A Design of WCDMA RF Transceiver with Its Performance Measuring

Jing-Fu Bao and Zhu-Sheng Kang

Abstract—A 2-GHz radio frequency transceiver is presented and implemented for third generation mobile communications using wide-band code division multiple access (WCDMA) scheme. Performance measuring systems are introduced for transmitter channel and receiver sensitivity, respectively. The transceiver achieves maximum output power of 22 dBm, dynamic range of 85 dB, adjacent channel power rejection ratio (ACPR) of $-41$ dB@5MHz, and receiver sensitivity of $-119.6$ dBm for 128-kb/s data at 3.84-Mcps spreading rate. The measured results indicate the conformity to the required commercial 2.0-GHz WCDMA specification and 3GPP requirements.

Index Terms—Adjacent channel power rejection ratio (ACPR), radio frequency technology, receiver sensitivity, wide-band code division multiple access (WCDMA), wireless communication.

1. Introduction

Wide-band code division multiple access (WCDMA) was designed to be a high performance system able to support advanced interactive applications or multiple simultaneous services with different quality of service parameters and high data rate, such as mobile commerce, position based services, and multimedia services\cite{1}. It is estimated that the mobile data traffic demand is reaching over 200 megabytes per user, per month currently\cite{2}, and that one billion cellular subscribers will enjoy 3G services by 2010\cite{3}.

The trend of future mobile communication applications will be a need for wideband mobile data networks with high average throughputs and such networks can provide users with wireless packet data access at peak rates up to from 384 kbps to 2 Mpbs, even to 14.4 Mpbs. In addition, these applications need to be carried over efficient Internet protocol (IP) networks. As a result, all these requirements has been to provide the push to cellular operators to work efficiently on migrating from current 2G/2.5G networks to the more efficient 3G networks and further to researchers to go beyond original 3G technology targets\cite{4}.

As the need for low cost, low power consumption and high performance user equipment is becoming important for the commercial development of 3G mobile handsets, the radio frequency (RF) transceiver of excellent characteristics and high sensitivity has considerably received attention. Some radio transceiver architectures for wideband cellular systems have been widely discussed\cite{2}, RF single-chip integration has been recently explored for compatible with major WCDMA networks, such as direct conversion receiver\cite{5,6}, tri-band transceiver\cite{3}, and full-CMOS transmitter and receiver\cite{7}. However, all these attentions mentioned above are mainly paid to the architecture design or chip implementation.

This paper describes a design of WCDMA RF system for 3G applications. Our emphasis is focused on the system performance with its measuring, particularly on the maximum output power of the transmitter and the sensitivity of the receiver, although the proposed architecture is oriented to be implemented on chip.

This paper is organized as follows. In Section 2, the proposed transceiver architecture is described with its building blocks features. Section 3 introduces the measuring systems and the measured performance of the transmitter and the receiver. The paper is summarized in Section 4.

2. Transceiver Architecture

A block diagram of the transceiver using the superheterodyne architecture is shown in Fig. 1. The system consists of up-link (transmitter) channel and down-link (receiver) channel. The frequency range covered by the transmitter is from 1920 MHz to 1980 MHz. The RF input frequency range of the receiver is from 2110 MHz to 2170 MHz. A duplexer filter connects each channel to the antenna for full duplex operation.

2.1 Transmitter Channel

The transmitter is composed of intermediate frequency (IF) local oscillator (LO), quadrature modulator, surface acoustic wave (SAW) bandpass (BP) filter, phase-locked RF LO, up-converter, RF power amplifier, and two automatic gain control (AGC) amplifiers before and after the up-converter, respectively.

I/Q baseband signals are quadrature modulated with the 380 MHz signal of local oscillator. The modulated signal (380 MHz) is adjusted in gain by TAGC1 and processed by SAW BP filter. The phase-locked LO up-converts the IF signal to the RF signal of 2300 MHz–2360 MHz. In RF band,
the signal is re-amplified by TAGC2, RF driving circuit, and RF power amplifier and finally fed into antenna of the transmitter through the duplexer.

2.2 Receiver Channel

Received signals from antenna are first amplified by the 2 stage RF low noise amplifiers (LNAs) providing total 30 dB of gain and filtered by the RF inter-stage filter at the LNA output. The IF SAW filter with low-pass impedance match is applied at the mixer output to suppress the LO fundamental. Then the receiver path provides IF variable AGC amplifier and quadrature demodulation functions to generate I and Q baseband outputs.

2.3 Design Considerations

For high performance purposes, the proposed transceiver is designed by a typical superheterodyne architecture. In such a structure the input signal in each channel is mixed with a reference signal to produce a signal at desired frequency, which can then be filtered and processed. In more importance, the superheterodyne structure provides good signal isolation to both RF circuit and IF circuit, and provides the up-link and down-link high reliability of the RF front-end system.

