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MCRG TITECH

TOKYO INSTITUTE OF TECHNOLOGY

Leading the world in science and technology, Tokyo Institute of Technology continues to evolve.

Tokyo Institute of Technology, or Tokyo Tech in short, was founded by the Japanese Government, Department of Education, as the Tokyo Vocatioanl Shool in 1881, and then renamed Tokyo Kogyo Daigaku (Tokyo Institute of Technology), in 1929. Following a brilliant history and tradition spanning over 125 years, Tokyo Institute of Technology continues to evolve as one of the world leading science and technology universities of the 21st century.

To be recognized as one of the world-class science and technology universities, Tokyo Tech fosters world-class graduates, develops new frontiers of world-class knowledge, and benefit society through transfer of knowledge by having:

- Three Undergraduate Schools: School of Science, School of Engineering, School of Bioscience and Biotechnology
- Graduate Schools: Graduate School of Science and Engineering, Graduate School of Bioscience and Biotechnology, Interdisciplinary Graduate School of Science and Engineering, Graduate School of Information Science and Engineering, Graduate School of Decision Science and Technology, and Graduate School of Innovation Management.
- Other Research Laboratories.

Tokyo Tech is committed to the following missions:

1. Producing world-class graduates
2. Creating world-class knowledge
3. Contributing to society through the utilization of knowledge

Tokyo Tech seeks to maintain the highest standard in its every mission.

(Information resources:http://www.titech.ac.jp/ and 2005 profile of Tokyo Institute of Technology.)

Tokyo Tech Logo

The logo of Tokyo Institute of Technology was designed by Prof. Shinji Hori in 1948. The white portion represents the Japanese character [工], which is the first character of 'engineering' (工業). The black part represents the Japanese character [大], which is the first character of 'university' (大学). This figure also symbolizes a swallow, which the Japanese regard a bird of good-luck.

東工大
Tokyo Tech

Tokyo Tech

Over the years, Tokyo Institute of Technology or 東京工業大学 (*Tokyo Kogyo Daigaku*) in Japanese had been described in several short names both in English and Japanese. In 2002, the university officially adopted "Tokyo Tech" as the international and "東工大" (*Tokodai*) as the Japanese abbreviation.

School Color

In 2004, Tokyo Tech resolved that its school color would be royal blue, the color that stands for advancement and evolution.

Mobile Communications Research Group

Mobile Communications Research Group (MCRG) of Tokyo Institute of Technology was established in 2001. The objective of the group is to conduct advanced research related to mobile communications.

MCRG consists of three laboratories:

1. Signal Processing laboratory
   (Staff: Prof. Hiroshi Suzuki, Associate Prof. Kazuhiko Fukawa, and Assistant Prof. Satoshi Suyama)
2. System laboratory
   (Staff: Prof. Kiyomichi Araki, Associate Prof. Hidekazu Murata, and Assistant Prof. Kei Sakaguchi)
3. Propagation and Antenna laboratory
   (Staff: Prof. Jun-ichi Takada, and Assistant Prof. Takuichi Hirano)

Our group conducts comprehensive research on the development of mobile communication systems covering a wide range of cutting edge technologies in the fields of antenna and propagation, transmission systems, hardware development and signal processing. The synergy in the group creates an ideal environment for cross-disciplinary discussions and tapping of expertise resulting in various notable joint projects and developments. Our group has a weekly seminar to share the latest research outcomes among internal laboratories and to gain insight on our research activities by inviting guest speakers.

Environment of the weekly seminar

MCRG members

An Open House is yearly organized to introduce our MCRG activities and build a network with external companies, institutes and organizations in the field of mobile communications. Distinguished speakers from both the academia and industry are invited to give key note speeches and lectures to contribute their views and visions for the future development of research in mobile communications.

In the 2006 Open House, five invited lectures were held and we would like to take this opportunity to express our thanks and appreciation to Dr. Hideto HORIKOSHI of Lenovo Japan, Dr. Takao INOUE of Fish Technologies, Dr. Teruya FUJII of Japan Telecom, Dr. Mamoru SAWAHASHI, Dr. Ken-ichi HIGUCHI, and Dr. Hidekazu TAOKA of NTT Docomo Inc., and Prof. Makoto ANDO (Tokyo Tech) for their valuable contribution to the Open House.

Visit our website at http://www.mcrg.ee.titech.ac.jp/

TOKYO INSTITUTE OF TECHNOLOGY

Laboratory Introduction
&
Annual Report 2006

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ARAKI LABORATORY

Professor Kiyomichi Araki

Prof. Araki (left) was born in 1949. He received the B.S. degree in electrical engineering from Saitama University, in 1971, and the M.S. and Ph.D. degrees in physical electronics both from Tokyo Institute of Technology in 1973 and 1978 respectively. In 1973-1975, and 1978-1985, he was a Research Associate at Tokyo Institute of Technology, and in 1985-1995 he was an Associate Professor at Saitama University. In 1979-1980 and 1993-1994 he was a visiting research scholar at University of Texas, Austin and University of Illinois, Urbana, respectively. Since 1995 he has been a Professor at Tokyo Institute of Technology. His research interests are in information security, coding theory, communication theory, ferrite devices, RF circuit theory, electromagnetic theory, software defined radio, array signal processing, UWB technologies, wireless channel modeling and so on. Prof. Araki is a member of IEEE, IEE of Japan and Information Society of Japan.

Assistant Professor Kei Sakaguchi

Asst. Prof. Sakaguchi was born in Osaka, Japan, on November 27, 1973. He received the B.E. degree in electrical and computer engineering from Nagoya Institute of Technology, Japan, in 1996, and the M.E. degree in information processing from Tokyo Institute of Technology, Japan, in 1998. From 2000, he is an Assistant Professor at the Tokyo Institute of Technology. He received the Young Engineer Awards both from IEICE and IEEE AP-S Japan chapter in 2001 and 2002 respectively, and Outstanding Paper Award both from SDR Forum and IEICE in 2004 and 2005 respectively. His current research interests are in MIMO propagation measurement, MIMO communication system, and software defined radio. Asst. Prof. Sakaguchi is a member of IEICE and IEEE.

Member of Araki Laboratory

Tree-Structure Based User Scheduling Algorithm

Multiple-input multiple-output (MIMO) technology has recently emerged as one of the most significant technical breakthroughs in modern communications as a promising solution to provide high data rates and highly reliable data link.

In a time-varying multi-user channel, different users experience peaks in their channel quality at different times; this effect can be exploited by scheduling users to transmit during the time when they have favorable channel conditions. The more users present, the more likely it is that suitably selected users have very good channels at any given time. Hence the total throughput of the system tends to increase with the number of users.

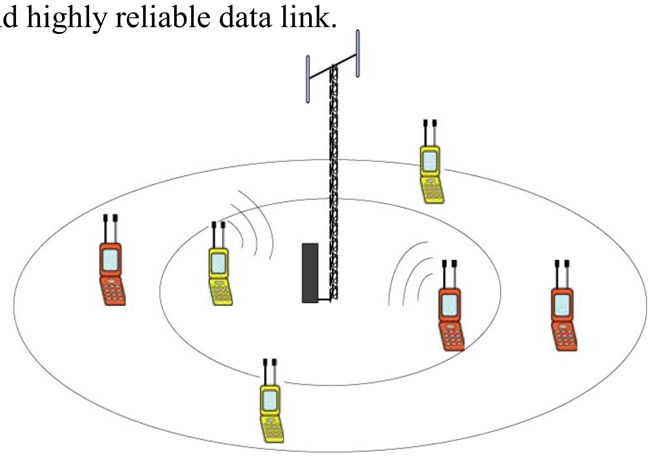
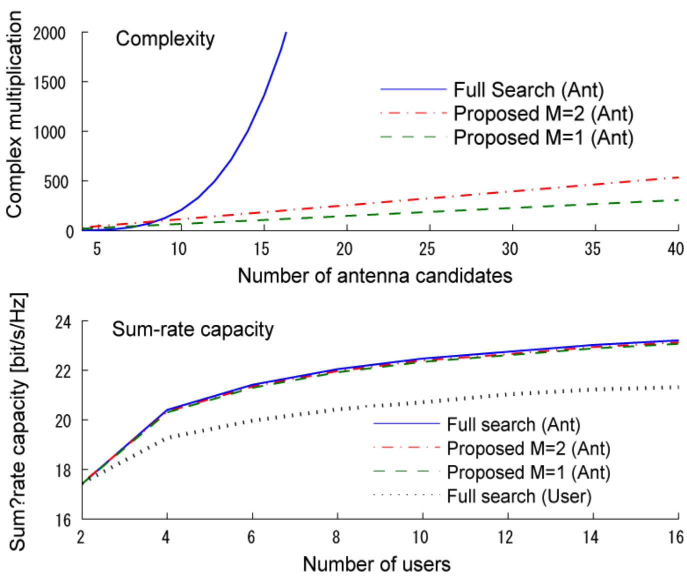


Figure of system model

We proposed a low complexity tree-structure based user scheduling algorithm in an up-link transmission of MLD-based multi-user MIMO wireless systems. An M-branch selection algorithm, which selects M most-possible best branches at each step, is proposed to maximize the whole system sum-rate capacity.

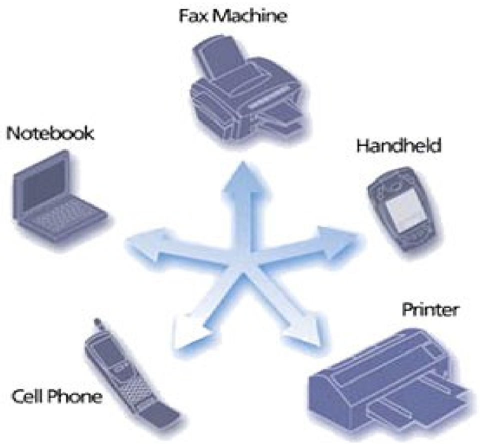


To achieve the maximum capacity in multi-user MIMO systems, antennas configuration and user selection are preformed simultaneously. The proposed algorithm can also be considered as an extended application of the M-algorithm proposed in QRM-MLD algorithm.

Figure shows the complexity and the performance of the system sum-rate capacity of the proposed algorithm. It is shown that the achievable performance is near to the full search scheme but the calculation complexity is significantly lower.

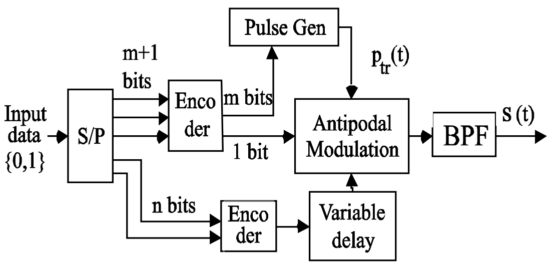
High speed Transmit-Reference UWB

Ultra wide-band (UWB) systems have recently emerged as a promising short-range radio technique for a high data rate in an indoor WLAN or WPAN. Later, Transmit-Reference UWB (TR-UWB) approach has been envisioned as a promising effective method to avoid channel estimation that are known to be difficult problems in UWB systems. However, in the TR-UWB system, at least two pulses with delay interval between pulses are necessary that leads to the decrease in data rate. In order to improve the performance of TR-UWB system, a new modulation scheme, Pulse-position Multi-pulse Modulation (PMM) has been introduced.



PMM DTR-UWB system

With the PMM modulation, the data bits to be transmitted influence the position, the type and the polarity of the data-modulated pulse.

