in a way that minimizes the mean of the squared error. The filter is very powerful in several aspects: it supports estimations of past, present, and even future states, and it can do so even when the precise nature of the modelled system is unknown [8]. Kalman Filter estimation is quite common in the literature at least for single user channel. In [9] and [10] the KF is used for tracking MIMO channels based on a low order autoregressive (AR) model. However, exact modelling of fast time varying channel with a low order model is impossible since the AR functions are irrational and higher order statistics are needed.

Process to be estimated: The Kalman filter estimates the state $x \in R^n$ of a discrete-time controlled process that is governed by the linear stochastic difference equation

$$x_k = Ax_{k-1} + Bu_{k-1} + w_{k-1} \tag{6}$$

with a measurement $z \in R^m$ that is

$$z_k = Hx_k + v_k \tag{7}$$

The random variables w_k and v_k represent the process and measurement noise respectively. They are assumed to be independent of each other, white, and with normal probability distributions

$$p(w) = N(0, Q), \quad p(v) = N(0, R). \tag{8}$$

The *n* × *n* matrix *A* in the difference equation 6 relates the state at the previous time step *k - 1* to the state *k* at the current step. The *n* × *l* matrix *B* relates the optional control input $u \in R^l$ to the state *x*. The *m* × *n* matrix *H* in the measurement Equation 7 relates the state to the measurement z_k [7] [8].

Table1: Discrete Kalman filter time update and measurement update

$$\hat{x}_k^- = A\hat{x}_{k-1} + Bu_{k-1}$$

$$P_k = AP_{k-1}A^T + Q$$

$$K_k = P_kH^T / (HP_kH^T + R)$$

$$\hat{x}_k = \hat{x}_k^- + K(z_k - H\hat{x}_k^-)$$

$$P_k = (1 - K_kH)P_k$$

The *a priori* state estimate at step k is defined as $\hat{x}_k^- \in \Re^n$ given knowledge of the process prior to step *k*, and $\hat{x}_k \in \Re^n$ to be *a posteriori* state estimate at step *k* given measurement z_k. *a priori* and *a posteriori* estimate errors are

$$e_k^- = x_k - \hat{x}_k^- \qquad (9)$$

$$e_k = x_k - \hat{x}_k \qquad (10)$$

The *a priori* estimate error covariance is then

$$P_k^- = E[e_k^- e_k^{-T}] \qquad (11)$$

and the *a posteriori* estimate error covariance is

$$P_k = E[e_k e_k^T] \qquad (12)$$

An *a posteriori* state estimate $\hat{x}_k$ can be computed as a linear combination of an a priori estimate $\hat{x}_k^-$ and a weighted difference between an actual measurement z_k and a measurement prediction Hx_k .

$$x_k = \hat{x}_k^- K(z_k - H\hat{x}_k^-) \qquad (13)$$

The difference $z_k - H\hat{x}^-{}_k$ is called the measurement innovation, or the residual. The *n* × *m* matrix *K* is chosen to be the gain or blending factor that minimizes the *a posteriori* error covariance.

$$K_k = P_k^- H^T (HP_k^- H^T + R)^{-1} \qquad (14)$$

$$K_k = P_k^- H^T / (HP_k^- H^T + R) \qquad (15)$$

The specific equations for the time and measurement updates are presented in Table 1. After each time and measurement update pair, the process is repeated with the previous *a posteriori* estimates used to project or predict the new *a priori* estimates [8].

III. SYSTEM MODEL

We have considered in our setup, multiple single-user links with two CCI sources. We assume the desired user has 2 transmit antennas, the two other interfering user has 2 transmit antennas each, and there are 2 receive antennas of the desired user. Here, we have used STBC before transmission.

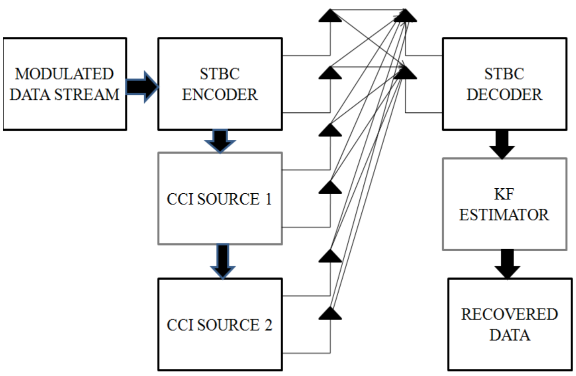

Figure .3. Transmitter and receiver structure of co-channel interference setup.

The system model for CCI set up in wireless communication is depicted in Figure 3.The received signal at the Receiver 3 is a complex signal with CCI content. This signal is estimated with the KF and the original signal is recovered approximately in the receiver.

