

# Channel Estimation Error Effects on Interference Alignment

Jinhyung Oh and Heon-Jin Hong

Radio Technology Research Division, Electronic and Telecommunications Research Institute (ETRI)

Daejeon, Republic of Korea

[jinhyung@etri.re.kr](mailto:jinhyung@etri.re.kr), [hjhong@etri.re.kr](mailto:hjhong@etri.re.kr)

**Abstract**— For overcoming the scarcity of frequency resources, spectrum efficiency should be always enhanced by adopting the novel transmission methods. Nowadays, there are a few brilliant transmission technique in academic investigation area such as interference alignment, multi-cell beamforming and cooperative communication. Interference alignment has received the spotlight to enormously enhance the spectral efficiency among above cited transmission schemes. Because the interferences occurred from multiple interfering nodes are aligned into predefined portion of radio resource domain such as space, time and frequency we think spectral efficiency can be increased even though multiple interferences are also happened. To implement the interference alignment into current mobile communication systems, however, channel state information should be well-transferred from receiving nodes to transmitting node to obtain the transmit precoder. And the channel state information is transport to not only desired link from its transmitter and receiver but also adjacent link from neighbor cell's transmitter to desired link's receiver. If the precoder and decoder is created with errored channel state information, the capacity of an IA network is decreased. In this paper, we have analyzed the channel estimation error effects on interference alignment. And we compare and simulate the channel estimation effects on interference alignment with different interference alignment algorithms.

**Keywords**— Channel estimation, interference alignment

## I. INTRODUCTION

To satisfy the demands for wireless access, wireless communication techniques such as LTE, WiFi, bluetooth have appeared to our real life. The request for wireless transmission access is gratified due to above multiple wireless approaches, however, interference problems become hot issues to increase the network performance. If somebody install the multiple wireless transmitters in small limited area, network performance can be reduced because of inter-cell interference between adjacent cells. However, because network capacity should be increased, multiple cells ought to be installed in small area. As you can see here, we have to simultaneously solve two problems: increasing network capacity and diminishing the inter-cell interference. Nowadays, interference alignment has emerged to be a good solution for above two problems. To well implement interference alignment, most important issue is to obtain the CSI from receiver to transmitter. However, because CSI do not always gather without error, performance of IA is changed due to channel estimation errors. In this paper, we

analyse the channel estimation error for IA and simulate the performance of IA when channel estimation errors occur or not.

## II. SYSTEM MODEL

The system model of K-user MIMO is depicted in Fig. 1. Each of Tx and Rx is equipped with M and N antennas, respectively. The N x M MIMO channel is generated between each Tx and Rx link. The received signal for i-th Rx is given by

$$\mathbf{y}_i = \mathbf{H}_{ii} \mathbf{P}_i \mathbf{s}_i + \sum_{j=1, j \neq i}^K \mathbf{H}_{ij} \mathbf{P}_j \mathbf{s}_j + \mathbf{n}_i \quad (1)$$

where  $\mathbf{P}_i \in \mathbb{C}^{M \times d}$  is the precoding matrix for the i-th Tx, d is the number of spatial streams,  $\mathbf{s}_i \in \mathbb{C}^{d \times 1}$  is the OFDM modulated transmission data symbol vector for the i-th Rx with  $\mathbb{E}[\|\mathbf{s}_i\|^2] \leq \frac{P}{d}$ , P is transmit power with single stream and  $\mathbf{n}_i \in \mathbb{C}^{N \times 1}$  is the additive white Gaussian noise (AWGN) vector with zero mean and unit variance. The received signal into Rx node is post-processed by multiplying the decoding matrix  $\mathbf{D}_i^H$ . The final received signal representation  $\tilde{\mathbf{y}}_i$  for i-th Rx after multiplying by the decoding matrix is formulated by

$$\tilde{\mathbf{y}}_i = \mathbf{D}_i^H \mathbf{H}_{ii} \mathbf{P}_i \mathbf{s}_i + \mathbf{D}_i^H \sum_{j=1, j \neq i}^K \mathbf{H}_{ij} \mathbf{P}_j \mathbf{s}_j + \mathbf{D}_i^H \mathbf{n}_i \quad (2)$$

