Proceedings of ISAP2012, Nagoya, Japan

2C2-2

Multi-link Indoor MIMO Measurements at 11 GHz using Scalable Wideband Channel Sounder

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1. Introduction

The recent explosion of mobile Internet usage results in the need for higher data rate in future mobile communication systems. One of the key technologies to satisfy this requirement is the multi-link transmission technique which utilizes the cooperative signal processing among spatially distributed multiple users and/or base stations, thus it is considered as more robust in ensuring the degree of freedom in spatial domain over the conventional single-link multiple-input-multiple-output (MIMO) systems [1]. However for the proper design and development of multi-link transmission systems, the level of inter-link channel correlation needs to be accurately modeled. Moreover since each user terminal and base station will also be equipped with multiple antennas, characterization of directional property at transmitter (Tx) and receiver (Rx) is also important for the design of array antennas. Previously, a lot of field measurement results reported focused on the characterization of multi-link propagation channel as summarized in [2]. However in the earlier works, channel stationarity is often assumed due to the limitations of channel sounder capabilities. Recently in [3], geometry-based multi-link channel modeling approach is proposed based on the measurement by dual-link MIMO channel sounder [4], and the propagation mechanisms which cause the correlation among two links are reported. Nevertheless, the existing results are still limited to specific frequency bands (below 2 GHz or 5 GHz) and environments, thus further evaluation based on the multi-link measurements is desired.

This paper presents the results from multi-link measurements in an indoor hall environment utilizing a scalable MIMO channel sounder at 11 GHz which is the extended version of 4×4 system reported in [5]. Measurement is conducted with one Tx - three Rxs setup which provides 4×4 MIMO channel matrices of vertical and horizontal transmissions for triple links. For the better understanding of propagation phenomena, directional measurements are also conducted by combining the three Rxs. The results indicated that the variation of eigenstructures of spatially separated links are highly correlated when Rxs share the line-of-sight (LoS) for Tx.

Table 1: System parameters

Center frequency	11 GHz
Signal bandwidth	400 MHz
Tx power per antenna	10 mW
No. of multitones	2048
Tone separation	195 kHz
No. of Tx	1
No. of Rx	3
No. of ch. per chassis	8

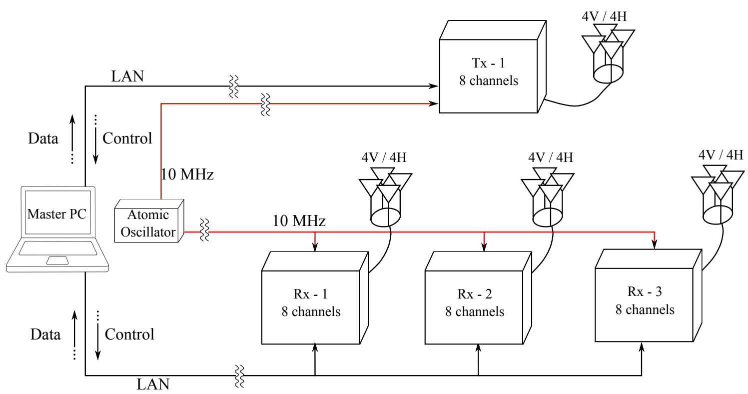
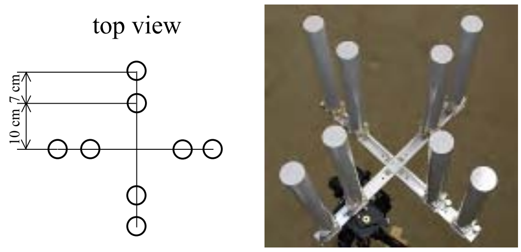
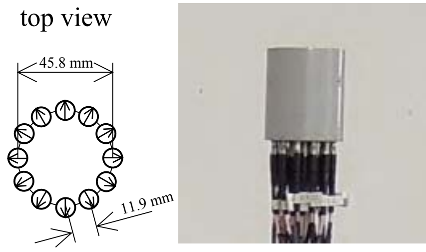