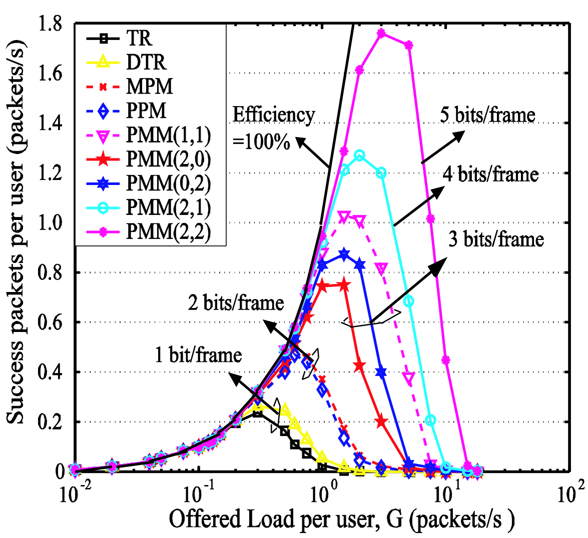


This modulation scheme, PMM(n,m) will increase the total data rate of system which depends on both the number of pulse positions ($N = 2^n$) and the number of different pulses ($M=2^m$) that have been used in the system. Then, PMM(n,m) system can be transmitted n+m+1 data bits per frame that is n+m+1 times when compared to the conventional TR-UWB system.

Simulation result

Figure shows the comparison of the multiple access performance with varying the offered load, G packet/user/s.

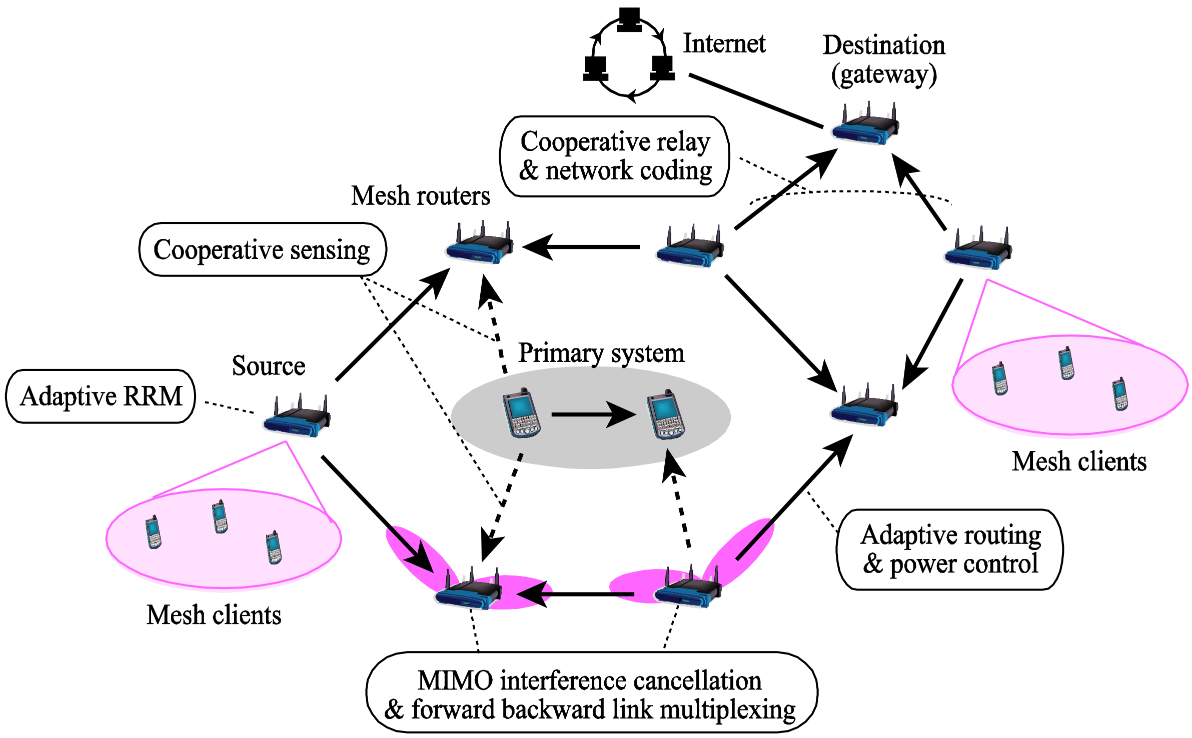
By using the proposed system, PMM(n,m), the system achieve more success packets. The performance has been improved as the number of data bits per frame increased. This is because when the number data bits per frame increased, it leads to the shorter packet length and access time period for one packet. Then, the system will have lower number access user in the same time and lower packet collision probability.



MIMO Mesh Network

Cognitive MIMO Mesh Network for Spatial Spectrum Sharing

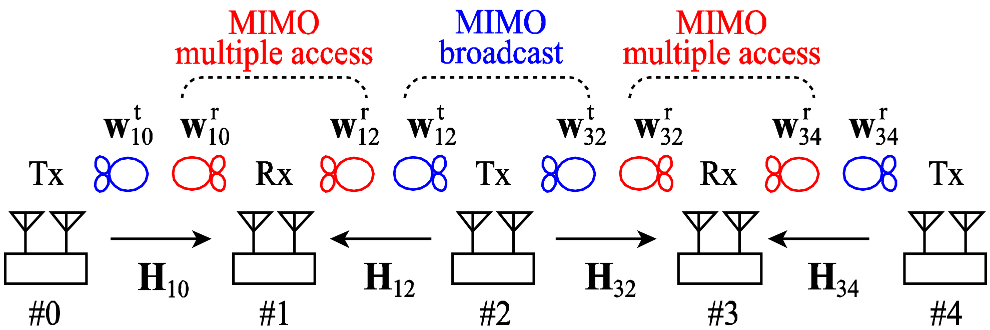
Cognitive radio is a new technology that dynamically allocates radio resources based on spectrum sensing results in a local wireless environment. The goal of introducing cognitive radio is to optimize area spectrum efficiency by means of dynamic management of radio resources in space, time, and frequency domains. In this research project, we are studying on a cognitive MIMO mesh network that can be overlaid on a primary wireless system by avoiding mutual interference not only by dynamic channel allocation but also by spatial signal processing as in the figure. As a first step of the research project, a new concept of MIMO scheme is proposed for transmit and receive interference cancellation and link multiplexing for a mesh network.



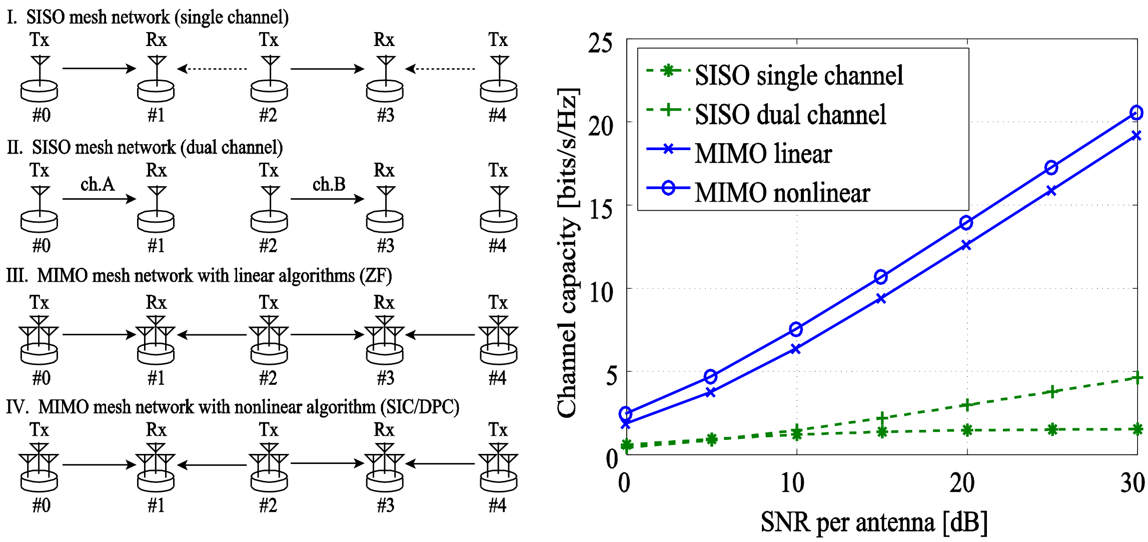
MIMO Interference Cancellation & Link Multiplexing

Wireless mesh network, consists of mesh routers and clients, has been getting much attention in the field of sensor network or wireless plant control system. Advantages of a mesh network are connectivity, robustness, and wide area coverage owing to multi-hop relay property. The mesh routers should supply the backbone with high capacity to support accumulated traffic from or to mesh clients. Since there are multiple transmission links in a mesh network, multiple access interference occurs, and it degrades throughput performance of the network severely. Multi-channel network architecture has been commonly introduced to avoid co-channel interference so far.

However, it also degrades the network channel capacity due to a waste of radio resources. To solve the problems, we have proposed MIMO mesh network as described in the figure. In the proposed MIMO mesh network, multiple antennas are employed in the mesh nodes to achieve interference cancellation and link multiplexing simultaneously. The proposed architecture can be considered as a concatenation of MIMO Multiple Access (MIMO-MA) and MIMO Broadcast (MIMO-BC) channels in a Multi-user MIMO (MU-MIMO) scenario. Receive interference cancellation and transmit interference cancellation can be achieved by MIMO-MA and MIMO-BC respectively. Moreover, forward and backward link multiplexing can be achieved by concatenating MIMO-MA and MIMO-BC, which improves the network channel capacity at least twofold.



It can be found from numerical analysis that performance of the proposed MIMO mesh network is about four times higher than that of SISO networks. It is due to the link multiplexing as well as the interference cancellation provided in the proposed MIMO mesh network. Analysis with adaptive Radio Resource Management (RRM), network coding, and dynamic routing algorithm will be our future works.



MIMO schemes for cellular network

1. Development of IEEE802.16e Simulator

The IEEE802.16e has gained attention as the primary wireless MAN (Metropolitan Area Network) standard for the future. We have developed the transmission simulator on MATLAB to analyze transmission performance in IEEE802.16e. It is possible to transmit using SISO, 4×4 MIMO and 4×2 MIMO in the simulator based on IEEE802.16e DL PUSC. The transmission performance of these transfer modes can be compared through the bit-error-rate (BER), throughput, and other parameters. Furthermore, the simulator has high scalability in dealing with the different FFT-point and CP-length configurations in the IEEE802.16e standard. Research on eigenmode (EM) precoding systems and adaptive modulation coding systems has been carried out through this simulator.

Table 1: Simulation parameters

No. of antennas, Tx×Rx	1×1, 4×4, 4×2
FFT size	128, 512, 1024, 2048
CP length	1/32, 1/16, 1/8, 1/4
Modulation	QPSK, 16QAM, 64QAM
Code rate	Convolution code (K=7) (1/2, 2/3, 3/4)
MIMO transfer mode	ZF, MMSE, EM-ZF, EM-MMSE, STBC-ZF, STBC-MMSE

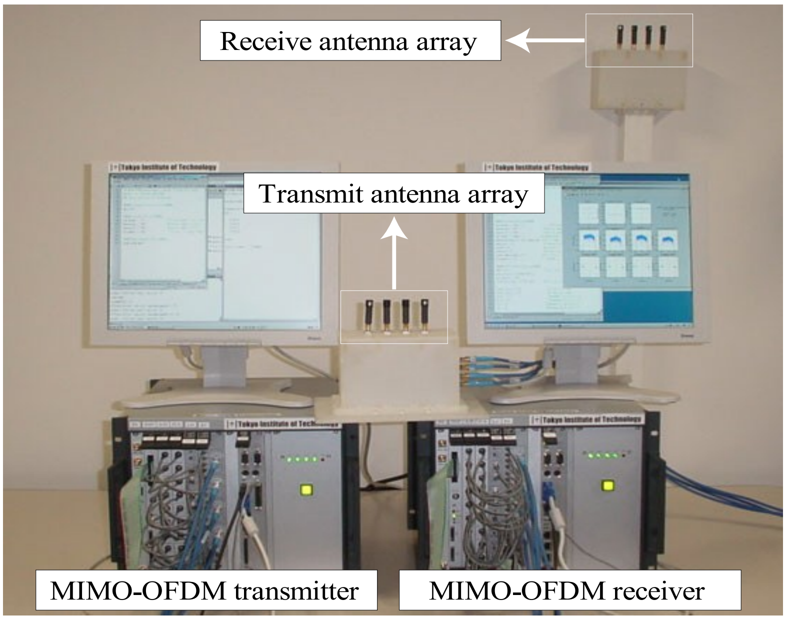


Fig1: The exterior of system

2. Implementation of Hardware

To evaluate the transmission performance of IEEE802.16e under real environments, we implemented the IEEE802.16e transmission system in hardware. The exterior of main system is shown in Fig1.