The stability of signal leveling from AGC circuit is essential in high data rate designs, such as WCDMA system. Therefore, variable AGC amplifiers are used in up-link circuit or down-link circuit to present required constant signal amplitudes to their next stages. In transmitter channel, two AGCs are used for large dynamic range of variable gain and variable precision control, whereas in down-link design, the precise level from the RAGC allows full use of the input range of the baseband detection.

In addition, the SAW filters in the up-link and down-link channels are utilized to improve signal quality and suppression ability of the system. The common RF LO and IF LO are designed for the consideration of space saving and power dissipation saving of the transceiver. Compared with zero-IF circuit scheme, which has DC-offset at the baseband output and therefore needs the cancellation of DC component, the designed structure gives an I/Q baseband output without any DC-offset.

3. Performance Test

The performance of the transceiver is measured on an evaluation board. The RF transmitting test system is shown in Fig. 2. Anritsu MG3861 generates a WCDMA signal fed into RF subsystem. The Anritsu MS8609S is used to test the transmitting power, error vector magnitude (EVM), adjacent channel power rejection ratio (ACPR), occupied bandwidth, and so on. The selection of RF channels and the setup of transceiver enabling level are supplied by the controller.

The IF quadrature modulator gives 380MHz signal of −58 dBm at 0.5 V or −13 dBm at 2.5 V to the TAGC1; the signal level can be adjusted automatically in practical applications. The two stages of AGCs (TAGC1 and TAGC2) supply the signal of total 85 dB gain. Table 1 summarizes the main measured performance of the transmitter channel.

Fig. 1. The block diagram of the WCDMA transceiver.

Fig. 2. Test system for the RF transmitted output performance.

Fig. 3. Test system for receiver performance.
level. Some of the test results of the receiver channel are given in Table 1. In our design, the main interest is in the receiver sensitivity. According to the 3GPP specification [8], the sensitivity at $1 \times 10^{-2}$ bit error rate (BER) should be tested in $2110 \text{ MHz} - 2170 \text{ MHz}$. The tested result of our system in $2140 \text{ MHz}$ is $-119.6 \text{ dBm}/3.84 \text{ MHz} (@\text{BER}=1 \times 10^{-3})$, as shown in Fig. 4.

Compared with the required sensitivity of $-117 \text{ dBm}$ in the 3GPP specification, the presented transceiver has a margin about 3 dB and better than the result given in [6]-[7]. A proper margin is valuable to cover the range of both basestations and terminals, or to offer terminals longer standby-time in network.

4. Conclusion

A RF sub-system has been designed for third generation WCDMA application. In a few years, such systems will provide high-speed mobile access to Internet, video transmission, etc. Key features of the design include superheterodyne architecture, AGCs design, and common local oscillators. The system has been implemented on an evaluation board. The performance test indicates that the designed system is better compliant with WCDMA 3GPP standards.

![Fig.4. The receiver sensitivity.](image)

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<th>System</th>
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<tr>
<td></td>
<td>The proposed results</td>
<td>The results of Ref. [6]</td>
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<tr>
<td>Transmitter</td>
<td>Frequency range</td>
<td>1920 MHz–1980 MHz</td>
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<tr>
<td></td>
<td>Dynamic range</td>
<td>85 dB</td>
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<td></td>
<td>Maximum output power</td>
<td>22 dBm</td>
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<tr>
<td></td>
<td>ACPR</td>
<td>$-41 \text{ dB} @ 5 \text{ MHz}$</td>
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<td></td>
<td>EVM</td>
<td>6.7%</td>
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<tr>
<td>Receiver</td>
<td>Frequency range</td>
<td>2110 MHz–2170 MHz</td>
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<tr>
<td></td>
<td>Dynamic range</td>
<td>80 dB</td>
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<tr>
<td></td>
<td>sensitivity(@2140MHz)</td>
<td>$-119.6 \text{ dBm}$</td>
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<td></td>
<td>ACS(@2140MHz)</td>
<td>$-45.6 \text{ dBm}$</td>
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<td>Overall NF</td>
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<td>I/Q gain mismatch</td>
<td>$\pm 0.5 \text{ dB}$</td>
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Table 1

Measured performance of the transceiver of Fig.1

References


Jing-Fu Bao was born in Zhejiang, China, in 1964. He received the Ph.D. degree from University of Electronic Science and Technology of China (UESTC) in 1996. From 1998 to 2004, he worked with Sony, Japan as a senior engineer. Dr. Bao is a currently professor with UESTC. His research interests include wireless communication, signal analysis and processing, and IC designs.

Zhu-Sheng Kang was born in Jiangsu, China, in 1957. He received the Ph.D. degree from UESTC in 1988. From 1990 to 1992, he was a research fellow with Birmingham University, U.K. and Loughborough Technology University, U.K. From 1997 to 2003, he worked with Infrared Engineering Co., U.K. and Scan-Tech Ltd. H.K. as a senior engineer. He is a currently associate professor with UESTC. His research interests include information processing, signal processing, and techniques of high-speed digitalization.