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### What's in an RF Front End?

By Christopher Bowick 02.04.2008 0

*The following is excerpted from Chapter 8 from a new edition of the book, [RF Circuit Design, 2e](#) by Christopher Bowick. (If you order a **copy** of this book before March 30, 2008 you can receive additional 20% off. Visit [www.newnespress.com](http://www.newnespress.com) or call 1-800-545-2522 and use code 91603.)*

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The RF front end is generally defined as everything between the antenna and the digital baseband system. For a receiver, this "between" area includes all the filters, low-noise amplifiers (LNAs), and down-conversion mixer(s) needed to process the modulated signals received at the antenna into signals suitable for [input](#) into the [baseband](#) analog-to-digital converter (ADC). For this reason, the RF front end is often called the analog-to-digital or RF-to-baseband portion of a receiver.

Radios work by receiving RF waves containing previously modulated information sent by a RF transmitter. The receiver is basically a low noise amplifier that down converts the incoming signal. Hence, sensitivity and selectivity are the primary concerns in receiver design.

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Conversely, a transmitter is an up converts an outgoing signal prior to passage through a high power amplifier. In this case, non-linearity of the amplifier is a primary concern. Yet, even with these differences, the design of the receiver front end and transmitter back end share many common elements like local oscillators. In this chapter, we'll concentrate our efforts on understanding the receiver side.

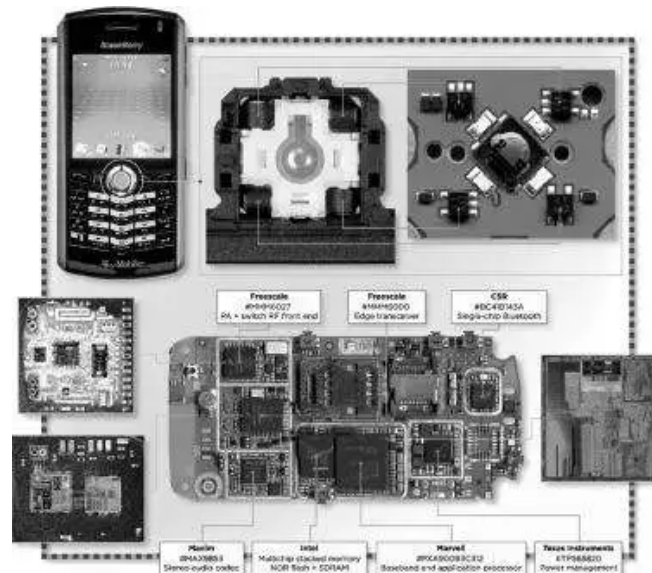
Thanks to advances in the design and manufacture of integrated circuits (ICs), some of the traditional analog IF signal processing tasks can be handled digitally. These traditional **analog** tasks, like filtering and up-down conversion, can now be handled by means of digital filters and digital signal processors (DSPs). Texas Instruments have coined the term digital radio processors for this type of circuit.

This **migration** of analog into digital circuits means that the choice of what front-end functions are implemented by analog and digital means generally depends on such factors as required performance, cost, size, and power consumption. Because of the mix of analog and digital technologies, RF front end chips using mixed-signal technologies may also be referred to as RF-to-digital or RF-to-baseband (RF/D) chips.

Why is the front end so important? It turns out that this is arguably the most critical part of the whole receiver. Trade-offs in overall system performance, power consumption, and size are determined between the receiver front end and the ADCs in the baseband (middle end). In more detail, the analog front end sets the stage for what digital bit-error-rate (BER) performance is possible at final **bit** detection. It is here that the receiver can, within limits, be designed for the best potential signal to noise ratio (SNR).

### **Higher Levels of Integration**

Look inside any modern mobile phone, multimedia device, or home-entertainment control system that relies on the reception and/or transmission of wireless signals and you'll find an RF front end. In the RIM **Blackberry** PDA, for example, the communication system consists of both a transceiver **chip** and RF front-end module (see Fig. 8-1).



*8-1. Tear down of modern mobile device reveals several RF front-end chips.  
(Courtesy of iSuppli)*

The front-end module incorporates several integrated circuits (ICs) that may be based on widely different semiconductor processes, such as conventional silicon **CMOS** and advanced silicon germanium (SiGe) technologies. Functionally, such multichip modules provide most if not all of the analog signal processing—filtering, detection, amplification and demodulation via a mixer. (The term “system-in-package” or SIP is a synonym for multichip module or MCM.)

Multichip front-end modules demonstrate an important trend in RF receiver design, namely, ever-increasing levels of system integration required to squeeze more functionality into a single chip. The reasons for this trend—especially in consumer electronics—come from the need for lower costs, lower power consumption (especially in mobile and portable products), and smaller product size.

Still, regardless of the level of integration, the basic RF **architecture** remains unchanged: signal filtering, detection, amplification and demodulation. More specifically, a modulated RF carrier signal couples with an antenna designed for a specific band of frequencies.

The antenna passes the modulated signals along to the RF receiver's front end. After much conditioning in the front-end circuitry, the modulation or information portion of the signal—now in the form of an analog baseband signal—is ready for analog-to-digital conversion into the digital world. Once in the digital realm, the information can be extracted from the digitized carrier waveforms and made available as audio, video, or data.

Before the advent of such tightly integrated modules, each functional block of the RF front end was a separate component, designed separately. This means that there were separate components for the RF filter, detector, mixer-demodulator, and amplifier. More importantly, this meant that all of these physically independent blocks had to be connected together.

To prevent signal attenuation and distortion and to minimize signal reflections due to impedance differences between **function** blocks, components were standardized for a characteristic impedance of 50 ohms, which was also the impedance of high-frequency test equipment. The 50-ohm coaxial **cable interface** was a trade-off that minimized signal attenuation while maximizing power transfer—signal energy—between the independently designed **RF** filter, LNA, and mixer.

Before higher levels of functional integration and thus lower costs could be achieved, it was necessary to design and manufacture these RF functional blocks using standard semiconductor processes, such as silicon CMOS IC processes.

Unfortunately, one of the drawbacks of CMOS technology can be the difficulty in achieving a 50-ohm input impedance. Still, it is only necessary to have the 50-ohm matched input and output impedances when the connection lines between the sub-circuits is long compared to the wavelength of the carrier wave. For ICs and MCMs at GHz frequencies, connections lines are short, so 50-ohm between sub-circuits isn't a problem. It is necessary to somehow get to 50 ohms to connect to the (longer) printed circuit board traces.

This is but one example of the changes that have taken place with modern integrated front ends. We will not cover all the changes here. Instead, we'll focus on the important design parameters that can affect the design of an RF front end, including the signal-to-noise ratio (SNR), receiver sensitivity, receiver and channel filter selectivity, and even the bit resolution of the ADC (covered later). This high-level description of the RF front end reveals not only the basic functioning but also the potential system trade-offs that must be considered.

Part 2 will take a look at several different radio architectures: detector, direct-conversion, and superheterodyne receiver configurations.

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