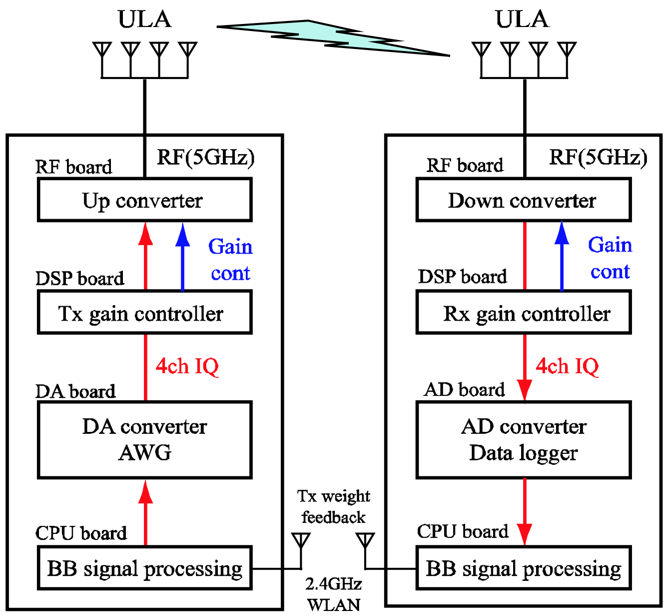
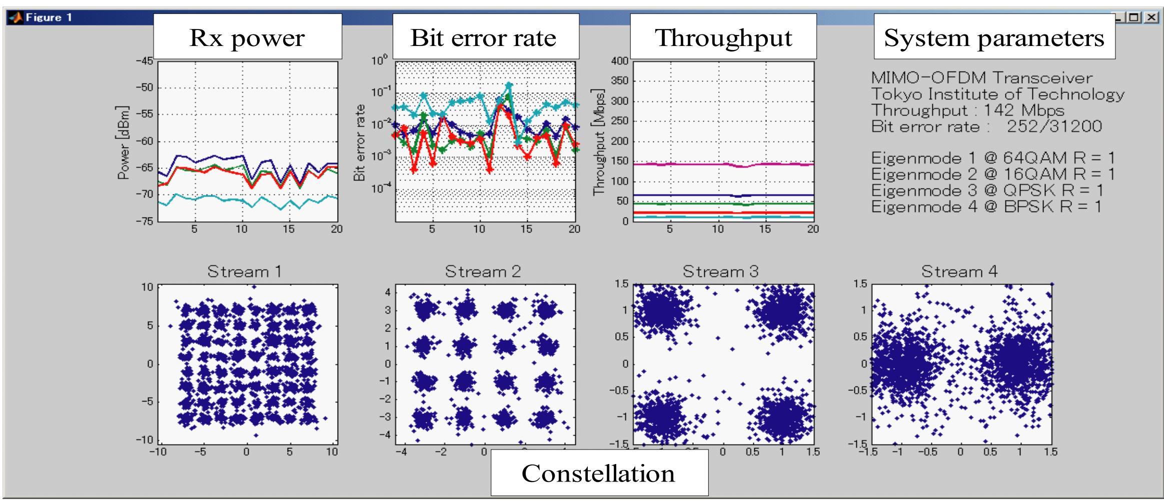


Fig2: Architecture of implementation

In Fig2 the architecture of the implementation is represented. The receive platform is composed of RF board, LO board, transmit front end board, receive front end board, signal processing board and CPU board as each function. These are placed in a compact PCI 6U rack. The Baseband signal processing is conducted on transmit front end board, receive front end board, and signal processing board. The Transmit front end board in transmitter works as the 4ch arbitrary waveform generator and the 4ch baseband signal can be outputted by inserting the transmitting signal using MEX functions in MATLAB.

Generation of transmit data signal, synchronization, channel estimation, FFT and so on are processed on MATLAB and loaded on the CPU board. The parameters relating to RF is shown in table2.

EM-ZF transmission results are shown for the system in Fig3. Transmission is through 4×4 transceiver antennas, at a signal-to-noise ratio (SNR) of about 25dB. BER is calculated easily, because receiver receives the transmitting bit streams beforehand.



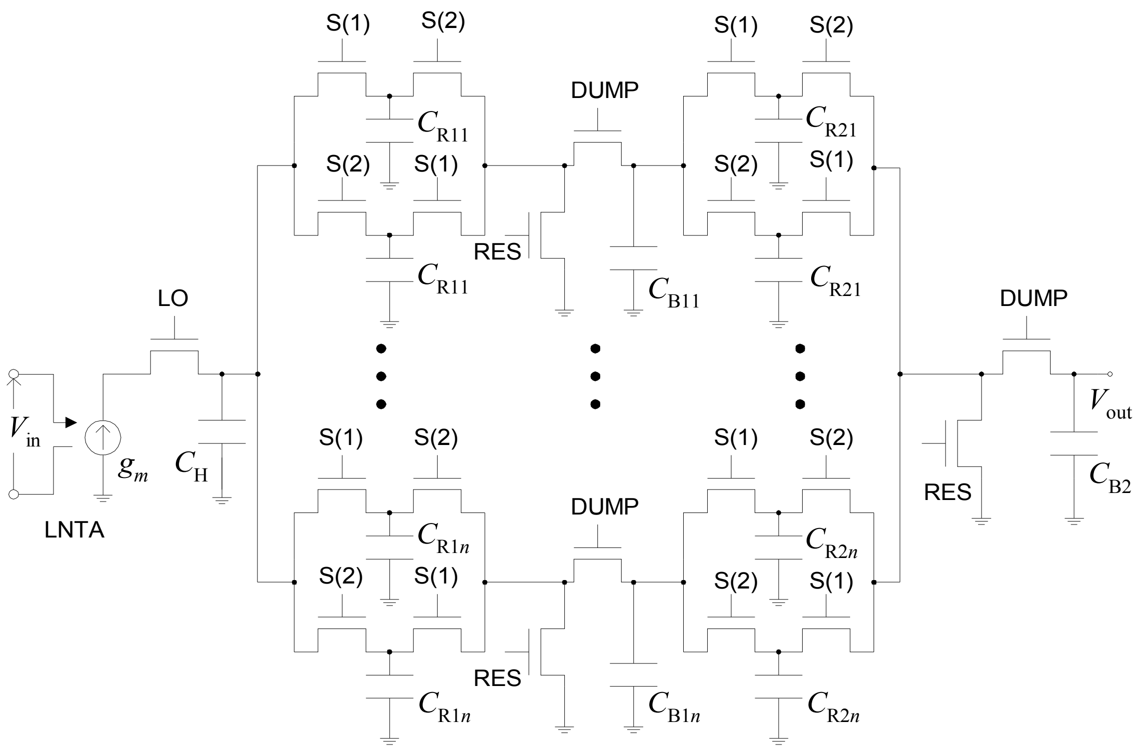
Future of Software Defined Radio

Digital RF Transceiver

Software defined radio (SDR) is of critical importance to the future of efficient and effective radio communication that must include interoperability between different protocols and standards with varying software, system and physical parameters. The transceiver is easily the toughest challenge for the realization of a true SDR system. The ideal transceiver must be able to respond smoothly to the rapidly changing protocols and transmit/receive signals operating at different frequencies and modulation techniques. This demanding requirement means that traditional RF design methods are insufficient and thus we are devoted to the research on digital RF transceiver which is widely recognized as an answer to the practical implementation of SDR.

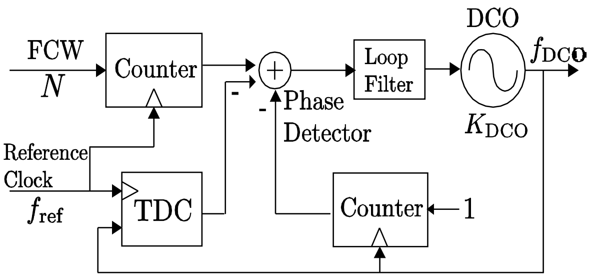
Direct Sampling Mixer with Serial-Parallel Structure

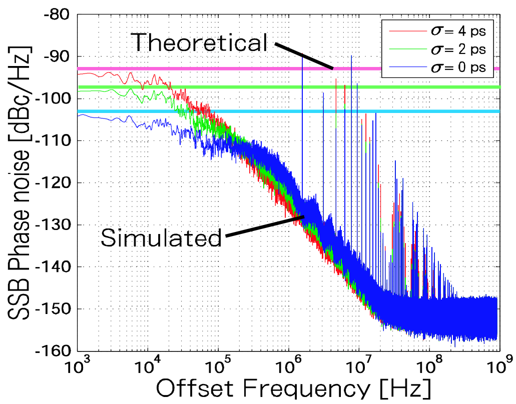
As part of our research program, we focus on Direct Sampling Mixer (DSM) as a possible solution for the digital RF of SDR. DSM, as the name suggests, is a discrete-time circuit that directly samples the RF signal, performs decimation and filtering to achieve its role as a mixer for down-conversion. However, the transfer function of DSM is only of first order and thus possesses poor skirt characteristics. To alleviate this problem, we propose a novel serial-parallel architecture for DSM where the number of attenuation poles can be configured thus achieving excellent skirt characteristics



Process Variation Effect on All-Digital Phase Locked Loops

All-Digital PLL(ADPLL) has been proposed for local oscillators of digital RF transceivers. The conventional VCO and Charge-pump(phase detector) are replaced by Digitally-Controlled Oscillator and Time-to-Digital Converter, which can be implemented with standard CMOS process. Compared with conventional PLL, ADPLL is immune from tuning voltage fluctuations. But the quantization errors of DCO and TDC may deteriorate the phase noise. We analyzed how much the process variation of TDC inverters effects on phase noise of ADPLL and verified with the simulation results.

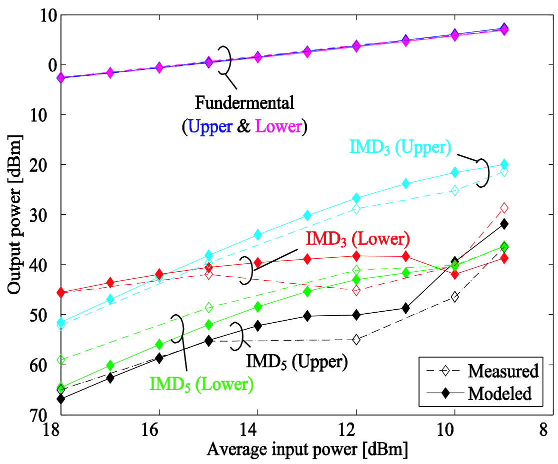


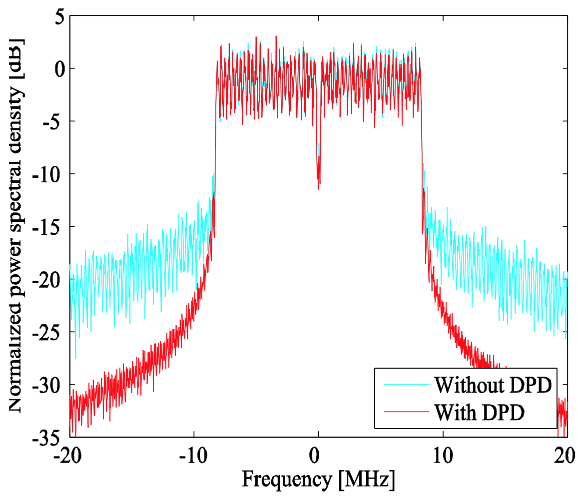


Compensation for Non-linear Distortion in Power Amplifiers

Power Amplifier (PA) is an indispensable component in a wireless communication. However, the I/O characteristic of PA has the nonlinearity in general. There is Digital Pre-Distortion (DPD) as a technology that makes amends for the distortion that occurs because of this nonlinearity. In DPD, it is necessary to model a nonlinear characteristic of PA accurately. The memory effect becomes visible characteristic of PA along with the wider bandwidth and the higher frequency of the signal. However, the model including those effects has not been established enough.