To measure the channel estimation error in this study, we generate the true MIMO wireless channel  $\mathbf{H}_{ki}$  from j-th Tx to i-th Rx with channel estimation error

$$\hat{\mathbf{H}}_{ij} = \mathbf{H}_{ij} - \mathbf{E}_{ij} \quad (3)$$

where  $\hat{\mathbf{H}}_{ij}$  is the estimated channel matrix,  $\mathbf{H}_{ij}$  is the true channel matrix and  $\mathbf{E}_{ij}$  channel estimation errored matrix. Normally, the precoding matrix  $\mathbf{P}_j$  is generated by estimated channel matrix after channel feedback from Rx to Tx if there is no feedback error or quantization error. In this research, we assume there is no feedback error when Rx transmits the estimated channel matrix to the Tx. So, the precoding matrix in our study is only affected by channel estimated errored matrix. And the decoding matrix is also generally generated by

estimated channel matrix. With above two premise, if the channel is estimated with error, the IA precoder and decoder is also generated in error condition. That means the performance of IA is expect to be deeply degraded.

### III. CHANNEL ESTIMATION ERROR ON IA

In this section, we will investigate the channel estimation error effects on interference alignment through performance analysis. As mentioned in the previous section, the performance of IA is expected to be degraded when channel estimation error is occurred. We need to recognize the cause for channel estimation error, the procedure of generating IA precoder and decoder with channel state information (CSI) and how much throughput degradation is happened.

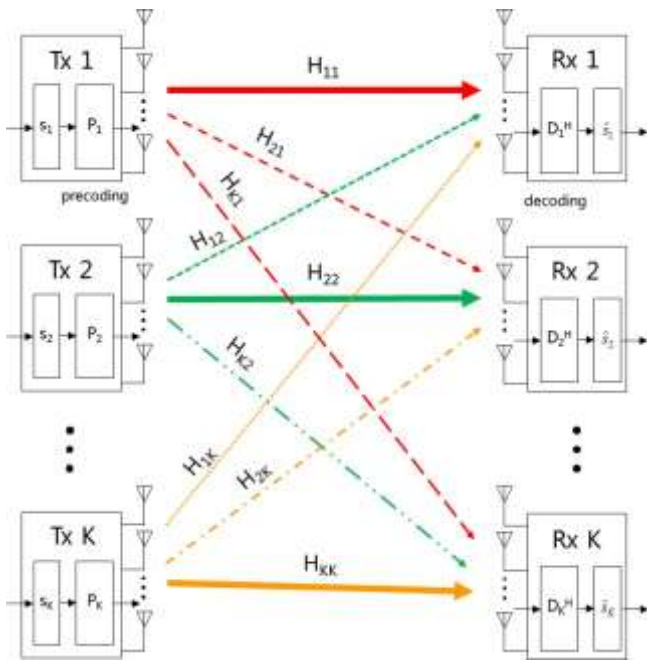


Figure 1. 3x3 Interference Channel

#### A. Cause for Channel Estimation Error

Estimating wireless channel always exists the probability that errors occur. In this paper, we assume there are three main issues to generate the error when we estimate the channel. First, if the coherence time is over, channel state information becomes different compare to previous CSI. In this case, channel estimation error is occurred when coherence time is changed. So, we require to compensate CSI between CSI of current and previous coherence time. And second, timing synchronization problem between transmitter and receiver can generate the channel estimation error. If timing synchronization is not synchronized, the receiver cannot be decoded the pre-known signal such as preamble sequence in IEEE 802.11 WLAN standard when transmitter sends the pre-known signal.

Through these above reasons, we should focus on effects of happening the channel estimation error.

#### B. Procedure of generating IA precoder and decoder

The method for generating IA precoder and decoder is represented in Fig. 2. When we first start the IA transmission, transmitter sends the pilot signal such as reference signal to the receiver to measure the CSI from Tx to Rx. After that, receiver should estimate the physical channel and gather the CSI to obtain the decoding vector. After generation of decoder in Rx, receiver sends the CSI to transmitter. After transmitter receives the CSI from receiver, Tx can generate the precoder with feedback CSI. Finally, we can start the IA transmission with IA precoder and decoder. Like this procedure in Fig. 2, channel estimation is very important for IA transmission because decoding and precoding vector generation are generated from the results of channel estimation and channel feedback of CSI, respectively.

