G-1-1(Invited)

Extended Abstracts of the 2010 International Conference on Solid State Devices and Materials, Tokyo, 2010, pp99-100

# Evolution of Transceiver Architectures toward Software-Defined and Cognitive Radios

Tsuneo Tsukahara[1], Takahiro Tsushima[1] and Hideyuki Ito[1]

[1] Univ. of Aizu
Tsuruga, Ikki-machi, Aizu-Wakamatsu City
Fukushima 965-8580, Japan
Phone: +81-242-37-2518, E-mail: tsuka@u-aizu.ac.jp

## 1. Introduction

Driven by increasingly user demands, communication systems are moving towards an era where ubiquitous connectivity using multi-systems and growing levels of integration will indispensable for most applications. However, radio-wave resources are limited and invaluable, especially in these days. Therefore, software-defied radios (SDRs) and cognitive radios (CRs), being a principal application of SDR, can be the key to greatly improving frequency-spectrum efficiency. SDRs strongly demand flexibility and re-configurability of radio frequency (RF) circuits, and thereby we can integrate multi-functions into a small handset.

Moreover, high-precision and low-cost quadrature modulators (QMODs) using CMOS devices are strongly needed for SDR transceiver LSIs. It's because, in recent years, multi-level modulations such as quadrature amplitude modulation (QAM) are used in wireless LANs (WLANs) and digital TVs, and will be used in the 4th-generation cell-phones. The QAM demands very small modulation errors of QMOD LSIs with about 1 %.

This paper describes the evolution of CMOS transceiver architectures, especially focusing on SDR and CR applications. Section 2 shows some examples of transceiver designs. In Section 3, we propose a high-precision complex quadrature modulator suitable for SDR and CR transmitters, featuring the inherent correction mechanism of local-oscillator (LO) phase and amplitude errors.

## 2. Trends of CMOS RF Transceiver Architectures

Traditionally, superheterodyne (SH) transceivers have been used in wireless transceivers for about 92 years. For channel selection, SH receivers need external filters, whose center- and cut-off frequencies are fixed depending on the system. The intermediate frequency (IF) filters are bulky and add costs to transceivers. The demand for smaller and less expensive transceivers has stimulated exploitation of new architectures suitable for single-chip radios.

Most transceivers suitable for single-chip integration have direct-conversion, wideband-IF, or low-IF configurations. In all of these configurations, channel selection can be done with on-chip active filters. The direct-conversion transceiver is also called the zero-IF architecture, and as the name implies, image does not exist, while DC offset and second-order distortion become new problems. Potentially, the direct-conversion configuration can be applied to any wireless system.

The wideband-IF transceiver, including sliding-IF configurations, has a high IF ranging from 100 to 200 MHz. Therefore, image signals are rejected using an external bandpass filter and an image-rejection mixer using complex multiplication. Because this combination can make image-rejection high, the wideband-IF transceiver also can be applied to any wireless systems.

The low-IF configuration is mainly used for a receiver because spurious transmission regulations are very stringent for transmitters. Since image signals are in-band signals, image-rejection is performed by only image-rejection mixers. Therefore, the low-IF configuration can be applied only when image-rejection specs can be set low, for example, in Bluetooth or GSM with IF=100 kHz where the adjacent signal is the image one.

Thanks to wide applicability, the direct-conversion configuration is frequently chosen for SDR receivers [1] and SDR transceivers [2]. Figure 1 shows a conceptual block diagram of an SDR transceiver proposed by an IMEC research group, which combines a CMOS RF chip with MEMS front-end modules [1]. DC offset cancellation becomes easier because wideband-baseband signals are used for high-speed applications such as the 3-G cell phones and WLANs. In Ref. 1, however, a low-IF receiver configuration with IF=100 kHz is exceptionally used for GSM with the narrow bandwidth of 200 kHz.

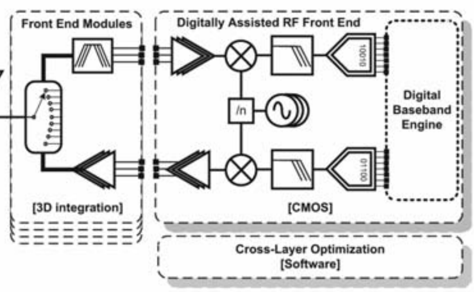


Fig. 1. Block diagram of an SDR transceiver.

In the IEEE802.22 committee, CR systems are being discussed [3]. These systems will use unused TV bands for mobile communications. A block diagram of a receiver chip intended for this CR system is shown in Fig. 2 [4]. It features multi-resolution spectrum sensing (MRSS) paths using analog correlator consisting of digital window generators (DWGs) and integrators. The MRSS senses unused signal bands at the beginning of a communication task.

Main signals are demodulated using a direct-conversion receiver.

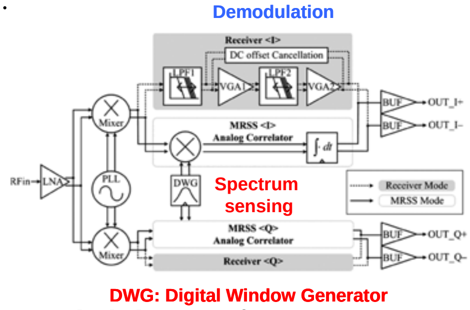

Fig. 2. Block diagram of a CMOS CR receiver.