In this research, first of all, the I/O characteristic of PA has been measured, and a nonlinear characteristic that contains memory effect based on the measured data has been modeled. Next, the computer simulation of DPD based on the model was executed, and the characteristic was clarified.





SUZUKI FUKAWA LABORATORY

web site: http://www.radio.ss.titech.ac.jp/

Professor Hiroshi Suzuki
received the B.S. degree in electrical engineering, the M.S. degree in physical electronics, and the Dr. Eng. Degree in electrical and electronics engineering, all from the Tokyo Institute of Technology, Tokyo, in 1972, 1974, and 1986, respectively. He joined the Electrical Communication Laboratories, Nippon Telegraph and Telephone Corporation (NTT), Japan, in 1974. He was engaged in research on devices in millimeter-wave regions. Since 1978, he has been engaged in fundamental and developmental research on digital mobile communication systems. He was an Executive Research Engineer in the Research and Development Department, NTT Mobile Communications Network, Inc. (NTT DoCoMo) from 1992 to 1996. Since September 1996, he has been a professor at the Tokyo Institute of Technology. He is currently interested in various applications of the adaptive signal processing to radio signaling: adaptive arrays, multiuser detection, and interference canceling for future advanced multiple-access communication systems. Prof. Suzuki is a member of IEEE and the Institute of Electronics, Information, and Communication Engineers (IEICE) of Japan. He received the Paper Award from the IEICE in 1995.

Associate Professor Kazuhiko Fukawa
received the B.S. and M.S. degrees in physics, and the Dr. Eng. degree in electrical and electronics engineering, all from Tokyo Institute of Technology, Tokyo, Japan, in 1985, 1987, and 1999 respectively. He joined Nippon Telegraph and Telephone Corporation (NTT), Japan, in 1987. Since then, he has been engaged in research on digital mobile radio communication systems and applications of the adaptive signal processing, including adaptive equalization, interference cancellation, and adaptive arrays. He was a Senior Research Engineer at NTT Mobile Communications Network Inc. (NTT DoCoMo), from 1994 to 2000. Since April 2000, he has been an Associate Professor at the Tokyo Institute of Technology. Prof. Fukawa is a member of IEEE and the Institute of Electronics, Information and Communication Engineers (IEICE) of Japan. He received the Paper Award from IEICE in 1995.

Assistant Professor Satoshi Suyama
received the B.S. degree in electrical and electronic engineering and the M.S. degree in information processing from Tokyo Institute of Technology, Tokyo, Japan, in 1999 and 2001, respectively. Since 2001, he has been an Assistant Professor in the Department of Communications and Integrated Systems at the Tokyo Institute of Technology. He is currently interested in various applications of the adaptive signal processing to radio signaling: turbo equalization, interference cancellation, and channel estimation for OFDM, MC-CDMA, and MIMO-OFDM. He is also interested in FPGA and DSP based simulators for radio signal processing. Prof. Suyama is a member of the Institute of Electronics, Information, and Communication Engineers (IEICE) of Japan. He received the Young Researchers' Award from the IEICE in 2005.

Implementation of MIMO-OFDM system simulator on a Large Scale FPGA Board

I. Introduction

For the research and development of the signal processing in mobile communication systems, a simulator implemented on the programable device, such as FPGA, is necessary to evaluate the novel algorithms for real time processing. In our laboratory, 2 x 2 MIMO-OFDM baseband simulator has been implemented on an FPGA board.

This report presents the enhanced simulator which can realize up to 540 Mbps using 100 MHz band-width with R=3/4, 64QAM transmission. To realize the high data rate transmission within the limited hardware resource, the receiver employs accurate timing recovery, matrix matrix inversion, bit LLR calculation in fixed-point processing, and effective LLR quantization. Separately from the simulator, the transmitter employing the Subcarrier Phase Hoping with Selected Mapping (SPH-SLM), which reduces the PAPR and increases the frequency diversity gain, has been developed and is also introduced in this report.

II. MIMO-OFDM Simulator for high data-rate transmission

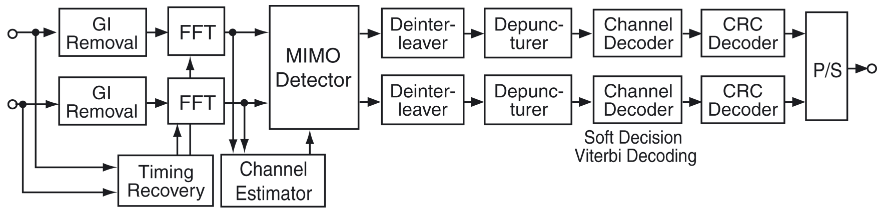


Fig.1 Block diagram of the receiver module

In order to realize the high data-rate transmission, the receiver employs enhanced signal processing. Fig.1 shows the block diagram of the implemented receiver module. In this receiver, at first, the timing recovery circuit performs the packet and FFT timing synchronization. After GI removal and FFT, MMSE detector outputs the bit LLR for each subcarrier by using the frequency response estimated by the pilot symbols. The LLR is used for the soft decision Viterbi decoding (SDVD) after deinterleaving and depuncturing. The CRC decoder detects the decision error of the decoded bits.

Fig.2 shows the block diagram of the accurate timing recovery. To recover the accurate FFT timing, it performs two processing; the tentative recovery using (i) correlation of the received signal and (ii) detection of the first arrival path using the estimated impulse response.

The MMSE detector employs an adaptive fixed-point control in the matrix inversion for highly reliable implementation.

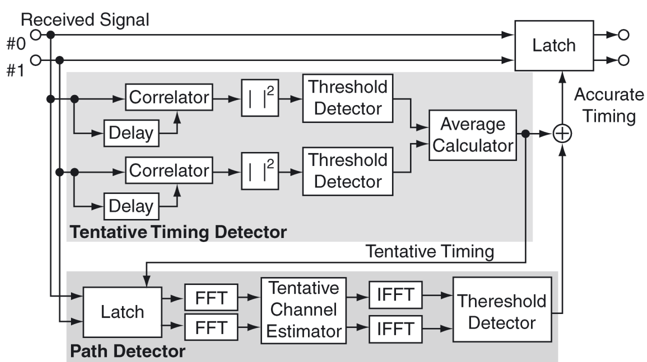


Fig.2 Accurate timing recovery

The quantized bit in the SDVD is transformed from 16 bits into 6 bits for real time operation and circuit reduction.

Fig.3 shows the PER performance comparison between the implemented timing recovery and conventional tentative one. This figure shows that the implemented one improves the performance and the results of computer simulation and FPGA implementation are almost the same.

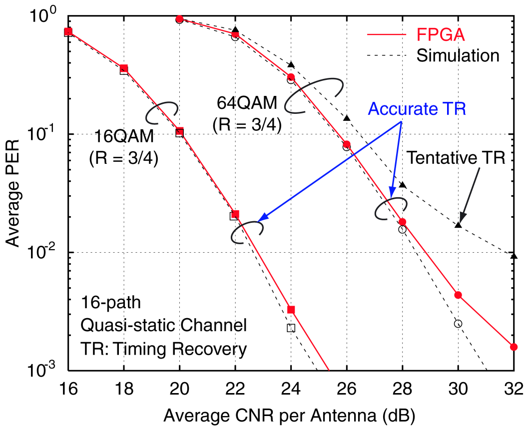


Fig.3 PER performance

III. Enhanced transmitter with SPH-SLM

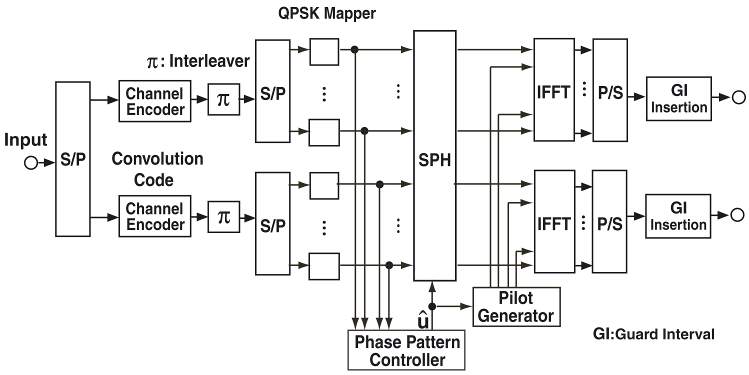


Fig.4 Block diagram of the transmitter employing SPH-SLM

Fig.4 shows the block diagram of the transmitter which employs SPH-SLM. Information bits are divided into 2 data streams, after channel coding and interleaving, the transmitter maps them into a modulation signal at each subcarrier. In the phase pattern controller, several phase matrices of all subcarriers are prepared as the phase patterns, and the controller selects an optimum phase pattern that can minimize the peak power for every symbol from them. The selected phase pattern is modulated into the pilot subcarriers.

Fig.5 and Fig.6 shows the transmitted symbol constellations of the conventional MIMO-OFDM transmitter and the one with SPH-SLM respectively. It is demonstrated that SPH-SLM can reduce the peak power effectively and achieve PAPR of less than 7 dB at CCDF of 10^{-3}.

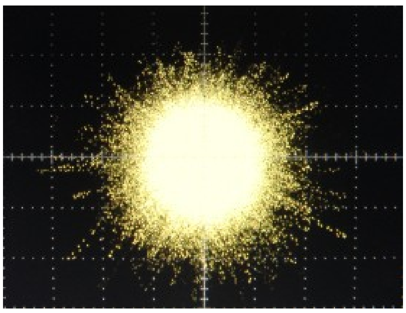


Fig.5 Conventional MIMO-OFDM transmitter

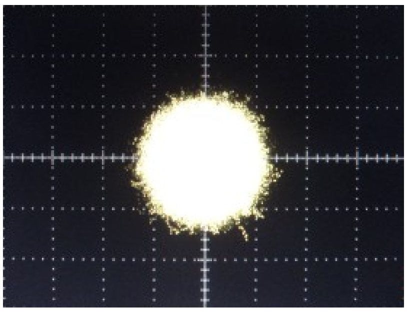


Fig. 6 With SPH-SLM

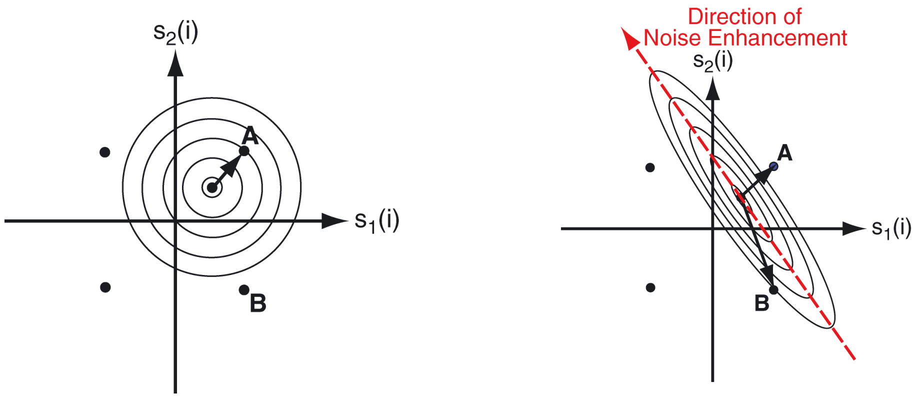
Reliable Signal Detection for High Data Rate Mobile Radio Transmission

I. Introduction

MIMO-OFDM is one of the most promising techniques to realize the high bit-rate and spectral efficient transmission. The optimal signal detection is based on maximum likelihood (ML) criteria or maximum *a posteriori* criteria, however, they required a prohibitive large amount of computational complexity. This report presents a novel suboptimal signal detection that reduces the complexity of the ML detection (MLD) for MIMO systems. Moreover, the application of the EM algorithm for MIMO-OFDM system , which can reduce the complexity of the MAP detection, is presented and a new adaptive algorithm for the channel estimation is introduced.