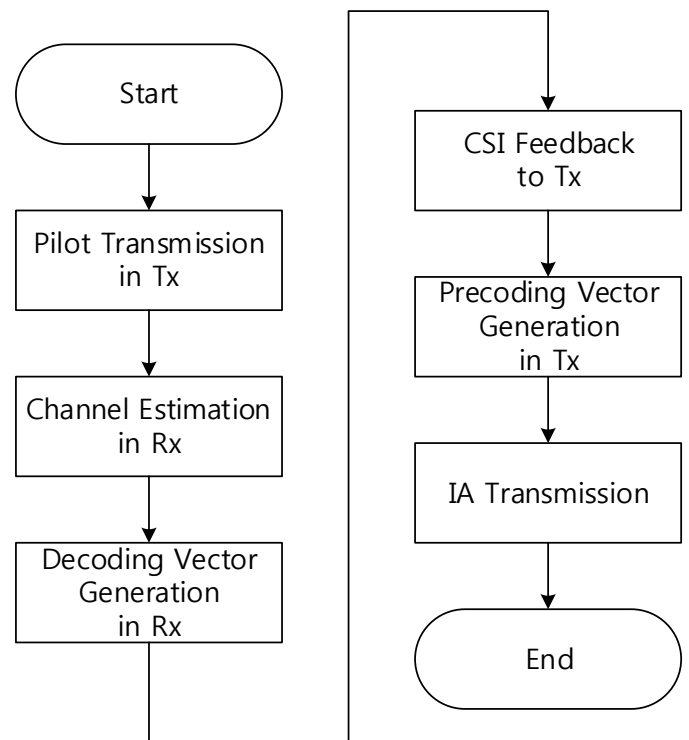


Figure 2. 3x3 Interference Channel

#### C. Mathematical Analysis for Channel Estimation Error on IA

Until now, there are many research results of IA, however, most of IA algorithms are suffered from channel estimation error by contaminating the precoder and decoder. To analyse the impacts of channel estimation error on IA in mathematical area, we suggest our SLNR based IA algorithm in [1]. The precoding matrix design of our SLNR based IA algorithm is described as below.

$$\mathbf{P}_j = \max \text{eigvec} \left[ \left( \sigma^2 \mathbf{I} + \sum_{j=1, j \neq i}^K \mathbf{H}_{ij}^H \mathbf{H}_{ij} \right)^{-1} \mathbf{H}_{jj}^H \mathbf{H}_{jj} \right] \quad (4)$$

And the decoder of our SLNR based IA algorithm is denoted by

$$\mathbf{D}_i \subset \text{null}(\mathbf{IAI}_i) \quad (5)$$

where

$$\mathbf{IAI}_i = [\mathbf{H}_{ij} \mathbf{P}_j, \dots, \mathbf{H}_{iK} \mathbf{P}_K], i \neq j, j = 1 \quad (6)$$

If the channel estimation error is occurred, the precoder and decoder are also generated with error like below mathematical expression.

$$\hat{\mathbf{P}}_j = \max \text{eigvec} \left[ \left( \sigma^2 \mathbf{I} + \sum_{j=1, j \neq i}^K (\hat{\mathbf{H}}_{ij} + \mathbf{E}_{ij})^H (\hat{\mathbf{H}}_{ij} + \mathbf{E}_{ij}) \right)^{-1} (\hat{\mathbf{H}}_{jj} + \mathbf{E}_{jj})^H (\hat{\mathbf{H}}_{jj} + \mathbf{E}_{jj}) \right] \quad (7)$$

$$\hat{\mathbf{D}}_i \subset \text{null}(\mathbf{IAI}_i) \quad (8)$$

$$\mathbf{IAI}_i = [(\hat{\mathbf{H}}_{ij} + \mathbf{E}_{ij}) \mathbf{P}_j, \dots, (\hat{\mathbf{H}}_{iK} + \mathbf{E}_{iK}) \mathbf{P}_K], i \neq j, j = 1 \quad (9)$$

Through above contaminated precoding and decoding matrix due to channel estimation error, network total performance of IA is expected to be reduced.