Figure 1: System block-diagram

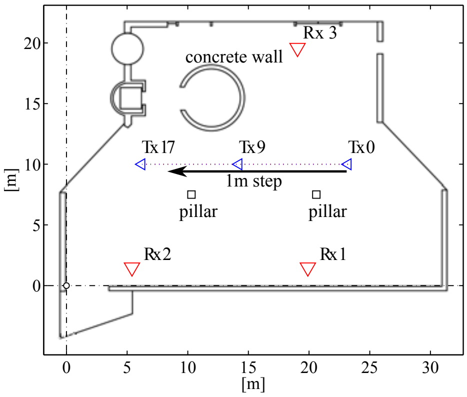


(a) Array for MIMO performance evaluation
V/H dual-polar dipole × 8 elements

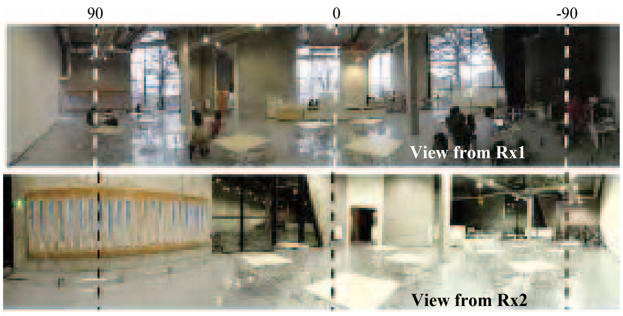


(b) Array for directional estimation
V/H dual-polar 12 elements UCA

Figure 2: Antenna array



(a) Floor plan at indoor hall



(b) Pictures taken at Rx-1 and Rx-2

Figure 3: Measurement environment

2. Measurement Setup

2.1 Scalable MIMO Channel Sounder

The fundamental parameters of the measurement system is summarized in Table 1. As shown in Figure 1, the measurement system consists of 8 × 24 MIMO configuration as a whole. One Tx or Rx chassis consists of 8 RF front-ends with DA (for Tx) or AD (for Rx) converters respectively, and multiple chassis can be connected between one another in a scalable manner. The channel probing signal format can be also flexibly modified depending on the system configuration as proposed in [6]. In this measurement, reference signal generated by single atomic oscillator is shared among multiple chassis for the synchronization. The signal transmission and snapshot capturing can be controlled by master PC via LAN.

For the array antennas, two types of antennas are used as shown in Figure 2. The array which consists of omni-directional dipole elements as shown in Figure 2(a) is for the MIMO performance evaluation, so the configuration and spacing of the elements can be flexibly changed. Uniform circular array (UCA) in Figure 2(b) is used for the purpose of directional estimation.

2.2 Measurement Environment

Figure 3(a) shows the layout of Tx and Rxs in the indoor hall at Tokyo Institute of Technology. All the Rxs were fixed, while the Tx was moved along the arrow on Figure 3(a). Then snapshots were captured every 1 m of Tx movement (move→stop→capture). There were a few people in the hall during the measurements, but the influence on the measured channel can be assumed to be almost negligible. The measurement is divided into two parts: 1) single-link 8 × 24 setup at Rx-1 and Rx-2 (one-by-one) for direction-of-arrival (DoA) estimation, 2) triple-link [one Tx (4V4H) - three Rxs (4V4H for each Rx)] setup for MIMO performance and inter-link correlation analysis. The results are shown in the following section.