## 3. A High-Precision Complex Quadrature Modulator

A new modulator is proposed with phase-and-amplitude error correction, as shown in Fig. 3 [5]. We call this a high-precision quadrature modulator (HP-CQMOD) which provides a complex modulated signal at the RF. Because HP-CQMOD uses two common-baseband quadrature mixers as shown in Fig 4, quadrature LO signals (LOI and LOQ) can affect each other at common-source nodes in dotted circles. This mixer is modified from a Harvey's receiver mixer [6]. Therefore, if quadrature LO-signals have phase errors from 90 degrees, they can be compensated at the mixer RF outputs at which a polyphase filter is added.

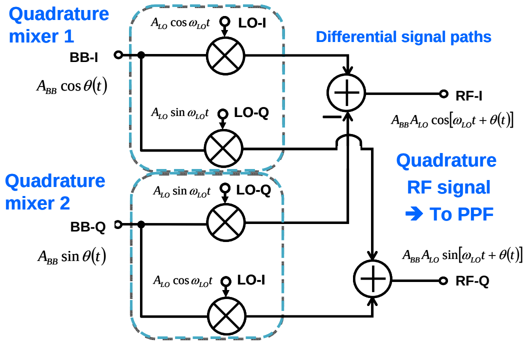

Fig. 3. High-precision quadrature modulator.

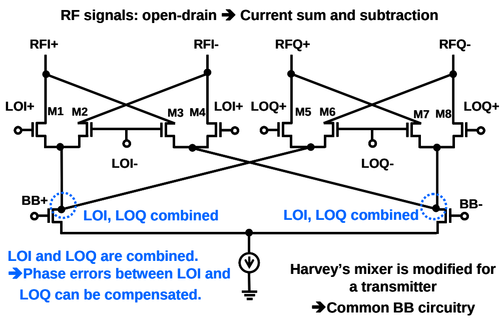

Fig. 4. Common-baseband quadrature mixer.

However, if the quadrature LO-signals have amplitude-errors or mismatches, they can not be compensated using this mixer. The amplitude-errors produce an undesired image signal at the negative frequency region as shown in Fig. 5 [7]. Therefore, a complex filter with an asymmetric frequency response can suppress the image signal, thereby reducing the undesired effects caused by the amplitude errors. So, we can use an RC-polyphase filter (PPF), as shown in Fig. 6 [8], or a complex bandpass filter adding at the RF outputs of the HP-CQMOD. Simulations show more than 30-dB increase of side-band-rejection.

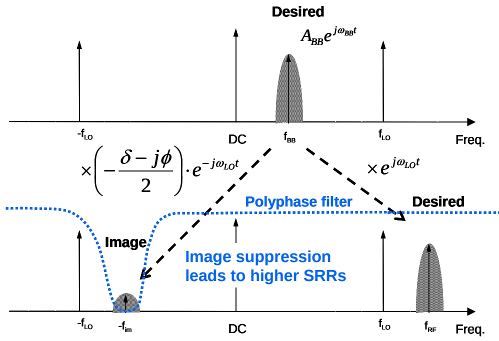

Fig. 5. Undesired image signal created by amplitude-errors.

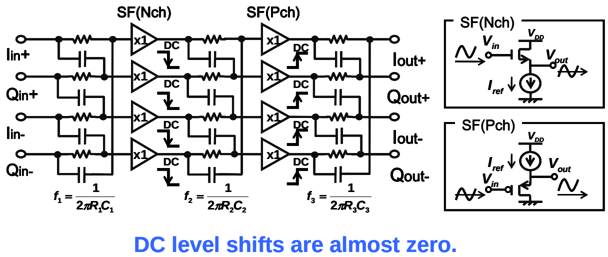

Fig. 6. RC-polyphase filter with source-follower buffers.

## 4. Conclusions

The evolution of CMOS transceiver architectures was described, especially focusing on SDR and CR applications. After explaining some examples of transceiver designs, we proposed a high-precision complex quadrature modulator suitable for SDR and CR transmitters. It features the inherent correction mechanism of LO phase and amplitude errors, using common baseband quadrature mixers and a complex filter. Simulations confirmed this property.


## Acknowledgements

This work is supported by VLSI Design and Education Center (VDEC), the University of Tokyo in collaboration with Cadence Design Systems, Inc. Moreover, this work is partially supported with the Commissioned Research Fund from ADVANTEST Corporation.


## References


[1] V. Giannini et al., *IEEE J. Solid-State Circuits*, vol. 44, no. 12, pp. 3486-3498, Dec., 2009.

[2] M. Ingels et al., *Digest of Int'l Solid-State Circuits Conference*, pp. 458-459, Feb. 2010.

[3] C. Corderio et al., *J. Communications*, vol. 1, no. 1, pp. 38-47, April 2006.

[4] J. Park et al., *IEEE J. Solid-State Circuits*, vol. 44, no. 1, pp. 258-268, Jan., 2009.

[5] T. Tsushima and T. Tsukahara, *The 2010 IEICE Society Conference*, Sept. 2010.

[6] J. Harvey and R. Harjani, *14th International Conference on VLSI Design*, Jan. 2001.

[7] T. Tsukahara, *Design of CMOS RF Circuits*, Maruzen, 2009.

[8] H. Ito and T. Tsukahara, *The 2010 IEICE General Conference*, C-12-8, March 15, 2010.