An Architecture of Reconfigurable Transceiver for OFDM/TDD based Portable Internet Service System

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Abstract: In this paper, we have presented the improved IF transceiver architecture and the implementation and experimental results on re-configurable transceiver based on digital IF for multiple wideband OFDM/TDD base stations for high-speed portable internet-service in which is issued Korea. The implemented IF transceiver has been designed to support multiple frequency allocations and multiple standards by only modifying the programmable software not its hardware like as the software-defined-radio concept. Also, the digital complex quadrature modulation technique has been used for the digital IF transmitter, which is able to combine multiple frequency bands in digital processing block not RF block and to reject the image frequency signals. And the bandpass sampling technique has been used for the digital IF receiver to reduce the sampling rate of ADC. This paper has shown the experiment results on the frequency response and constellation on the base-station implemented using the modified IEEE 802.16a/e physical layer channel structure based on OFDM/TDD.

Keywords : orthogonal frequency division multiplexing (OFDM), time division duplexing (TDD)software defined radio (SDR), digital IF transceiver, FPGA, analog to digital converter, digital to analog converter.

1. INTRODUCTION

Today, most wireless communication systems, especially such as the high-speed portable internet-service that will be commercialized in Korea, require higher data rate service above to a few mega bit per second. The radio frequency systems for such service should be designed with a very high signal to noise ratio (SNR) and a wide bandwidth. Due to the high data rate, robustness against the hostile multi-path fading and a minimized inter-symbol-interference over single-frequency systems in cellular service, the orthogonal frequency division multiplexing (OFDM) and high other modulation is commonly used in high speed internet service systems such as wireless LAN. But in spite of above advantages to OFDM, the factors such as phase noise, frequency offset, DC offset and IQ mismatch are more important for the transmission methods as OFDM and QAM. The digital RF transceiver as the concept of the software-defined-radio is expected to theoretically solve those problems. But, because of the low operating frequency and resolution of digital devices such as DACs and ADCs, the digital transceiver based on digital IF technology has been developed from only a few years ago [1-4].

Recent advances in ADCs or DACs with high sampling rate and high bit resolution above to 100Msps and 16bits respectively are possible to implement directly the digital signal frequency conversion scheme on IF to baseband in the digital domain. Also, as the high speed field programmable gated arrays operating up to about 100MHz can be available on the cellular base station systems, SDR systems on which is useful for re-configurable communication systems supporting the multi-modes or multi-standards only by modifications of its software is realizable to implement.

Here, the implemented digital IF technologies are the bandpass sampling technique for reduction of the sampling rate of ADC, the decimation or interpolation halfband filter technique with the polyphase type and digital complex quadrature modulation technique for rejection of the image frequency signals, etc. Many literatures are published about efficient digital filters [5-6] and channelizer/dechannelizer using the polyphase multirate system [7-8] for SDR systems.

In this paper, we present the re-configurable digital IF transceiver architecture for supporting multiple wideband OFDM/TDD based on IEEE 802.16a/e standard, and the simulations have been performed to certify this presented transceiver architecture. Also the experiment results on the spectrum and error vector magnitude are shown for the base-station developed in our laboratory with the modified IEEE 802.16a/e TDD standard.

This paper is organized as follows. In the second section, we describe the architecture of digital IF transceiver available on wideband OFDM base station systems. And we show the validity of the presented transceiver architecture by simulation on the modified IEEE 802.6a/e 64QAM physical channel structure in the third section. In the forth section, the digital IF test module implemented on PCB boards with single FPGA, ADC and DAC and its experiment results on the frequency response and constellation are described. A conclusion remark is presented in the last section.

2. ARCHITECTURE OF DIGITAL IF TRANSCEIVER

2.1. Structure of digital IF transmitter

The presented architecture of the digital IF transmitter supporting two frequency allocations (FAs) bands in wideband OFDM/TDD base stations is shown in Fig. 1. The IQ signals received from a physical channel modem corresponding to each multiple FA are injected into the digital IF transmitter as the sample rate of 11.42Msps defined by OFDM sample rate in our system. And, zeros are inserted by five times of sample rate to interpolate to higher sample rate. These zeropadded complex multiple FA signals are filtered by by the finite impulse response (FIR) filters using Park-MacClellan algorithm. The band limited complex baseband signals filtered by digital filter is up-converted by complex quadrature modulation technique.

