A UNIFIED SIMULATION PLATFORM FOR REAL-TIME PERFORMANCE VERIFICATION AND TESTING OF MIMO SYSTEMS WITH TURBO SIGNAL DETECTION TECHNIQUES

Sakaki akahiro and Hirotomo Iwasaki, Cybernetics Technology Co., Ltd., Daitoh Bldg. 4F, 32-1, Takada 3, Tokyo, Japan.

Abstract:

Recently, the multiple-input multiple-output (MIMO) system concept has attracted enormous attention in wireless communications research arena because of its high capacity gain over single-input ingle-output (SISO) systems. The key message from the MIMO capacity analysis is that the *ergodic* capacity of MIMO channels as a whole increases in proportion to the number of the antennas used. However, this is the case when the MIMO channel is spatially uncorrelated, and the spatial correlation makes crucial impact on the capacity. MIMO signal transmission performance largely depends on the signal detection techniques used.

Increase in the information bit rate by spatial multiplexing as well as enhancement of diversity order via space-time coding are the major benefits of MIMO systems. A lot of research work on MIMO signal transmission and detection techniques have been done in the last one decade. Recently, iterative signal detection techniques have been intensively researched with the aim of applying them to beyond third-generation (B3G) systems, because they in common can achieve almost the same performance as the optimal maximum likelihood detector performances without requiring prohibitively large computational efforts. Among them, soft-cancellation and minimum mean squared error (SC-MMSE) signal detection algorithm [1] is the most computationally efficient, flexible, and powerful technique, when solving *interference-related*problems associated with different kind of radio access techniques such as multiple access interference (MAI) in code division multiple access (CDMA) [2], inter-channel and inter-block interference (ICI and IBI, respectively) in orthogonal frequency division multiplexing (OFDM) [3], and inter-symbol and co-channel interference (ISI and CCI, respectively) in single carrier-based time division multiple access (TDMA) [4]. For those applications as well as for other candidate technologies, SC-MMSE MIMO signal detection techniques are presently in the phase of practical consideration towards B3G systems.

Now, given the current MIMO research trend described above, real-time performance verification and testing through prototyping based on the SC-MMSE concept is very important and meaningful when system feasibility is sought for. This paper introduces a unified simulation

platform designed for testing and performance verification of SC-MMSE MIMO systems. The platform can provide a real-time broadband signal transmission simulation capability, whatever radio access schemes are aimed at. The latest version of the platform has 8 x 8 MIMO radio link connections based on [5], for each of which up to 16-path tapped-delay-line propagation can be simulated, resulting in 1024 multi-path components present in the platform.

A unique point of the proposed platform is that it has systolic array ASIC implementation of the recursive least square (RLS) algorithm, called eMIMOchips, that can be for the acquisition of symbol- and frame-timings, and channel estimation. Furthermore, significant modifications have been made on the systolic array RLS processor so that it can be used to run the time-averaging common covariance estimation-based SC-MMSE algorithm [6] on the platform. By using this capability of the platform, performances of techniques for solving interference problems, described above, based on SC-MMSE MIMO can be, in common, be tested through real-time simulations using the platform.

The full paper version of this contribution is organized as follows: Section 1 introduces background and concept of the platform design for MIMO systems. Section 2 derives systolic array structure of the time-averaging common covariance estimation-based SC-MMSE algorithm. Section 3 then describes the systolic array RLS algorithm implementation that has three operation modes: (1) synchronism acquisition, (2) channel parameter estimation, and (3) execution of time-averaging common covariance estimation-based SC-MMSE algorithm. The connection of the function blocks and parameter setting for the three modes are detailed. Section 4 shows results of fixed-point simulations conducted to identify the sensitivity and numerical stability of the systolic array implementation SC-MMSE. This paper is finally concluded with summary.

[1] S. Haykin, M. Sellathurai, Y. de Jong, and T. Willink, “Turbo MIMO for Wireless Communications ”, IEEE Com.Mag., Vol. 42, No. 10, pp. 48-53, 2004 [2] X. Wang and V. Poor, “Iterative (Turbo) Soft Interference Cancellation and Decoding for Coded CDMA”, IEEE Trans. Com., Vol. 47, No. 7, pp. 1046-1061, 1999 [3] Y. Sagae, S. Suyama, H. Suzuki, and K. Fukawa, “An OFDM Turbo Equalizer for Scattered Pilot Signals in Multipath Environments with Delay Difference Greater than Guard Interval,” Conf. Rec. of IEEE VTC2004-Spring, Milan, Italy [4] D. Reynolds and X. Wang, “Low-complexity Turbo-equalization for Diversity Channels”, Signal Processing, Elsevier Science Publishers, Vol. 81, No. 5, May 2000, pp. 989-995 [5] S. Tsukamoto, T. Sasoh, T. Sakaki, S. Tomisato, T. Asai, and T. Matsumoto, “A Complex Baseband Platform for Spatial-Temporal Mobile Radio Channel Simulations”, ”, IEEE Trans. VT, Vol. 51, No. 5, pp. 989-997, 2002 [6] K. Kansanen and T. Matsumoto, “A Computationally Efficient MIMO Turbo Equalizer”, Conf. Rec. of IEEE VTC2003-Spring, April 2003, Jeju