The state space equations for tracking the MIMO channel can be expressed as:

$$h(t+1) = A(t)h(t)$$
$$s(t) = C(t)h(t) + v(t)$$

where *h* is the channel tap, *A* is a time-varying transition matrix, *C* is the observation matrix and *v* is the measurement noise vector. On the receive antenna, the noise *n* has the Gaussian probability density function with

$$p(n) = 1/\sqrt{2\Pi\sigma^2}\exp(-(n-\mu^2))/2\sigma^2$$

with $\mu_{hi,j} = 0$ and $\sigma_h{}^2{}_{i,j} = No/2$. A first-order Auto-Regressive (AR) model provides a sufficient model for time varying channels. Therefore, *A* can be a diagonal matrix of autoregressive model factor *α*, where

$$\alpha = E[h_{ij}(t+1) * h_{ij}^*(t)]$$

The KF expression for MIMO channel is divided into two parts. First part is the predictor

$$\tilde{h}(t+1|t) = A(t)\tilde{h}(t|t)$$
$$P(t+1|t) = A(t)P(t|t)A^{*T}(t)$$
$$\varepsilon(t) = s(t) - C(t)\tilde{h}(t+1|t)$$
$$K(t) = P(t+1|t)C^{*T}(t)[C(t)P(t+1|t)C^{*T}(t) + R_v]^{-1}$$

and the second part is the update is given as

$$\tilde{h}(t+1|t+1) = \tilde{h}(t+1|t) + K(t)\varepsilon(t)$$

where, $R_v = \beta I$ and *β* is a covariance of the noise vector v. The *K* matrix is called the Kalman gain and the *P* matrix is called the estimation error covariance. Alamouti's transmit diversity space-time coding scheme relies on the availability of accurate channel state information (CSI) at the receiver. However, motion between the transmitter and the receiver results in a change in the propagation path and channel uncertainties become prevalent. To eliminate this problem, Kalman filter is used to estimate the channel.

IV. EXPERIMENTAL RESULTS

In this section, simulation results are presented. In this work, range of signal to noise ratio (SNR) considered is −10 to 10 dB. The channel experienced by each transmit antenna is independent from the channel experienced by other transmit antennas. For the transmit antenna, each transmitted symbol gets multiplied by a randomly varying complex channel matrix *hi,j* . As the channel under consideration is Rayleigh, the real and imaginary parts of *hi,j* are Gaussian distributed. of *hi,j* having mean μh = 0 and variance $\sigma h2$ =1/2.

The channel experienced between each transmit to the receive antenna is randomly varying in time. The performance of the Kalman estimator proposed here performed satisfactorily and is better than of some similar works already reported in severely faded environments over the range of SNR −10 to 10 dB. The components of the system and channel parameters during the work are summarized in Table II.

TABLE II: Parameters adopted for the systems

PARAMETERS	ADOPTED VALUES
Multiple antenna system	MIMO
Transmitter antenna	TX= 2
Receiver antenna	RX=1, 2 respectively
Modulation schemes	BPSK and QPSK
Signal to Noise Ratio (SNR)	-10 to 10 dB
Frequency selective channel	Rayleigh fading
STBC DECODING	Alamouti

The performance of the channel estimator based on Kalman filter is tested through simulations for CCI affected signal. It is seen that the estimated component nearly matches the original signal. This is observed in Figure 4. The plot shows the estimated values nearly matches the original value for up to sample no 40. But for other values there are fluctuations due to variations in the channel.

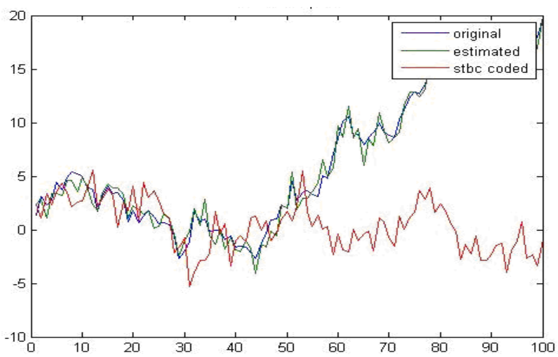

Figure4: Combined plot showing estimated, estimated with STBC, original signal of co-channel interfered signal.

Figure 5 shows a comparative diagram of the original channel coefficients and the first 100 estimated values are shown. The estimated coefficients are almost identical to the desired values. The Kalman Gain is shown in the Figure 6.It is approaching the value 0 which satisfactorily show the CCI is well cancelled by the Kalman Filter. From Figure 5, we see that the estimation process fluctuates upto around 40 samples but beyond that it stabilizes. The estimate nearly matches the desired value. It means that beyond the 40 samples, the proposed approach cancels CCI better.