First, the complex baseband signal passed by digital filters corresponding to the first FA is upconverted to -5MHz center frequency, and its image frequency component exists on +5MHz. Similarly, in case of the second FA, the complex baseband signal is upconverted to +5MHz, and its image frequency component exists on -5MHz. These complex signals of each FA after digital complex quadrature modulation are summed to be the complex signal with multiple FA bands. Therefore, the desired multiple FA signals are combined with its image signals on baseband. The digital complex baseband signal of two FAs is again up-converted to 15.8MHz by the complex quadrature modulation method before used.

To obtain the digital IF signal of 130MHz, we have used a commercial DAC chip [9] made in Analog Devices, in which are including three interpolation filters, NCOs and dual DACs with high sample rate close to 400Msps, because it is difficult to operate on FPGA over 260Msps as Nyquist sampling rate. The image frequency components generated by the combination of FAs can be rejected using the quadrature modulation in DAC chip. The digital IF signal with 228.4Msps data rate, twenty times of 11.42MHz sample rate, interpolated by two halfband filters in DAC chip is converted into 130MHz analog signal by DAC and is transmitted to RF boards and antennas.

2.1. Structure of digital IF transmitter

The presented architecture of the digital IF receiver for two FA bands is shown in Fig. 2. As generally known, this structure consists of wideband, high speed and high resolution ADC, digital mixers, NCOs, decimators and digital filters. In our structure, the received analog IF signal whose center frequency is 130MHz, bandwidth is 20MHz corresponding to two FA bands is digitized by wideband and high resolution ADC. The received signal from RF receiver is two FAs and down-converted by quadrature NCOs with 10.8MHz and 20.8MHz center frequency, respectively.

Even though the low pass filter used in the RF part should not be sharpened as frequency cutoff characteristics, the decimation FIR filters used in our digital IF receiver are sufficiently possible to distinguish the desired signal from other signal interferences.

The available ADC is AD6645™ made in Analog Devices inc., whose specifications are 80Msps sampling rate and 14bits resolution [10] for our applications.

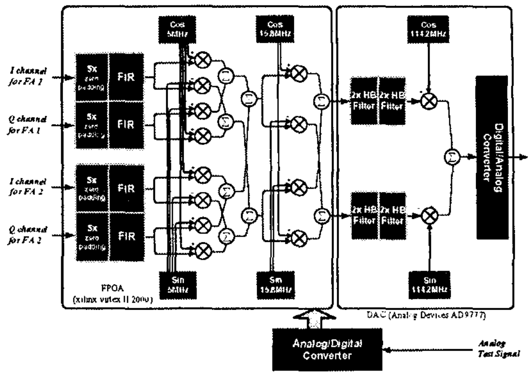


Fig. 1. Architecture of digital IF transmitter

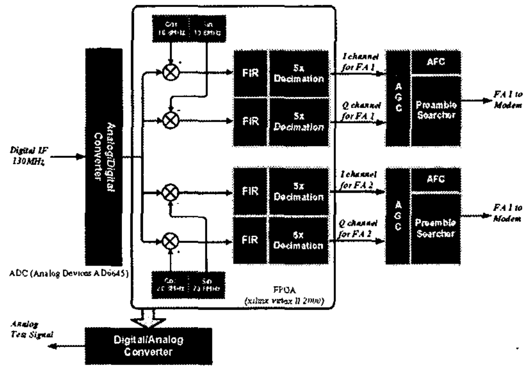


Fig. 2. Architecture of digital IF receiver

3. SIMULATION RESULTS

In this section, the computer simulation results are shown to certify the previously proposed structure of the digital IF transceiver for wideband OFDM/TDD base stations. The physical layer specifications for the modified IEEE 802.16a/e TDD are shown in Table 1.

Table 1 Physical layer specifications for our simulations

Contents	Specifications
Duplexing method	TDD
Modulation method	OFDM, 64QAM
FFT size/Used data subcarriers	2048/1536
Channel bandwidth	10MHz per one FA
Subchannel spacing	5.57617kHz
Sample frequency	11.42MHz

The simulated transmit signal spectrum of digital IF transmitter is shown in Fig. 3.

In Fig.3, the center frequency of real signal is 98.4MHz and that of its image signal is 130MHz. The difference between real signal and image signal on spectrum is only that the sign of cosine in demodulator is opposite each other. Although the droop is in image signal, the image signal is selected to obtain a higher intermediate frequency than real signal. The spurious as well as real signals shown in Fig. 3 will be eliminated by SAW filters within the RF transceiver.