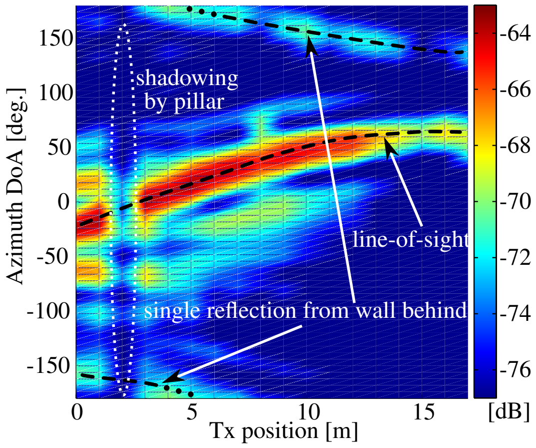


Figure 4: Power-azimuth spectrum: Rx-1

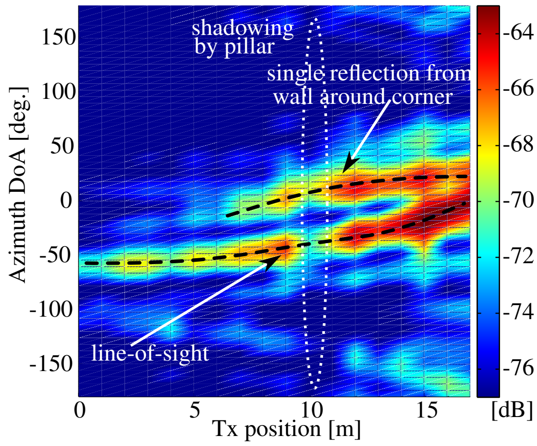


Figure 5: Power-azimuth spectrum: Rx-2

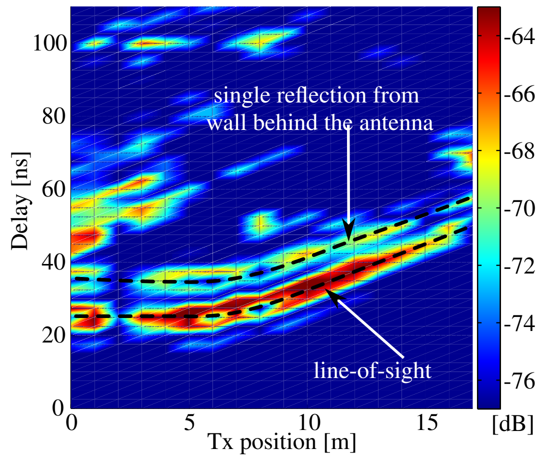


Figure 6: Power-delay spectrum: Rx-1

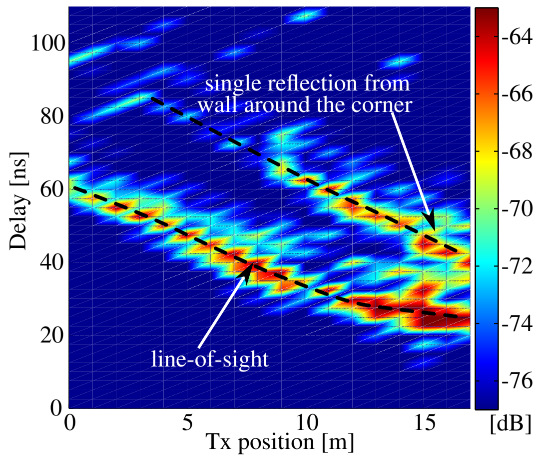


Figure 7: Power-delay spectrum: Rx-2

3. Measurement Results

3.1 Propagation mechanism: results from single-link setup

For the understanding of dominant propagation mechanisms, receive beamforming is done at Rx-1 and Rx-2 based on the estimated V-polar channels i.e. only the 1×12 elements of measured 8×24 MIMO matrix are used. The array response of the UCA measured in an anechoic chamber is used for the DoA estimation. The estimated power-azimuth and power-delay spectrum at different Tx positions are shown in Figure 4 - 7. At Rx-1, single reflection by wall behind the antenna was observed in addition to the LoS component. At Rx-2, LoS component becomes significant as the Tx becomes closer. Also the single reflection from wall around the corner is observed. The results indicate that no significant scatterers common for both links exist, so the LoS components are considered to dominate the correlation structure of both links. Although DoA estimation measurement has not been conducted at Rx-3, a similar trend is expected. Therefore the blockage of LoS by concrete wall (on left top in Figure 3(a)) may be the turning point of change in the correlation structure.

3.2 Measured Eigenvalues and Inter-link Correlation

To characterize the inter-link correlation for the design of multi-link transmission technique, not only the shadowing correlation (correlation of mean path-gain) among multiple links but also the variation and correlation of the eigenstructure of MIMO channel matrices need to be evaluated. For this purpose, eigenvalues are calculated for each link by applying eigenvalue decomposition of the correlation matrices where each channel matrix is normalized by its Frobenius norm.