II. Suboptimal Algorithm of MLD for MIMO Channels

The suboptimal algorithms can be classified into 2 categories. One is the state reduction type algorithm such as M-algorithm, sphere decoding and ordering QRD. However this type of algorithm still need a number of candidates to be searched to maintain the BER performance. Another type is linear detection such as ZF-MLD, however, its performance is not enough because of the noise enhancement or drastically reduced candidates. Fig.1 shows the effect of the noise enhancement in signal detection space. As shown in (a), the nearest point A represents the correct hard decision without the noise enhancement. However with the noise enhancement, as shown in (b) not the point A but the another point B minimizes the metric and is selected as the hard decision.



(a) without noise enhancement **(b) with noise enhancement**

Fig.1 Effect of the noise enhancement

To cope with this problem, the proposed algorithm uses the linear filtering of ZF/MMSE for the initial guess, and searches the signal candidates in the direction of the noise enhancement with a gradient based algorithm. Among these candidates, the one which has a maximum likelihood value will be selected.

Fig.2 and Fig.3 shows the average BER performance and the complexity of the proposed suboptimal algorithm, MLD, ZF, and conventional suboptimal algorithm; ZF-MLD and ordering QR-MLD. These figures show that the proposed suboptimal algorithm is much superior to the conventional suboptimal algorithms in BER performance, while requiring low complexity.

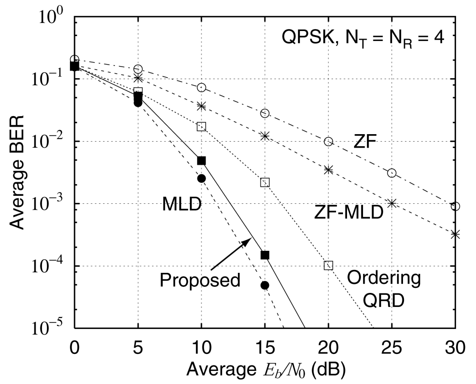


Fig.2 Average BER performance

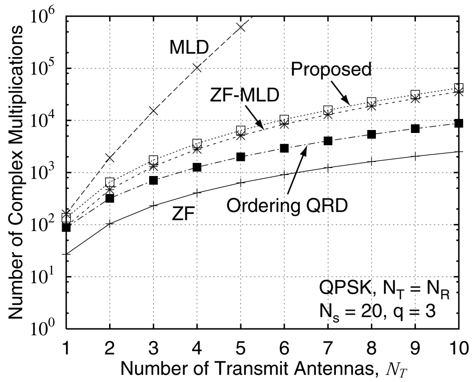


Fig.3 Number of multiplications

III. EM Algorithm for MIMO-OFDM

The EM algorithm can reduce a prohibitive large amount of computational complexity of the MAP estimation to a feasible amount by recursive approximation. There are two different schemes to apply the EM algorithm for the MIMO-OFDM receiver. The one performs the MAP-based signal detection and is referred to as SD-EM (signal detection). The other performs the MAP-based channel estimation and is referred to as CE-EM (channel estimation). Both schemes iterate signal detection and channel estimation unless the number of iterations exceeds a predetermined number.

Differently from the conventional EM-based receiver employing the minimum mean square error (MMSE) channel estimation, the proposed receiver performs the channel estimation by the recursive least squares (RLS) algorithm in order to track a fast fading channel. For further improvement, the proposed receiver applies two new adaptive algorithms that can be derived from message passing on factor graphs. The one, which is referred to as S-RLS, exploits all detected signals for smoothing, whereas RLS exploits only the target time signal and the past signals. The other exploits all detected signals but one of the target time, and is referred to as SR-RLS.

A block diagram of the proposed receiver is shown in Fig. 4. The receiver is mainly composed of the ML detector, the MAP detector, the channel estimator, and the LDPC decoder. log likelihood ratio (LLR) is updated and passed from the ML/MAP detector to LDPC decoder, or vice versa.

Fig.5 shows the average packet error rate (PER) performance of the proposed receivers employing SD-EM. The numbers of transmit antennas and received antennas were set to 2 and 2. Half rate LDPC code was used as the channel coding and normalized maximum Doppler frequency was set to 0.03. S-RLS and SR-RLS are superior to RLS and can realize PER less than 10^{-2}.

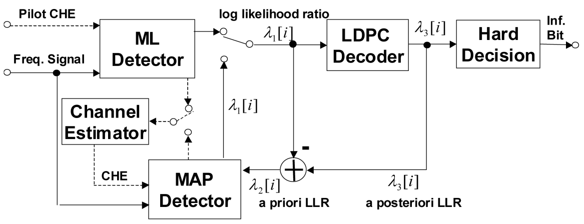


Fig.4 block diagram of MAP receiver

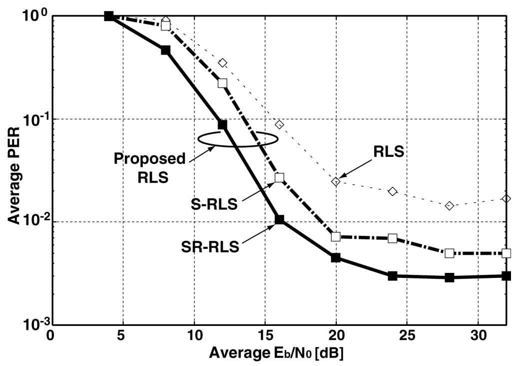


Fig.5 PER performance

Suzuki Fukawa Laboratory

Co-channel interference canceller in MIMO OFDM mobile radio systems

I. Introduction

MIMO-OFDM is the one of the most promising techniques for high bit-rate mobile communications because it can utilize the spectrum efficiently and improve the system capacity. However, the conventional detectors cannot maintain sufficient BER performance in co-channel interference environments. Thus, the ML detector (MLD) with the array combing (AC) , referred to as AC-MLD, has been proposed to suppress the interference by spatial-temporal prewhitening filtering. In this report, two schemes that can improve conventional AC-MLD as for the complexity and the performance are presented.

II. Recursive Eigenvalue Decomposition (EVD)

Fig.1 shows a block diagram of AC-MLD. A parameter estimator employing estimates coefficients of the whitening matched filters and the channel impulse response. It's based on the EVD of the auto-correlation matrix of the extended received signal vector.

One major problem of AC-MLD is that it requires a large amount of computational complexity because it performs parameter estimation by the nonrecursive EVD. To reduce the complexity, a recursive EVD method is applied to AC-MLD.

Such application enables AC-MLD to update the parameters while reducing the complexity.

Fig.2 shows the computational complexity versus the dimension of the auto-correlation matrix. It can be seen that the computational complexity of the recursive EVD is much less than that of the nonrecursive one while other simulation results show that the BER performance of the recursive one is much close to the nonrecursive one.

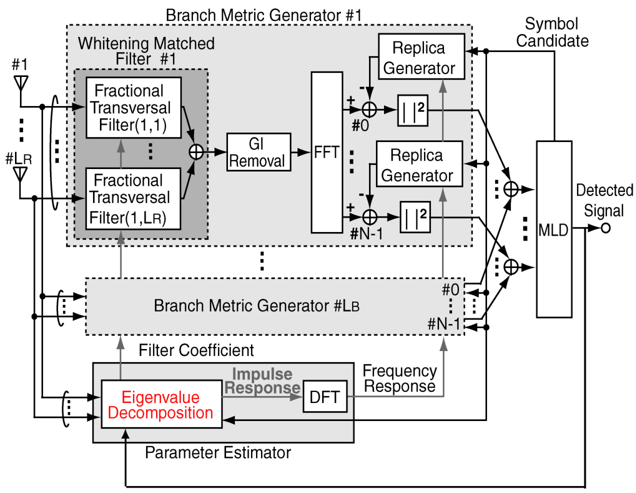


Fig.1 Conventional AC-MLD

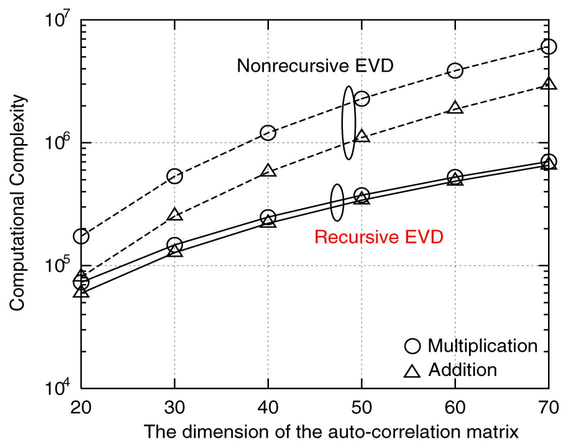


Fig.2 Computational complexity

III. Adaptive MU-AC-MLD

As another problem, the conventional AC-MLD (SingleUser-AC-MLD) suffers from BER degradation when a difference in average angle of arrival between desired and interfering signals is small. To solve such a problem, MultiUser-AC-MLD is proposed in our laboratory. However, under a noisy channel condition, MU-AC-MLD is likely to be inferior to SU-AC-MLD in BER performance because the former estimates more parameters. Therefore, we also propose two control algorithms for switching between SU-AC-MLD and MU-AC-MLD. As shown in Fig. 4, computer simulations demonstrate that the proposed control algorithms can properly select one detector that is superior in BER performance to the other.

