Direct Conversion Receiver Design for Mobile Phone Systems – Challenges, Status and Trends

(Invited Presentation)

Fazal Ali
Nokia Mobile Phones, San Diego, CA. 92131

Abstract – **This presentation will give an overview of the design issues related to the implementation of direct conversion receiver for mobile phones, provide the current status and discuss future trends.**

I. Direct Conversion Radio – A new Paradigm in Mobile Phones:

In the past several years, the mobile phone market has experienced a significant growth. As the industry transitions from 2G to 3G, the phones are becoming more application and feature rich. These new small size phones not only support the basic voice feature in multiple frequency bands but also support high-speed data, multi-media applications, GPS location technology and Bluetooth wireless connectivity. The RF section of these new phones has experienced significant size reductions (Figure 1) due to evolution of radio architectures, enabling semiconductor IC technologies, and innovative system/circuit design techniques.

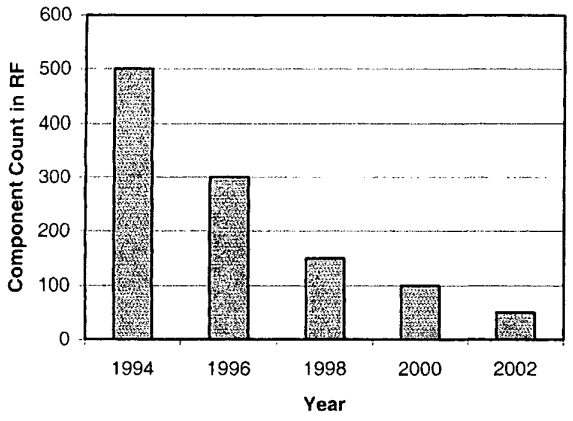

Figure 1: RF component count reduction in GSM Mobile handsets over the years

Increased pressure for small form factor, low cost, reduced bill of materials and low power consumption in radio applications of mobile phones have triggered the industry to resurrect the direct conversion transceiver radio architecture. Long abandoned in favor of mature super heterodyne architecture, direct frequency conversion has emerged over the last six years as the de-facto standard for GSM handset design. Among the handset manufacturers currently using direct conversion architectures are Alcatel, Nokia, Ericsson, Samsung, Siemens to name a few. Also, several RFIC suppliers (Infineon, Conexant, Analog Devices, Phillips, Qualcomm, TI, etc.) are currently offering standard direct conversion chipsets for GSM handsets and have started to offer the same for WCDMA and CDMA systems.

Each of these digital cellular systems differ from each other (Table 1) in frequency bands, modulation schemes, channel bandwidth, duplex spacing etc. and have distinct RF system requirements (e.g. sensitivity, IIP3, IIP2, phase noise, LO leakage)

This presentation will focus only on the direct conversion receiver design issues as related to system requirements of GSM, WCDMA and CDMA protocols.

II. Direct Conversion Receiver:

In a direct conversion receiver (Figure 2), the incoming RF signal is amplified by a LNA and then directly demodulated to baseband I and Q signals. Channel selection of the I and Q signals is done by low pass filters. This receiver architecture offers several advantages, which makes it very suitable for multi-band, multi-standard operation. They are:

- Removal of off-chip IF and sometimes RF SAW filters *(cost, size and part count reduction)*
- Programmable IF bandwidth *(allows several IF bandwidth in the same radio)*
- Use of only one Local Oscillator *(only one phase noise contribution)*
- Elimination of image frequency *(reduced specs. on RF pre-select filter)*
- Higher levels of integration leveraging high performance RF/Mixed signal process
- Total system solution utilizing innovative system/circuit design techniques

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TABLE I

Comparison of GSM, CDMA2000 & WCDMA Systems

PARAMETERS	GSM			CDMA 2000		WCDMA
	GSM	DCS	PCS	CELL	PCS	EUROPE
FORWARD LINK (MSRX) (MHz)	935-960	1805-1910	1930-1990	869-894	1930-1990	2110-2170
REVERSE LINK (MSTX) (MHz)	890-915	1710-1785	1850-1910	824-849	1850-1910	1920-1980
CHANNEL SPARING	200 KHz			1.25 MHz		5 MHz
MULTIPLE ACCESS	TDMA			DS-CDMA		DS-CDMA
DUPLEX SPACING (MHz)	45	95	80	45	80	190 (variable)
MODULATION FL	GMSK 0.3			QPSK		QPSK
MODULATION RL				HPSK		HPSK

But the downside is that we lose several features (e.g. selectivity, AC coupling and amplitude and phase accuracy) of the super heterodyne architecture. The principal challenges of direct conversion receiver are as follows:

- DC offsets (Static and dynamic)
- Second order intermodulation
- LO Leakage, signal isolation, self mixing
- Amplitude and Phase mismatch
- 1/f noise in baseband IF

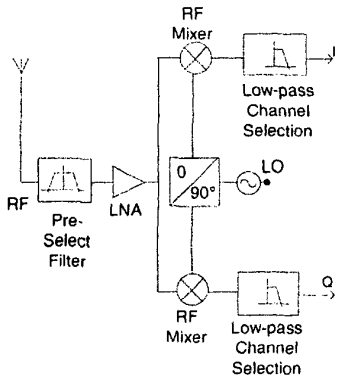

Figure 2: Block diagram of a Direct Conversion Receiver

The presentation will address how the above-mentioned challenges are currently being addressed in the receiver implementation of GSM, WCDMA and CDMA handsets. Measured performance and examples will be cited.