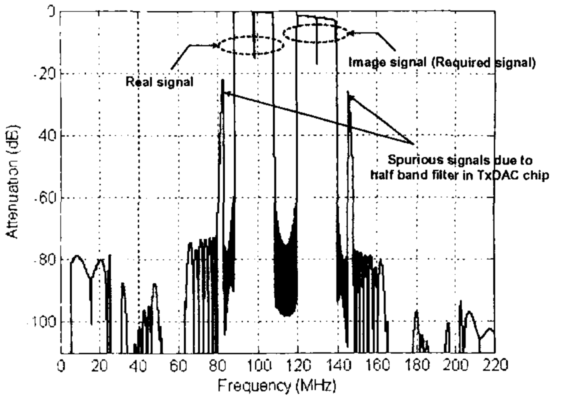
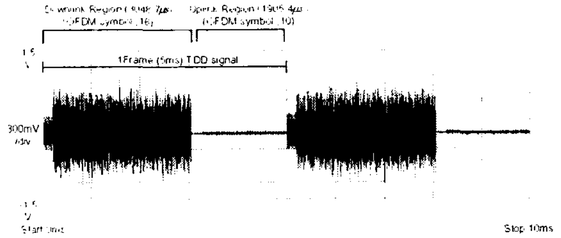


Fig. 3. Simulated frequency response of digital IF tranmitter Architecture of digital IF receiver

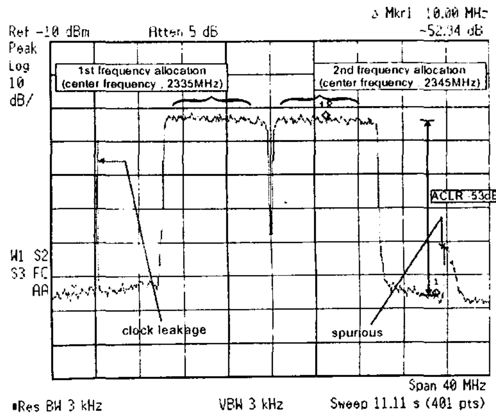
4. EXPERIMENT RESULTS

The transmit signal and power spectrum of the output of digital IF transmitter for two FAs with 2.34GHz center frequency and 20MHz bandwidth measured by using the vector signal analyzer and spectrum analyzer are shown in Fig. 4.

As shown in Fig. 4(a), this is the OFDM/TDD transmit signal and its frame length is 5msec. This signal have measured and captured by HP 89440 VSA. The ACLR is about -53dBc and other spurious can be rejected by the bandpass filters with more sharpened side-lobe characteristics as shown in Fig. 4(b).



(a) TDD transmit signal in down link (5msec frame)



(b) Measured spectrum of TDD transmit signal with two FAs

Fig. 4. Characteristics of the measured digital IF signal

The constellation on 64QAM is shown in Fig. 5 to evaluate the digital receiver including both IF and RF block. The measured error vector magnitude (EVM) is -34dB and this is sufficient to obtain the bit error rate of 10^{-6} without coding gain for the portable internet service.

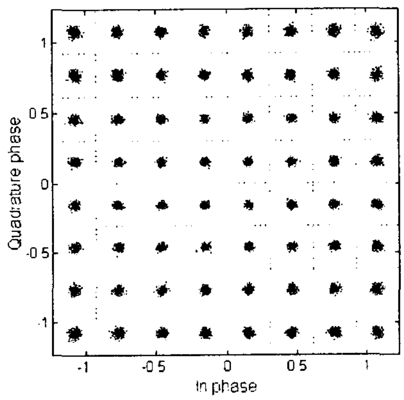


Fig. 5. Measured 64QAM constellation of received signal at digital IF receiver (number of points ; 23040 corresponding to one frame)

5. CONCLUSIONS

We have presented the improved digital IF transceiver architecture for multiple wideband OFDM/TDD base stations and its implementation and experimental results also have shown in this paper.

The digital complex quadrature modulation technique that is able to reject image frequency components has been used for digitally combining the multiple band signals Also, the bandpass sampling technique has been applied in our receiver architecture and the digital filters such as FIR and halfband filter with high dynamic range have been designed to extract the desired signal from the adjacent FAs. We have developed the digital IF transceiver module of which is composed single FPGA, ADC and DAC. This paper has presented the experiment results on the frequency response and constellation of the implemented digital IF transceiver using a modified IEEE 802.16a/e TDD physical channel model. The results have been obtained that the dynamic range is about 53dB at 130MHz IF center frequency.

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