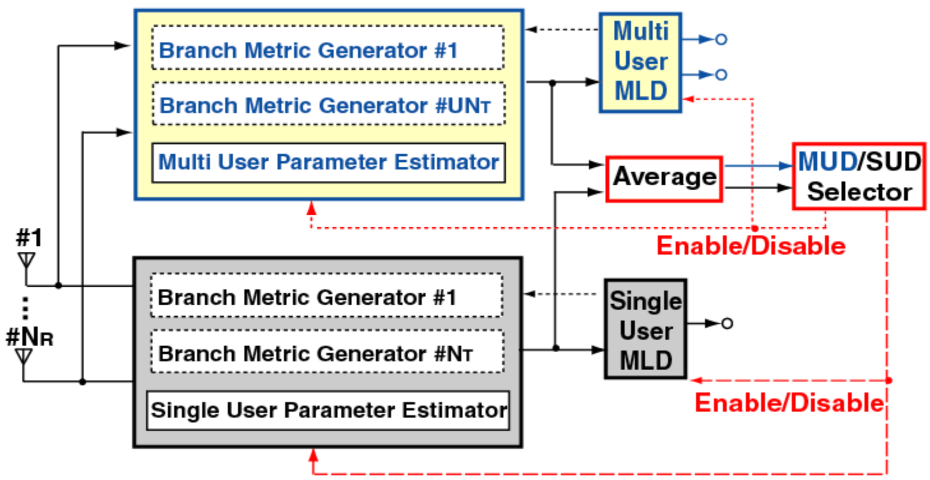


Fig.3 Adaptive MU-AC-MLD

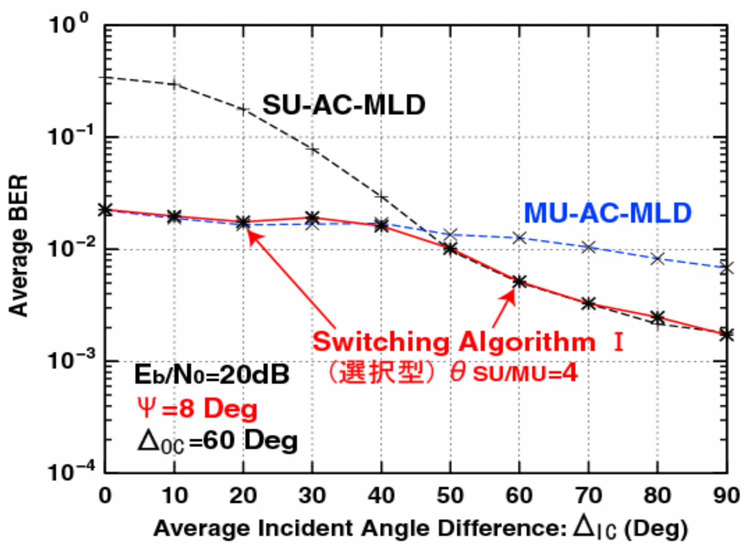


Fig.4 BER Performance

Highly efficient mobile radio packet protocol with multiuser detection

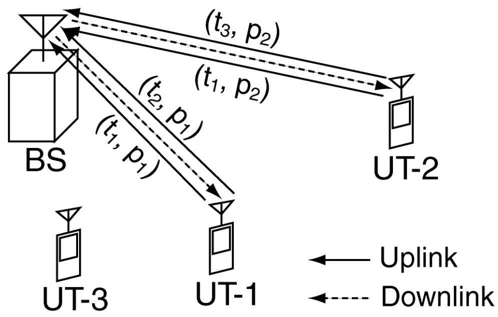
I. Introduction

Recently, mobile radio packet is a hot topic because demands of the high-speed data transmission have been growing rapidly.

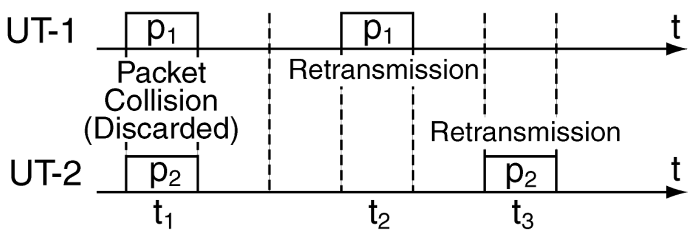
One major problem of the mobile radio packet based on the random access protocol is that packet collision degrades its throughput performance because collided packets are discarded. Multiuser detection (MUD) and reliability combination for automatic repeat request (ARQ) protocol are promising to solve such a problem, because MUD can separate collided packets into each packet and the reliability combination can reduce the number of retransmissions for ARQ protocol. This report presents the packet transmission protocols with MUD for mobile radio packet system.

II. Packet retransmission protocols with multiuser detection

Fig. 1 (a) shows a scene of packet collision at the base station (BS) by two packets transmitted from user terminals (UT-1 and UT-2), and (b) the time schedule. The packet collision occurred at t_1 and the packets were discarded. UT-1 and UT-2 retransmit each collided packet at t_2 and t_3. The proposed packet protocols control the timing of packet retransmission for combining reliabilities. Two reliabilities are metric, which is the squared Euclidean distance between the received signal and its replica signal, and log likelihood ratio (LLR) of coded bit. Bit LLR can be obtained from the metric.

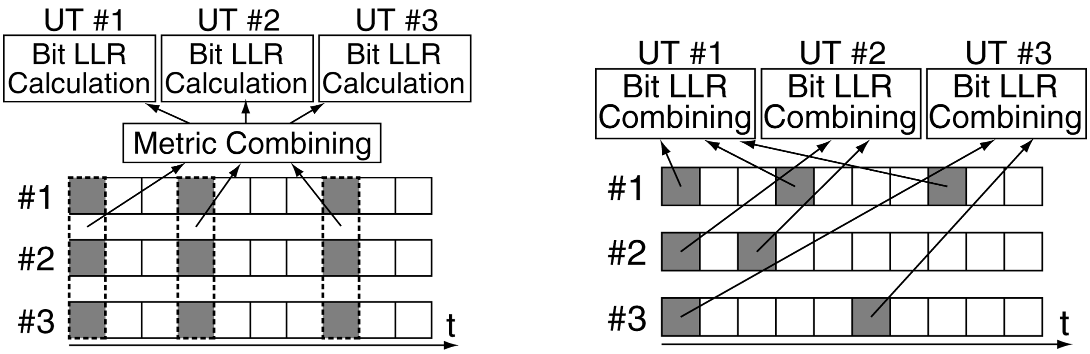


(a) Packet collision by two packets



(b) Time schedule

Fig.1 Mobile radio packet system with random access protocol



(a) MC-MUD (b) LC-MUD

Fig.2 Packet retransmission by proposed protocols

Fig. 2 shows the packet retransmissions of (a) MC-MUD: metric combining multiuser detection, and (b) LC-MUD: LLR combining multiuser detection. MC-MUD separates the collided packets by MUD and combines the metric in packet retransmission. To combine the metrics, the collision of the same packets is required. Therefore, the retransmission protocol of MC-MUD is complex and degrades the efficiency of time slots. On the other hand, since LC-MUD combines bit LLR in packet retransmission, the collision of the same packets is not required. Therefore, the retransmission protocol can be simplified, and the throughput performance increases because the efficiency of time slots improves.

III. Performance Evaluation

The throughput performances of the proposed systems were evaluated by computer simulations, which follows the WLAN specification. Fig. 3 shows average throughput performance which the systems employing the proposed schemes (MC-MUD and LC-MUD) achieved. For comparison, the performances of conventional schemes (MUD and NDMA) are also shown. The number of user terminals is three, and the number of packets which MUD can separate is also three. LC-MUD achieved over 50 % higher throughput than conventional schemes and 20 % higher than MC-MUD.

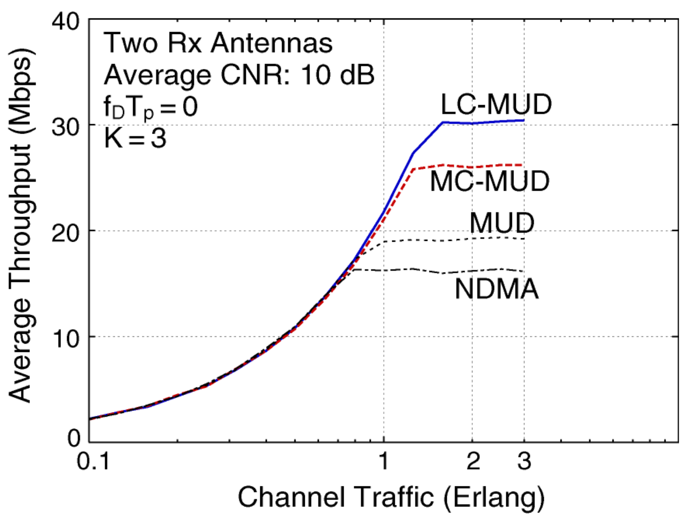


Fig.3 Throughput performance

TAKADA LABORATORY

Professor Jun-ichi TAKADA

was born in Tokyo, Japan, in 1964. He received the B.E., M.E., and D.E. degrees from the Tokyo Institute of Technology, Tokyo, Japan, in 1987, 1989, and 1992 respectively. From 1992 to 1994, he was a Research Associate at Chiba University, Chiba, Japan. From 1994 to 2006, he was an Associate Professor at the Tokyo Institute of Technology before becoming a Professor. He has been participating in European COST action 2100 "Toward mobile broadband multimedia networks." His current research interests are wireless propagation and channel modeling, array signal processing, Cognitive radio, and application of wireless communication and information technology for regional/rural development. Dr. Takada is a member of IEEE, IEICE, Applied Computational Electromagnetics Society (ACES), and ECTI Association, Thailand.

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「MIMO 伝搬特性の測定装置・測定方法・解析方法・モデル化」

平成十七年九月 電子情報通信学会和文論文誌B

あなたの標記論文は本会通信ソサイエティの学問技術分野の発展に貢献する優秀な論文と認められました

よってここに通信ソサイエティ論文賞規程により論文賞牌および賞金を贈呈し表彰いたします

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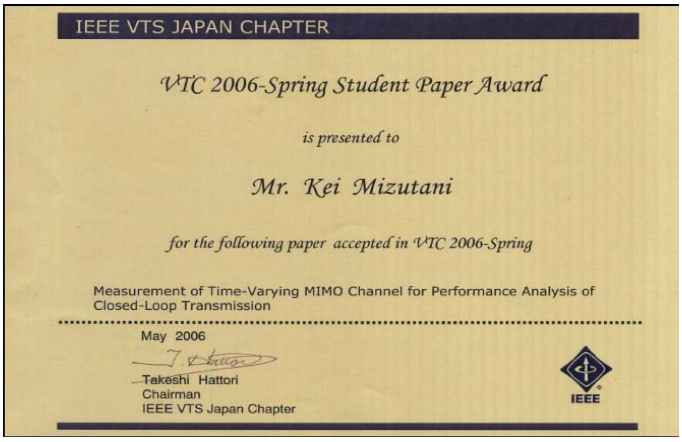
Prof. Takada won IEICE'06 Society Tutorial Paper Award



IEEE VTS JAPAN CHAPTER

VTC 2006-Spring Student Paper Award

is presented to

Mr. Kei Mizutani

for the following paper accepted in VTC 2006-Spring

Measurement of Time-Varying MIMO Channel for Performance Analysis of Closed-Loop Transmission

May 2006

Takeshi Hattori
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IEEE

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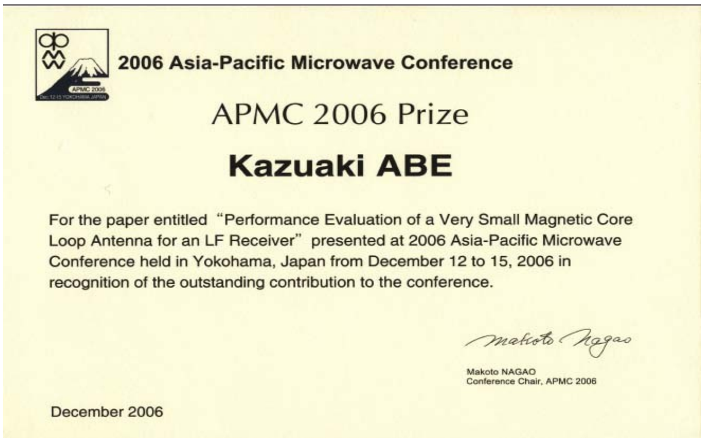

2006 Asia-Pacific Microwave Conference

APMC 2006 Prize

Kazuaki ABE

For the paper entitled "Performance Evaluation of a Very Small Magnetic Core Loop Antenna for an LF Receiver" presented at 2006 Asia-Pacific Microwave Conference held in Yokohama, Japan from December 12 to 15, 2006 in recognition of the outstanding contribution to the conference.

Makoto NAGAO
Conference Chair, APMC 2006

December 2006

Abe won Best Paper Award of APMC 2006

The Associate Editors Committee of Special Section on Wide Band Systems
Presents

WBS Student Paper Award

to

Hiroaki TSUCHIYA

for the outstanding technical paper titled
"Investigation of Ultra-Wideband Propagation Channel based on a Cluster Scheme"

co-authored by
Katsuyuki HANEDA, and Jun-ichi TAKADA

published in the Special Section on Wide Band Systems of the November 2006 issue of the IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences.

