LTE Baseband DSP/FPGA for Beamspace MIMO RF Antenna

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Abstract— As the MIMO processing gets popular in LTE wireless mobile communication, the number of RF chains of eNodeB for MIMO processing gets increased, which results in the increase of cost and the volume of eNodeB base-station. In order to solve this problem, the Beamspace MIMO RF Antenna has been proposed. The advantage of Beam-space MIMO RF Antenna is to reduce the RF chain which results in the cost reduction of LTE RF module. In order to support Beam-space MIMO RF Antenna, the LTE baseband signal from LTE modem should be transformed. This transformation includes the matrix and trigonometric computation which is complex to be performed by FPGA. From this observation, authors have implemented baseband algorithm in DSP processor which enables the complex matrix computation efficiently. The requirement of DSP processing is 300 Mbps in 33 MHz band which supports 4 streams. While DSP processor is very efficient for the matrix computation, there should be interface module between baseband DSP and the impedance loading module for Beam-space MIMO RF Antenna. Authors have implemented this interface module with FPGA. The interface between DSP processor and FPGA has been implemented PCIe (PCI Express) to support high-speed serial IO. The integration system has been designed with LTE modem that supports 4×4 MIMO. The testing of full integration system consists of baseband DSP, FPGA, LTE modem and Beam-space MIMO RF Antenna module. Various spectrum analyzers have been used to validate the design of Beamspace MIMO RF baseband system during the test procedure.

1. INTRODUCTION

As the MIMO processing gets popular in LTE wireless mobile communication, the number of RF chains of eNodeB for MIMO processing gets increased, which results in the increase of cost and the volume of eNodeB basestation. In order to solve this problem, the Beam-space MIMO RF Antenna has been proposed. The advantage of Beam-space MIMO RF Antenna is to reduce the RF chain which results in the cost reduction of LTE RF module. In order to support Beamspace MIMO RF Antenna, the LTE baseband signal from LTE modem should be modified. This modification includes the matrix and trigonometric computation which is complex to be performed by FPGA. From this observation, authors have implemented baseband algorithm in DSP processor which enables the complex matrix computation efficiently. The requirement of DSP processing is 300 Mbps in 33 MHz band which supports 4 streams. While DSP processor is very efficient for the matrix computation, there should be interface module between baseband DSP and the impedance loading module for Beam-space MIMO RF Antenna.

In the following Section 2, the current trends and problems of Beamspace MIMO RF researches are described. In Section 3, the architecture of LTE baseband processing for Beamspace MIMO RF to handle the problems of the current Beamspace MIMO RF researches is described. In Section 4, the implementation of the proposed architecture is described. In Section 5, conclusion follows.

2. BEAMSPACE MIMO RF

In the single-RF MIMO transmitter, each of spatially multiplexed streams is mapped into the respective basis beam pattern, which is contrast to conventional MIMO transmitters where symbol streams are driven to different antenna elements. The radiated beam pattern of this beam-space multiplexing with a two-element antenna can be decomposed.

The main advantage of ESPAR (Electronically Steerable Parasitic Array Radiator) antenna is that ESPAR antenna requires only a single RF chain for reducing the complexity of transmitter's complexity, as compared to the current MIMO system. In the current MIMO system, each symbol is mapped to each antenna. But, each symbol is mapped to each orthogonal basis pattern in ESPAR system. The critical problem of beam-space MIMO system using ESPAR antenna with single RF chain for MIMO system is that the impedance to induce the radiation current between parasitic elements antenna is uncontrollable. In order to make parasitic elements antenna induce the current for radiation, it is very essential to implement the controllable impedance matrix between parasitic elements antennas. In Figure 1, the Beamspace MIMO ESPAR Antenna system is shown.

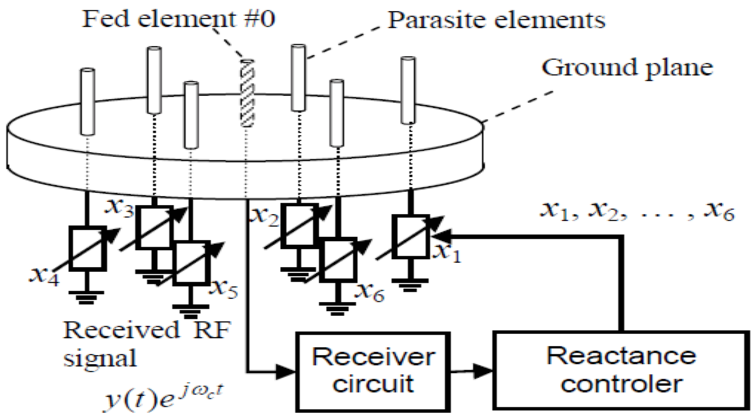

Figure 1: Beamspace MIMO ESPAR Antenna system.

3. LTE BASEBAND PROCESSING FOR BEAMSPACE MIMO RF

In Figure 2, the diagram of current 2×2 LTE downlink system (150 Mbps capacity) is shown. The IQ Signal from LTE modem through QAM modulation will go through 2 RF chains with DACs and PAs.

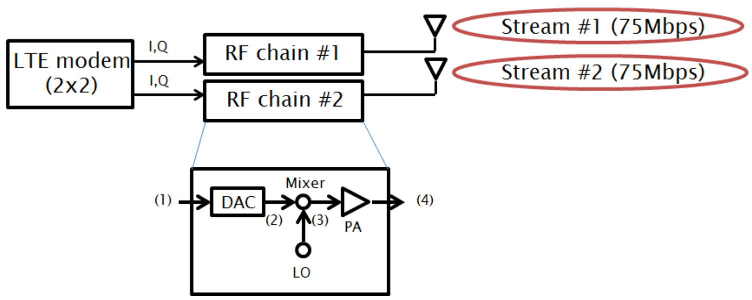

Figure 2: Current 2×2 LTE Downlink system (150 Mbps capacity).