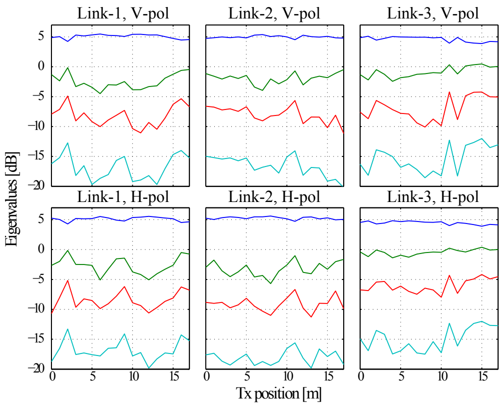


Figure 8: Variation of eigenvalues

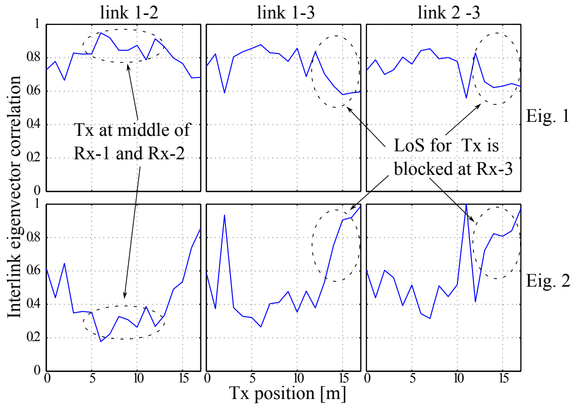


Figure 9: Inter-link eigenvector correlation

The variation of eigenvalues in terms of Tx position is shown in Figure 8. To extract the correlation property of eigenstructure, the inner product of the eigenvectors was calculated as proposed in [7]. The results are shown in Figure 9, where inter-link correlation of higher two eigenvalues are selected since others are almost negligible.

Table 2: Mean eigenvalues [dB]

link	λ_1	λ_2	λ_3	λ_4
1	5.07	-2.49	-8.24	-16.83
2	4.98	-1.93	-8.01	-16.63
3 (LoS)	4.82	-1.27	-7.86	-16.34
3 (NLoS)	4.08	0.19	-4.68	-12.87

As expected from the identified propagation mechanisms, the observed correlation is dominated by the existence of LoS components. Particularly, the effect of shadowing by the concrete wall on the LoS of Link-3 can be clearly seen from the inter-link eigenvector correlation results in Figure 9. The magnitude of eigenvalues averaged over the measured Tx route is shown in Table 2.

4. Conclusion

In this paper, the results from multi-link measurements in an indoor hall scenario at 11 GHz are presented. By utilizing the capability of the scalable channel sounder, the observed inter-link correlations are explained by the identified propagation mechanisms. In the future, the performance comparison between the single-link and multi-link transmission techniques in terms of channel capacity will be analyzed.

Acknowledgments

This work was partly supported by “The research and development project for expansion of radio spectrum resources” of The Ministry of Internal Affairs and Communications, Japan.

References

[1] G. J. Foschini and M. J. Gans, “On Limits of Wireless Communications in a Fading Environment when Using Multiple Antennas,” *Wireless Personal Communications*, pp. 311–335, 1998.

[2] C. Oestges, “Multi-link propagation modeling for beyond next generation wireless,” in *Loughborough Antennas and Propagation Conference (LAPC), 2011*, November, 2011.

[3] J. Poutanen, F. Tufvesson, K. Haneda, V. Kolmonen, and P. Vainikainen, “Multi-Link MIMO Channel Modeling Using Geometry-Based Approach,” *IEEE Transactions on Antennas and Propagation*, no. 99, pp. 1–1, 2011.

[4] V. Kolmonen, P. Almers, J. Salmi, J. Koivunen, K. Haneda, A. Richter, F. Tufvesson, A. Molisch, and P. Vainikainen, “A dynamic dual-link wideband MIMO channel sounder for 5.3 GHz,” *IEEE Transactions on Instrumentation and Measurement*, vol. 59, no. 4, pp. 873–883, 2010.

[5] Y. Konishi, M. Kim, M. Ghoraishi, J. Takada, S. Suyama, and H. Suzuki, “Channel Sounding Technique Using MIMO Software Radio Architecture,” in *European Conference on Antennas and Propagation (EuCAP) 2011*, April, 2011.

[6] M. Kim, J. Takada, and Y. Konishi, “A Novel Scalable MIMO Channel Sounding Technique and Measurement Accuracy Evaluation with Transceiver Impairments,” *IEEE Transactions On Instrumentation And Measurement (to be published)*.

[7] V. Kolmonen, K. Haneda, T. Hult, J. Poutanen, F. Tufvesson, and P. Vainikainen, “Measurement-Based Evaluation of Interlink Correlation for Indoor Multiuser MIMO Channels,” *IEEE Antennas and Wireless Propagation Letters*, vol. 9, pp. 311–314, 2010.