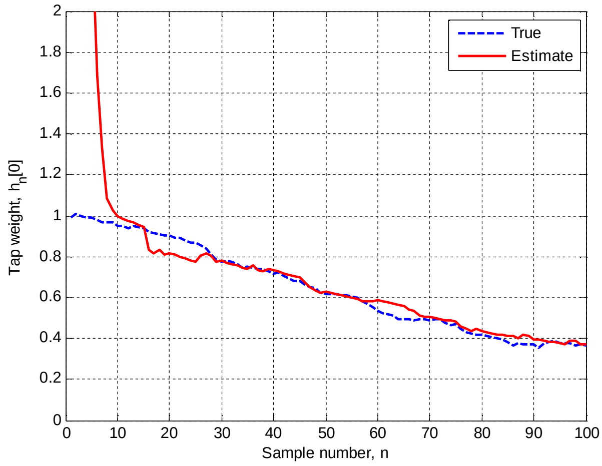

Figure 5: The true and estimated channel coefficients

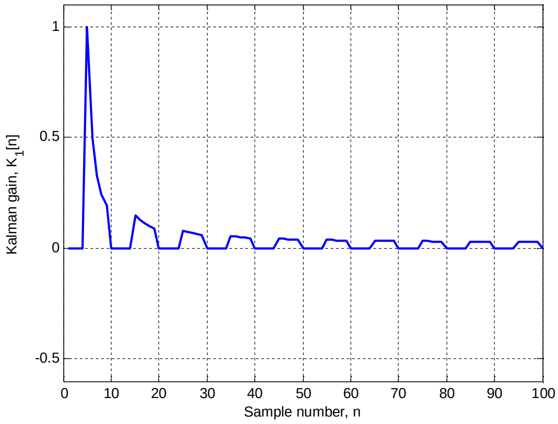

Figure 6: Kalman Gain

V. CONCLUSION

CCI is a vital problem in the MIMO channel. In this work Kalman Filter is used to estimate the signal from the MIMO set-up filled with CCI. We specially used an application specific KF for a coded MIMO set-up which cancels CCI successfully. It shows successful recovery of the required data with around 40% of available data. The performance of the STBC coded set-up is found to be better compare to the uncoded form.

REFERENCES

[1] T. S. Rappaport, Wireless Communications - Principles and Practice, Pearson Education, 1997.

[2] A Arunachalam and H El Gamal “Space-Time Coding for MIMO Systems with Co-Channel Interference”,IEEE Transactions on Wireless Communications, vol. 3, no. 6, pp. 1953-1958, 2004.

[3] L. Qiang, J. Zhu, G. Xingang and C. N. Georghiades "Asynchronous Co-channel Interference Suppression in MIMO OFDM Systems", In proceeding of IEEE International Communications Conference, pp. 5744-5760, Glasgow, Scotland, June, 2007.

[4] Y. Song and S. D. Blostein "Data Detection in MIMO Systems with Co-Channel Interference" , in Proceedings of. IEEE VTC '02, Vancouver, BC, Canada, pp. 3-7, 2002.

[5] A. Batra and J. R. Barry "Blind Cancellation of Co-Channel Interference", IEEE Global Telecommunications Conference, Singapore, vol. 1, pp. 157-162, November 1995.

[6] C. Hung, N, G,z Zablan and L. S. Leng, "Co-channel Interference Cancellation Based on MIMO Space-Time System" IRACST International Journal of Engineering Science and Technology, vol.2, no.1, pp. 111-116, 2012.

[7] R. E. Kalman, "A new approach to linear filtering and prediction problems," *Journal of Basic Engineering*, vol. 82, no. 1, pp. 35–45, 1960.

[8] G. Welch and G. Bishop, "An Introduction to the Kalman Filter,"Availabl at *www.cs.unc.edu/ welch/media/pdf/kalman-intro.pdf.*

[9] T. Y. Al-Naffouri and A. A. Quadeer, "A Forward-Backward Kalman Filter-based STBC MIMO OFDM Receiver," *EURASIP Journal on Advances in Signal Processing*, 2008.

[10] K. J. Song, "Novel Channel Estimation Algorithm Using Kalman Filter For Ds-Cdma Rayleigh Fading Channel," *Proceedings of IEEE International Conference on Acoustics, Speech, and Signal Processing* , vol. 25, pp. 429–432, 2003.

[11] K. Teo, "Kalman Filter-Based Channel Estimation For Space-Time Block Code," *47th Midwest Symposium on Circuits and Systems*, vol. 2, pp. 669–672, 2004.

[12] K. Ahn, "Decision Feedback Detection for Space-Time Block Coding over Time–Selective Fading Channels," *Proceedings of 14th IEEE International Symposium on Personal, Indoor and Mobile Radio Communication*, pp. 1983–1987, 2003.

[13] W. Ling, "Kalman Filter Channel Estimation Based on Comb-Type Pilot in Time-Varying Channel," *International Conference on Wireless Communications, Networking and Mobile Computing*, pp. 1–3, 2006.

[14] H. Mahmoud, "Kalman filter channel estimation based on Comb type pilots for OFDM system in time and frequency - selective fading environments," *International Conference on ommunications, Computers and Applications*, pp. 59–64, 2008.

[15] V. Tarokh, N. Seshadri and A. R. Calderbank, "Space Time Codes For High Data Rate Wireless Communication: Performance Analysis And Code Construction," *IEEE Transactions on information Theory*, vol. 44, no. 2, pp. 744–765, March 1998.

[16] V. Tarokh, N. Seshadri and A. R. Calderbank, "Space Time Block Codes From Orthogonal Designs," *IEEE Transactions on Information Theory*, vol. 45, no. 5, pp. 744–765, 1999.

◈◈◈