Investigations on Miniaturized RF Front-end in MIMO Channel Emulator

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Abstract

This paper details the investigations on miniaturized RF front-end in MIMO channel emulator. The operation frequency band of Channel Emulator is from 400MHz to 6GHz with 100MHz signal processing bandwidth. The spur characters of receiver and transmitter are simulated. The test measurements of miniaturized RF front-end in MIMO channel emulator are shown. The key performance EVM and phase noise of frequency synthesizer satisfy MIMO Channel emulator’s requirements.

Keywords: Miniaturized RF front-end; Channel Emulator; Frequency synthesizer; EVM

1. Introduction

With the wide application of Multiple Input Multiple Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) transmission technologies which can increase data transmission rate significantly in 4G [1], especially in LTE-Advanced and LTE, the importance of MIMO channel measurement in wireless communication system has been further enhanced since the performance of MIMO systems is greatly affected by the characteristics of the channels. Although the traditional communication channel measurement which is time-consuming and lacks repeatability is the closest way to the most realistic propagation environment, the measurement is not suitable for the laboratory environment. With the purpose of implementing the channel simulation in indoor lab environment and reproducing the characteristics of fading due to signal propagation in space, radio channel emulators are designed to evaluate the performance of systems and terminals.

The Propsim FS8 developed by Anite, which is the market’s most compact channel emulator in terms of size and weight. It supports up to 8 RF and 32 digital channels with frequency band from 30 to 2700MHz. The single unit of the equipment supports up to 40MHz aggregated signal bandwidth [2-3]. The ACE MX2, a form-factor-optimized version for LTE and other 4G protocols, developed by Azimuth is 60% quieter and smaller than the ACE MX [4-5]. The equipment supports from SISO up to 8×4 MIMO systems. The signal bandwidth is 50MHz.

This paper focuses on the miniaturized RF Front-end in MIMO channel emulator. The RF front-end has the advantage of wideband, small size, good phase noise, low cost and high performance. The channel emulator designed in this paper supports two input channels and two output channels, which is composed of baseband processors and RF front-end. The baseband processors deal with digital signal processing about modeling algorithm of channel fading. The RF front-end copes with the RF signal reception and baseband signal transmission. The RF front-end is made up of frequency synthesis, transmitter and receiver. The LO signal working for receiver and transmitter is provided by frequency synthesizer. The transmitter converts the baseband signal to the radio frequency and the receiver converts the received radio frequency to baseband signal. The miniaturized RF front-end can work from 400MHz to 6GHz with 100MHz signal processing bandwidth.

2. Design of System

The proposal of the RF front-end in the system is based on superheterodyne scheme. To achieve extremely splendid performance and reduce the size of the system, digital IF scheme is used. To avoid the LO pulling and achieve the isolation between LO and power amplifiers, the RF transceiver adopts dual frequency conversion structure. The whole size of the system has been strikingly reduced thanks to the proper layout of the PCB.

The architecture of the RF front-end is shown in Fig.1 and the details of the system are as follows. The RF front-end includes RF transmitter, RF receiver and frequency synthesizer. The upper half part of Fig.1 is a transmitter containing frequency converter module made up of mixers, IF variable gain amplifier module, and filters for spurious reduction. Digital attenuators and power amplifiers are cascaded in IF module which are the main part of tuning the output power dynamic range. The bottom half of Fig.1 is a receiver containing RF detectors, frequency converter module, IF variable gain amplifier module, and filters for spurious reduction. Logarithmic detectors and limiters are used in RF receiver in case of damage of chips because of unexpected high power signals.
The local oscillations used in Fig. 1 are implemented by frequency synthesizers. The IF LO is provided by integer-N PLL synthesizer. RF LO is provided by fractional-N PLL synthesizer with the bandwidth from 2.4GHz to 5.2GHz. The frequency synthesizer has the advantage of wideband, low phase noise and small size. The PCB layout of miniaturized RF front-end is shown in Fig. 2.

3. Simulation of front-end

In order to prove the feasibility of wideband RF front-end, simulations are implemented based on ADS (Advanced Design System). Harmonic simulation analysis of the transceiver which indicates the degree of distortion is executed.

The spur characters of receiver are simulated as shown from Fig. 3 to Fig. 5. The receiver’s input signal is 5GHz shown as in Fig. 3. IF output signal after converter module is shown as Fig. 4. The spur character of whole receiver after IF filter is shown as Fig. 5. The harmonic restraining is well done in the receiver.

The spurious simulation of the transmitter is shown as Fig. 6. The result shows that the system has made an identical performance.
Figure 6. Output spur character of the transmitter at 3.1GHz

4. Experimental Results

In order to evaluate the performance of RF front-end, external LTE signals with 20MHz maximum bandwidth based on 64 QAM (Quadrature Amplitude Modulation) work as the input signals. Due to the limitations on space, the EVM results at 2.6GHz which is the most commonly used in LTE system are shown in Fig.7 and Fig.8. The results show that miniaturized RF front-end works well for the LTE system. The EVM of RF receiver at 2.6GHz is 1.44%. The EVM of RF transmitter at 2.6GHz is 1.97%.

Figure 7. The EVM of transmitter at 2.6GHz

Figure 8. The EVM of receiver at 2.6GHz

The ROHDE&SCHWARZ FSUP Signal Source Analyzer is used for the measurement of the phase noise and spurious components of the frequency synthesizers. However, due to space constraints, only output frequency at 2.6GHz can be shown here in Fig.9. The phase noise is -108dBc/Hz at 1kHz offset, -110dBc/Hz at 100kHz offset and -137dBc/Hz at 1MHz offset. The frequency synthesizer has low phase noise performance.

Figure 9. Phase noise at 2.6GHz

5. Conclusions

A miniaturized RF front-end in channel emulator is shown in this paper. The RF front-end has the advantage of wideband, small size, good phase noise, low cost and high performance. The test results satisfy the design requirement.

6. Acknowledgements

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7. References


2. Anite Propsim FS8 channel emulator technical datasheet


4. ACE MX/MX2 MIMO Channel Emulator Product