As described in the previous chapter, it is very necessary to make impedance matrix at parasitic elements antenna in Beamspace MIMO system controllable. For that reason, the IQ signals from LTE modem should be transformed into the impedance value for making impedance matrix controllable. From this consideration, the following architecture for Baseband processing for Beamspace MIMO RF in 4×4 LTE downlink system (300 Mbps capacity) is shown Figure 3.

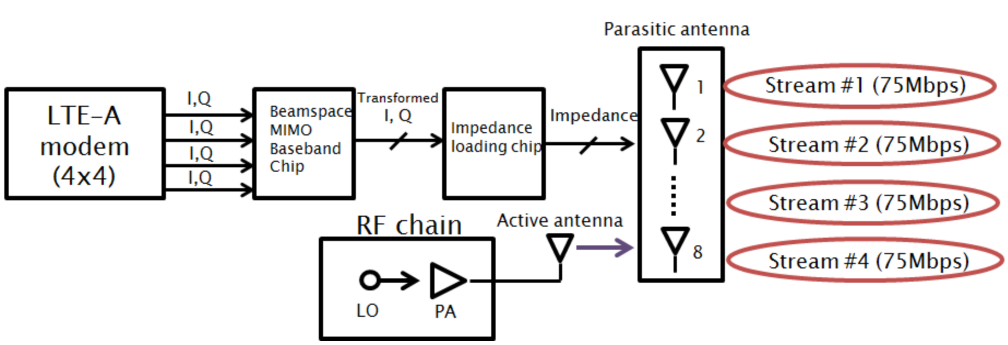

Figure 3: Proposed Beamspace MIMO Baseband system with 4×4 LTE Downlink (300 Mbps).

The purpose of Impedance loading chip is to provide impedance to Parasitic elements Antenna. In Impedance loading chip module, it is very essential to make impedance matric to Parasitic elements Antenna controllable.

4. IMPLEMENTATION

In order to realize the function of baseband processing to the impedance loading module, the following architecture in Figure 4 is proposed. For DSP processor, Texas Instruments DSP is used. For FPGA, Xilinx FPGA is used. For the Downlink of LTE system, IQ signal from LTE modem is transferred from LTE eNodeB through Optic SFP interface. The transformation of IQ signal to Impedance loading value is performed in DSP processor. Algorithm and DSP SW are designed considering LTE system capacity 300 Mbps. Part of Impedance loading transformation is performed in Xilinx Virtex FPGA. The interface between Beamspace MIMO Baseband system and Impedance loading chip is handled in FPGA. The interface between DSP processor and FPGA is designed with PCIe (PCI Express) using high speed Serial IO. The Interface between FPGA and Impedance loading chip is implemented with SMA, GPIO and FMC interface. The SW in DSP processor is implanted using TI CCS (Code Composer Studio). Xilinx FPGA is implemented using Verilog HDL. Depending on the complexity of transformation algorithms, all algorithms can be implemented in FPGA.

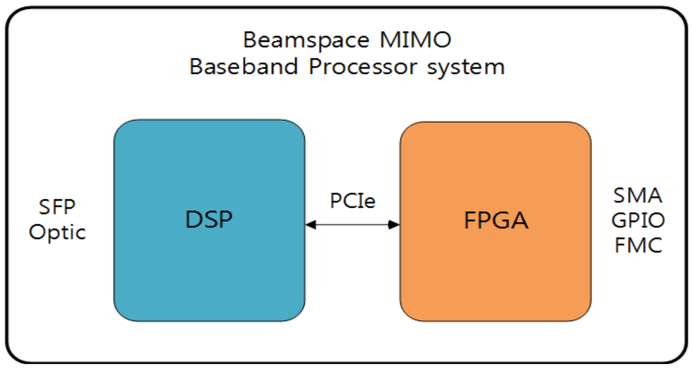

Figure 4: Proposed DSP/FPGA architecture for Baseband processing in Beamspace MIMO.

5. CONCLUSION

In MIMO processing, the number of RF chains of eNodeB for MIMO processing gets increased, which results in the increase of cost and the volume of eNodeB base-station. In order to solve this problem, the Beamspace MIMO RF Antenna has been proposed. The advantage of Beam-space MIMO RF Antenna is to reduce the RF chain which results in the cost reduction of LTE RF module. In order to support Beam-space MIMO RF Antenna, the LTE baseband signal from LTE modem should be transformed. This transformation includes the matrix and trigonometric computation which is complex to be performed by FPGA. From this observation, authors have implemented baseband algorithm in DSP processor which enables the complex matrix computation efficiently. The requirement of DSP processing is 300 Mbps in 33 MHz band which supports 4 streams. While DSP processor is very efficient for the matrix computation, there should be interface module between baseband DSP and the impedance loading module for Beam-space MIMO RF Antenna. Authors have implemented this interface module with FPGA. The interface between DSP processor and FPGA has been implemented PCIe (PCI Express) to support high-speed serial IO. The integration system has been designed with LTE modem that supports 4×4 MIMO. The testing of full integration system consists of baseband DSP, FPGA, LTE modem and Beamspace MIMO RF Antenna module. Various spectrum analyzers have been used to validate the design of Beamspace MIMO RF baseband system during the test procedure. From the test performed so far, it is shown that the Baseband processing system for Beamspace MIMO RF Antenna works correctly to provide the controllability of impedance matrix parasitic elements antennas.

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