#### IV. PERFORMANCE ANALYSIS

In this section, we analyse the performance impacts of channel estimation error in IA algorithms. At first, we explain our simulation environments like below table.

TABLE 1. SIMULATION ENVIRONMENT

| Parameters                       | Values           |
|----------------------------------|------------------|
| Channel model                    | 802.11ac B model |
| Number of Tx node                | 3                |
| Number of Rx node                | 3                |
| Number of antennas at AP and STA | 4                |
| Subcarrier                       | 256              |

Through above simulation environments, we simulate the channel estimation error impacts on our developed SLNR and ZR based IA algorithm. We simulate the performance of our IA algorithm with changing channel estimation error from 1% to 10%. From our simulation results, if channel estimation error is happened about 1%, the average sum rate is almost same as perfect channel estimation case from 0 dB to 25dB in SNR scale. However, the performance of IA with 5% and 10% channel estimation error case is much degraded than 1% case and

saturated from 30dB and 35dB, respectively. From this results, we can check the no channel estimation error condition is best for average sum rate, however, if some errors is occurred, the amount of error quantity should be lower than below 5% to maintain the ideal performance.

#### V. CONCLUSIONS

In this paper, we check the channel estimation effects on interference alignment by showing the performance comparison between with and without channel estimation error case. We also notify the performance of IA with channel estimation error is lower than that of without channel estimation error. However, because channel estimation error cannot be perfectly reduced, we should know how much portion of channel estimation error can affect the IA performance. We check the performance of IA in perfect case is almost same as 1% channel estimation error until SNR 25dB. In the future, we will investigate the IA performance effects of channel feedback error from receiver to transmitter.

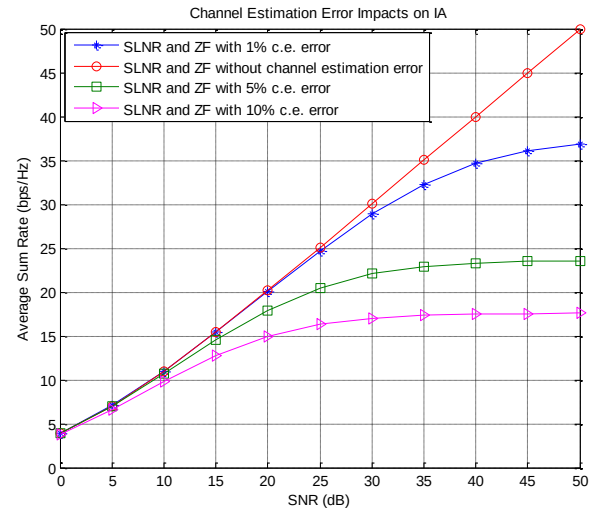


Figure 3. Performance comparison with and without channel estimation error

#### ACKNOWLEDGMENT

This work was supported by the ICT R&D program MSIP/IITP. [B0101-15-222, Development of core technologies to improve spectral efficiency for mobile big-bang] and [12-921-01-301, Short Range Wireless Transmission Technology with Robustness to Radio Interferences]

#### REFERENCES

- [1] Jinhyung Oh; Gwangzeon Ko; Kim, I.; Hyunduk Kang; Myungsun Song; Jaeick Choi, "Distributed implicit interference alignment in 802.11ac WLAN network," in ICT Convergence (ICTC), 2013 International Conference on , vol., no., pp.421-426, 14-16 Oct. 2013



**Jinhyung Oh** received his B.S degree in Electrical Communications Engineering from Korea Advanced Institute Science and Technology (KAIST), Daejeon, in 2008 and M.S. degree in Electrical and Electronic Engineering from Korea Advanced Institute Science and Technology (KAIST), Daejeon, in 2010. In 2010, he joined the Electronic and Telecommunications Research Institute (ETRI) where he is a researcher of the Radio Technology Department. His research interests

include wireless communications, interference analysis and digital beamforming.



**Heon-Jin Hong** received the B.S. and the M.S. degrees in electronic engineering from Chungnam National University in 1986, 1990, respectively. Currently, he is a principal member of research staff of Electronics and Telecommunications Research Institute. His research interests include spectrum engineering.