Shin'ichi TACHIKAWA
Guest Editor-in-Chief for the Special Section on Wide Band Systems of IEICE

August 10, 2006

Tsuchiya won Student Paper Award of IEICE Transactions: Special Issue on Wideband Systems

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Gilbert won PIMRC'06 Best Student Paper Award(Asia Pacific)

Polarization Characteristics of NLOS Microcell Environment inside University Campus

In multiple input multiple output (MIMO) systems, polarization parameters have recently been introduced in order to ensure capacity improvement in the case that depolarization occurs when transmitting waves interact with scatterers in the environment. Therefore, our objective is to compare the polarization characteristics for 3 different non-light of sight (NLOS) routes inside a campus environment.

Measurement Scenario and Equipment

The microcell measurement was carried out in O-okayama campus of Tokyo Institute of Technology. The transmitter (Tx) antenna was fixed and mounted on a tripod with a height of 1.79 m from the ground while the receiver (Rx) antenna was mounted on a cart with a height of 1.65 m. The measurement was done on 3 different NLOS routes along 3 parallel street canyons. Each route was also composed of 3 Rx positions separated by 10 m each, therefore, the total measurement points are 9. The distance from Tx to Rx is between 57 m and 116 m.

The Medav RUSK Fujitsu channel sounder [1] was employed to accomplish the measurements. A periodic multicarrier frequency signal was utilized as the test signal at the center frequency of 4.5 GHz with a 120 MHz bandwidth resulting in a propagation delay resolution of 8.3 ns. The other measurement parameters can be found in [2]. The path delay, directions of departure (DoD) and arrival (DoA) are estimated for the 4 polarization pairs: co-vertical (γ_{VV}), co-horizontal (γ_{HH}), horizontal Tx - vertical Rx (γ_{VH}) and vice versa (γ_{HV}).

Polarization Ratio

The cross-polarization ratio (XPR) describes the polarization behavior of the channel changing from a certain polarization to another by excluding the effect of antennas. The relationships are shown below.

$$\mathrm{XPR}_{\mathrm{V}}^{\mathrm{BS}} = 10\log_{10}\left(\frac{|\gamma_{\mathrm{VV}}|^2}{|\gamma_{\mathrm{VH}}|^2}\right)\ [\mathrm{dB}] \quad (1)$$

$$\mathrm{XPR}_{\mathrm{H}}^{\mathrm{BS}} = 10\log_{10}\left(\frac{|\gamma_{\mathrm{HH}}|^2}{|\gamma_{\mathrm{HV}}|^2}\right)\ [\mathrm{dB}] \quad (2)$$

$$\mathrm{XPR}_{\mathrm{V}}^{\mathrm{MS}} = 10\log_{10}\left(\frac{|\gamma_{\mathrm{VV}}|^2}{|\gamma_{\mathrm{HV}}|^2}\right)\ [\mathrm{dB}] \quad (3)$$

$$\mathrm{XPR}_{\mathrm{H}}^{\mathrm{MS}} = 10\log_{10}\left(\frac{|\gamma_{\mathrm{HH}}|^2}{|\gamma_{\mathrm{VH}}|^2}\right)\ [\mathrm{dB}] \quad (4)$$

The co-polarization ratio (CPR) is the ratio of co-vertical and co-horizontal polarization as follows:

$$\mathrm{CPR} = 10\log_{10}\left(\frac{|\gamma_{\mathrm{VV}}|^2}{|\gamma_{\mathrm{HH}}|^2}\right)\ [\mathrm{dB}] \quad (5)$$

Results and Discussions

Figure 1 shows the cumulative distribution function (CDF) of each XPR and CPR for all identified paths and measurement points, respectively. In the XPR cases, there are 2 groups distinct by the co-polarizations independent from the BS and MS side. Moreover, the mean and standard deviation (STD) values of XPR and CPR are shown in table 1.

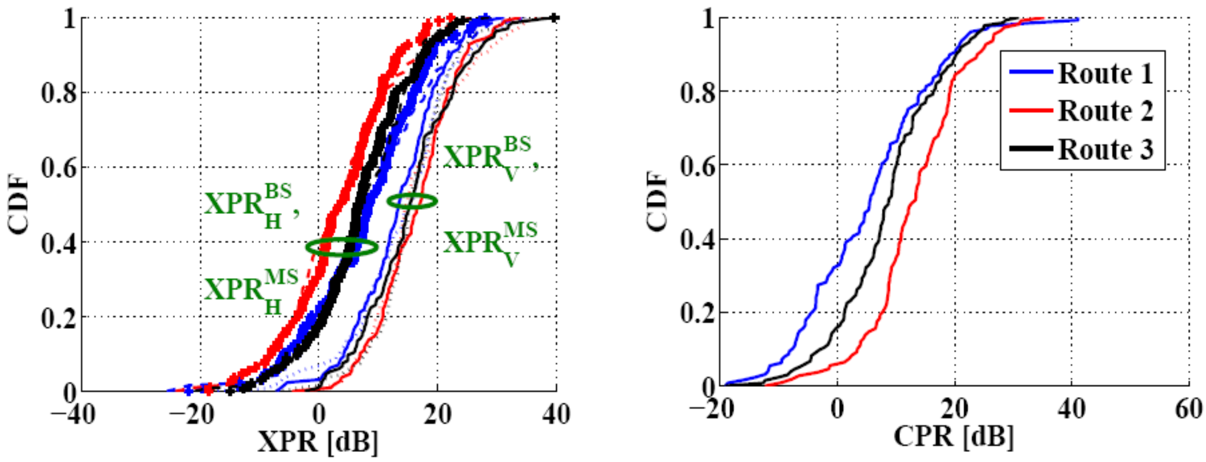


Figure 1 CDF of XRP and CPR

Table 1 XPR and CPR in dB scale

	Route1		Route2		Route3	
	Mean	STD	Mean	STD	Mean	STD
XPR_V^{BS}	13.2	7.4	16.3	7.0	15.5	8.1
XPR_V^{MS}	14.1	9.2	16.3	7.9	15.6	6.8
XPR_H^{BS}	8.6	10.7	3.3	9.7	7.1	8.5
XPR_H^{MS}	7.8	9.8	3.2	8.7	7.0	8.6
CPR	5.5	11.2	13.1	8.5	8.5	9.1

Acknowledgment

This research is supported by the National Institute of Information and Communications Technology of Japan (NICT).

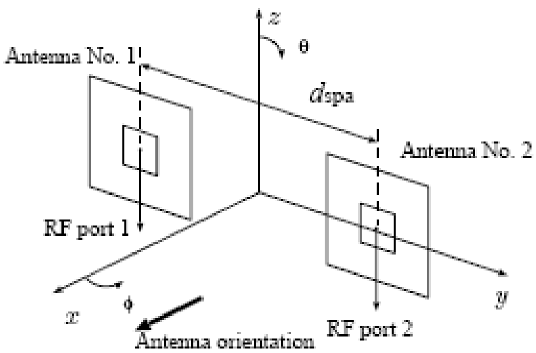
CDF of XPR and CPR

Performance Evaluation of RF Adaptive Array Antennas Based on Indoor Propagation Measurement

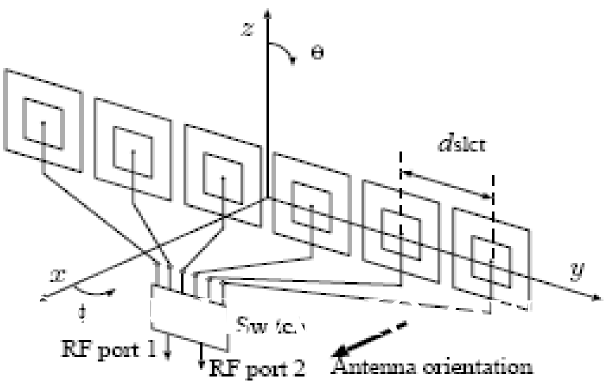
Introduction

Performance improvement by adaptive array antennas (AAA) that can be controlled in the radio frequency (RF) process (RF-AAA) has been reported in MIMO transmissions. For example, (1) antenna selection type AAA by using RF-switches and (2) beam steering type AAA by using variable reactance devices are well-known. Although these RF-AAAs work with different mechanisms, they contribute quite similar benefits to the improvement of the transmission performance. This report focuses on the performance evaluation between these two kinds of RF-AAAs in a 2 × 2 MIMO transmission scheme by using the measured propagation data in line-of-sight (LOS) and non-LOS (NLOS) environments.

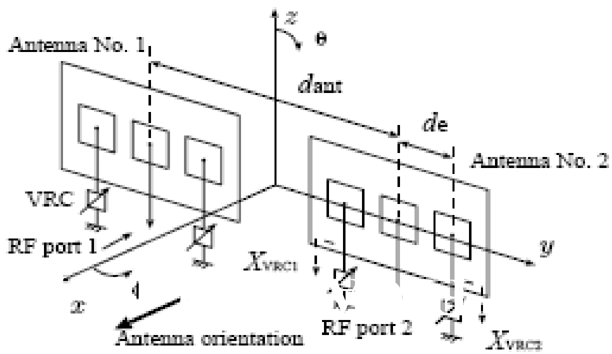
Considered Configurations



(a) Single element



(b) RF-AAA-AS



(c) RF-AAA-BS

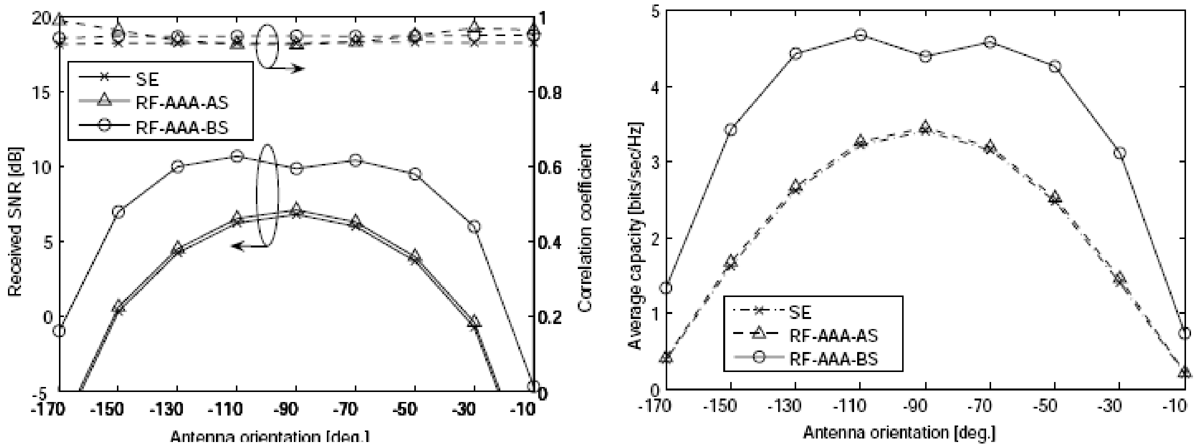
Simulation Results and Discussion

The analysis is dedicated to wireless LAN so that the simulation is based on the IEEE 802.11a communication system.

Simulation condition

Center frequency	4.5GHz
Number of transmitting antennas L_{Tx}	2
Number of receiving antennas L_{Rx}	2
Number of snapshots	10,000
Number of subcarriers K	48
Bandwidth	20MHz

Simulation results



(a) Received SNR of Port 1 and correlation coefficient.

(b) Average capacity.

Fig. 1 Transmission characteristics when the antenna orientations are changed in the LOS environment.

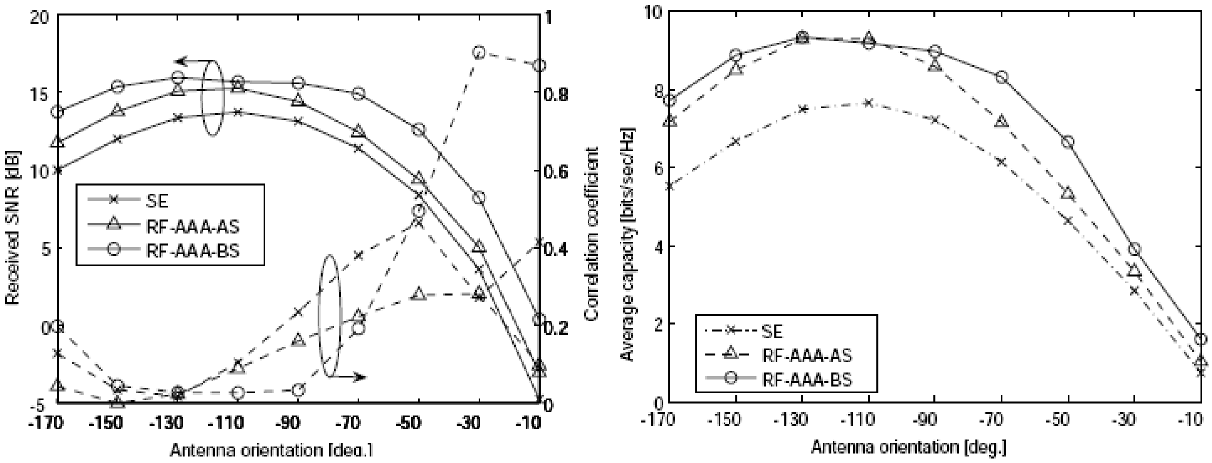


Fig. 2 Transmission characteristics when the antenna orientations are changed in the NLOS environment.

It is revealed that beam steering by ESPAR antenna can provide higher capacity than the antenna selection by RF-switch in the LOS and NLOS environment.

Scattering Loss Statistics inside an Arched Tunnel

Introduction

Scattering loss or the additional loss of a path from its free space path loss due to scattering, is calculated from channel sounding measurements done inside an arched tunnel. The scattering losses are classified according to the structure of the tunnel and its mean and standard deviation are computed. These statistics can serve as a guide especially for ray-based simulations on the range of additional loss due to scatterings inside tunnels.

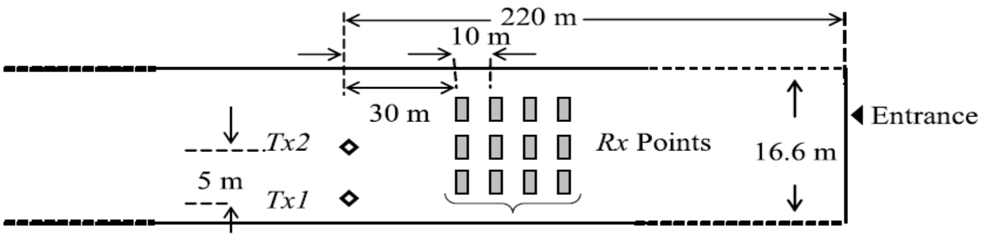
Measurement Equipment and Scenario

The RUSK-DoCoMo channel sounder [1] was employed to accomplish the measurements. The related parameters can be found in Table 1.

Table 1 Measurement Parameters

Parameter	Value
Center frequency, f_c	5.2 GHz
Bandwidth	100 MHz
Tx signal	multitone
Tx power	40 dBm
Tx antenna	vertically aligned sleeve dipole
Tx antenna height	6.2 m (Tx1), 8 m (Tx2)
Rx antenna array	cylindrical, 4 rings × 24 dual polarized patch elements
Rx antenna height	2.5 m
Rx points	204 points for each Tx
Synchronization	Cesium clocks

The tunnel where the measurements were accomplished was managed in the second Tomei highway in Shizuoka. It can accommodate up to 3 car lanes and has a semicircular arched cross section. It is 16.6 m wide on the ground level and the maximum height at the center of the cross section is 8.5 m. The measurement scenario where the experiment was performed for 2 transmitter (Tx) cases with 204 receiver (Rx) points each is depicted in Fig.1.



Results and Discussion

By employing the estimated angle-of-arrivals, the last scattering point can be identified whereas the estimated delay helps to confirm if the extracted path is a single-bounce or multiscattering. Using single-bounce scatterings, the scattering loss, L_s, per path l was calculated using the estimated delay τ and estimated path gain g as well as the Tx antenna gain g_T as shown below:

$$L_{s,l} = \frac{1}{(4\pi f_c \tau_l)^2} \frac{1}{g_l} g_{T,l} \quad (1)$$

Table 2 Scattering Loss Comparison

Scatterer	Tx1 mean [dB]	Tx2 mean [dB]	Tx1 std [dB]	Tx2 std [dB]	Tx1 # of path	Tx2 # of path
ground	12.2	16.4	4.5	4.9	245	330
left sidewalk	14.9	18.0	4.9	4.7	50	63
right sidewalk	13.8	17.3	3.9	4.5	134	127
left wall	15.8	15.9	5.3	4.5	100	166
right wall	15.5	17.0	4.1	4.6	135	157
left light-frame	13.0	15.8	5.8	4.6	66	198
right light-frame	17.6	19.5	3.7	4.2	143	192
ceiling	14.3	15.9	5.7	5.2	65	133

Table 2 gives the scattering loss statistics for both Tx cases including the number of paths used. The results show that the mean of scattering loss for the wall transmitter case located near the left wall (Tx1) is less than the mean of the scattering loss for the ceiling transmitter case (Tx2) for all scatterers. The standard deviation on the other hand does not vary much for both cases.

Conclusion

This paper discusses the scattering loss statistics from channel sounding measurements performed in an arched tunnel. The results show that the scattering loss of the classified scatterers is mainly dependent on the mean. The shape of the cumulative distribution function does not vary much due to the similar standard deviations.

References

[1] Rusk-Vector Channel Sounder. Available: http://www.channelsounder.de/

Performance Evaluation of a Very Small Magnetic Core Loop Antenna for an LF Receiver

By receiveing standard radio waves, radio controlled watches or clocks can provide precise date and time. However, radio controlled watches tend to have a larger size than conventioanl watches, because of the additional antenna and receiver inside the watch. To achieve a relatively better size and design, antenna miniaturizatio is also needed.

Magnetic core loop antennas (MCLAs) are widely used in radio controlled watches. The conventioanl design procedure donsists of the trial porduction and the sensitivity measurement. The typical length of MCLAs used in the watch is about 20 mm, even though the wavelength of the radio wave is several kilometers. For such electrically extremely small antennas, it is not appropriate to use an electromagnetic simulator used in the simulation of ordinary antennas. Instead we use a magnetic field simulatior based on finite element method as we consider such MCLAs as a magnetic fielf sensors. The magnetic field simulator is a part of software used for electromechanical analysis. Such a simulator can handle the magnetic material and the eddy current in the LF region.

This research work describes a method for evaluating the performance of the MCLA used for receiving time standardsvia long wave radio signals.

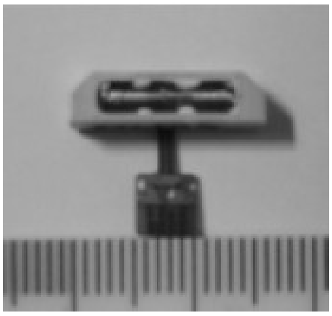


Fig. 1 The MCLA used in radio controlled watches

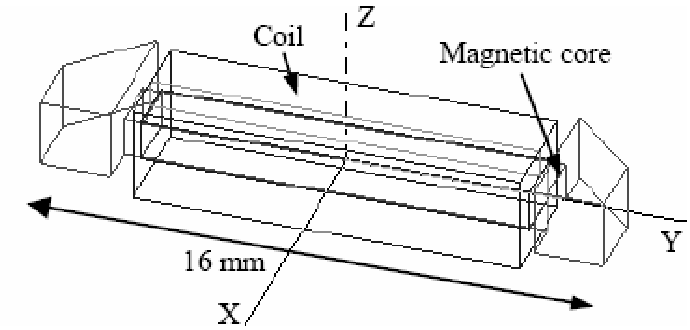


Fig. 2 Simulation model of the MCLA

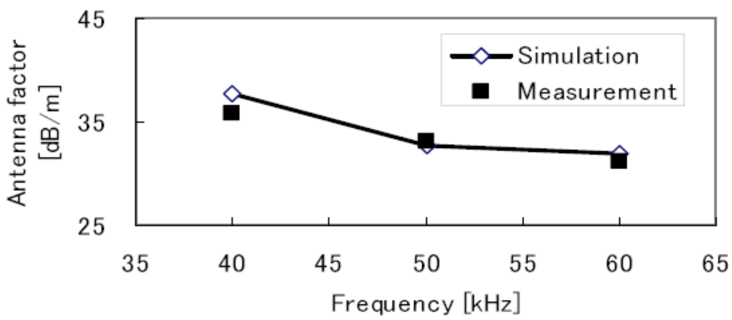


Fig. 3 Antenna Factor of the MCLA

Simulation Results

Radio controlled watches with fully-integrated antennas are highly desired to relatively improve the overall design. However, such integration causes a degradation of the receiving sensitivity, because the shielding effect and eddy current loss are increased when a metal case is used.

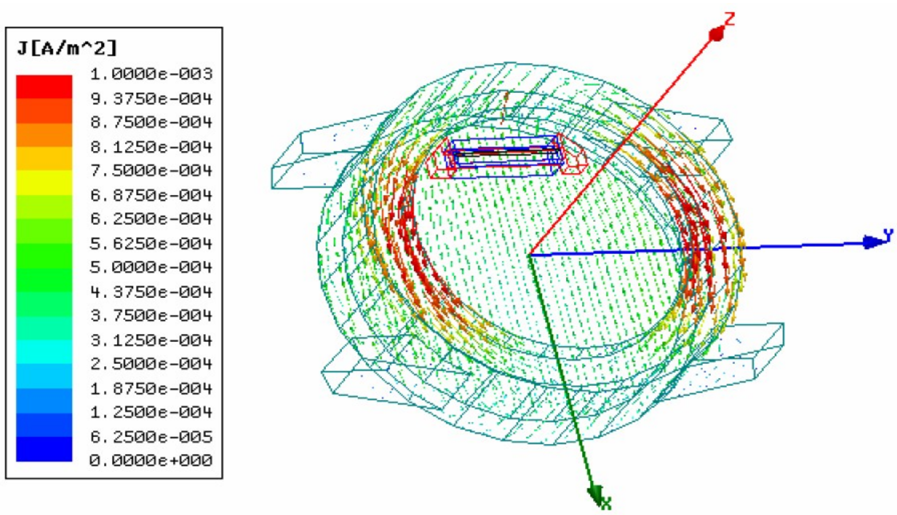


Fig. 4 Current density generated in a metal case

We investigated these eddy currents that are generated in a metal case by magnetic field simulation. The fully-integrated antenna model is put in a magnetic field of 40 kHz. Figure 6 shows the electric current density vector from the simulation. The primary observed result is that eddy currents are stronger near the antenna and at both sides of the bezel. Further miniaturization of the MCLA was seen to contribute more in optimizing the overall design.

Conclusion

In this work, we discussed a method of evaluating the performance of a very small MCLA. We explained the simulation model and the measurement procedure in order to obtain the performance. The simulation results agree with the measurement results.

An amorphous metal antenna consists of laminating sheets. It can be modeled and equivalent bulk structure that is handled in the simulator by setting anisotropic characteristics. We also investigated eddy currents generated in a metal case which included the MCLAs.

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