cover story

Flexible Chip Set Arms 802.11a/b/g WLANs

This software-driven, dual-chip solution provides the performance and versatility needed to support the three major WLAN standards at data rates to 54 Mb/s.

Wireless local-area networks (WLANs) are now well established in business enterprise networks, and growing in home applications. Until now, such networks have been based upon the IEEE 802.11b standard at 2.4 GHz. But increasing demands for more WLAN bandwidth and faster data rates have fostered the newer IEEE 802.11a and g standards with greater security and better support of multimedia services. To enable these emerging WLAN standards, RF Micro Devices (Greensboro, NC) has developed the model RFCS5420 software-driven, flexible dual-band, two-chip solution that works across all three standards and allows seamless connectivity among all three systems.

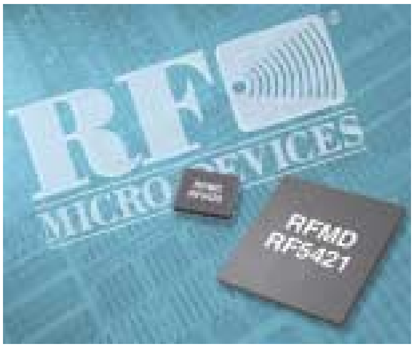
A chip set designed for connectivity to IEEE 802.11a/b/g networks will require three main building blocks:
1. A radio subsystem with transceivers capable of operating at 2.4 and 5 GHz.
2. A modem that supports orthogonal-frequency-division-multiplex (OFDM) and complementary-code-keying (CCK) modulation schemes.
3. A unified media-access controller (MAC) with support for IEEE 802.11a/b/g and the extensions to these standards.

The RFCS5420 chip set consists of a model RF5425 transceiver integrated circuit (IC) and a model RF5421 bandband/MAC IC. Both ICs are implemented in 0.18-μm, +1.8-VDC complementary-metal-oxide-semiconductor (CMOS) technology which offers extremely low power consumption in both transmit and receive modes. The RFCS5420 chip set can be functionally viewed as a composite of distinct IEEE 802.11a and IEEE 802.11b/g chip sets, each with its own radio, modem, and MAC subsystems that share a common host interface. The RF5425 transceiver is based on a *True Zero-IF* CMOS radio-transceiver architecture. Only front-end amplifiers and bandpass filters are needed for a complete dual-band 2.4- and 5-GHz WLAN radio solution.

JIM BOHAC
Marketing Manager
RF Micro Devices (San Jose Office), 7628 Thorndike Rd., Greensboro, NC 27409; (336) 664-1233, FAX: (336) 931-7454, Internet: www.rfmd.com.

The RF5421 baseband/MAC IC includes a complete implementation of IEEE 802.11a/b/g CCK and OFDM modems and an ARM9 processor that executes the bulk of the processing functions required for MAC processing. The RF5421 also includes hardware accelerators for modem aiding functions and full-speed encryption and security support. Together, the two ICs execute all of the Layer 1 and 2 functions required for IEEE 802.11a/b/g operation, thereby freeing significant high-speed processing chores from a host processor.

The RFCS5420 chip set **(Fig. 1)** supports data rates to 11 Mb/s (1, 2, 5.5, and 11 Mb/s) in CCK mode at 2.4 GHz and data rates to 54 Mb/s (6, 9, 12, 18, 24, 36, and 54 Mb/s) in OFDM mode at 2.4 and 5 GHz. The radio transceiver operates in the 2.4-GHz industrial-scientific-medical (ISM) band, the 4.9-to-5.1 GHz Japan band, and



1. The RFCS5420 WLAN chip set consists of the RF5425 2.4/5-GHz RF transceiver IC and the RF5421 baseband/MAC IC.

the 5.15-to-5.35-GHz UNII band. The chip set provides support for a wide range of modulation formats, including BPSK, QPSK, 16QAM, and 64 QAM. The chip set's unique AccuChannel equalization provides as much as 4-dB improvement in signal-to-noise ratio (SNR) in typical office environments, which translates into a 32-percent increase in WLAN range and about 70-percent more coverage area when operating in OFDM mode.

The RF5425's zero-IF radio IC features a direct-conversion architecture **(Fig. 2)**, requiring only one mixer stage to convert the desired RF signals directly to and from baseband signals without any IF stages and without the need for external surface-acoustic-wave (SAW) filters. Most zero-IF radio designs also integrate the low-noise amplifier (LNA), voltage-controlled oscillator (VCO), and the baseband filters on a monolithic die. In fact, such integrated single-chip zero-IF transceivers have performed well for many years in cellular and pager applications and they are beginning to emerge in WLAN radio designs as well. A major advantage of the zero-IF architecture on CMOS is that it enables the implementation of a full dual-band transceiver on a monolithic die with a minimum increase in die size compared to a single-band implementation. The zero-IF radio architecture eliminates an IF stages, reducing complexity and power consumption. Furthermore, several on-chip circuits, i.e. synthesizers, can be shared for both bands.

Of course, no radio architecture is ideal. Some of the common RF problems inherent with the zero-IF architecture are DC offset, flicker noise, and LO pulling. DC offsets are mainly generated by the LO leakage, which self-mixes, thereby creating a DC component in the signal chain that affects the receiver performance and can cause the RF stages to saturate. Flicker noise, also known as 1/f noise, is low-frequency device noise that can corrupt signals in the receiver chain. Flicker noise is more pronounced with the zero-IF architecture because of the direct conversion to low-frequency baseband signals. Another concern with direct conversion is the pulling of the LO by the power-amplifier (PA) output, which affects the direct upconversion process. This is because the high-power PA output, which has a spectrum centered around the LO frequency, can disturb (or pull) the frequency of the transmitter VCO.

The RF5425 incorporates proprietary filters designed to provide superior adjacent-channel and alternate adjacent-channel rejection while minimizing noise contributions. An innovative VCO-design and frequency-planning architecture minimizes phase noise and LO pulling in the transmitter.

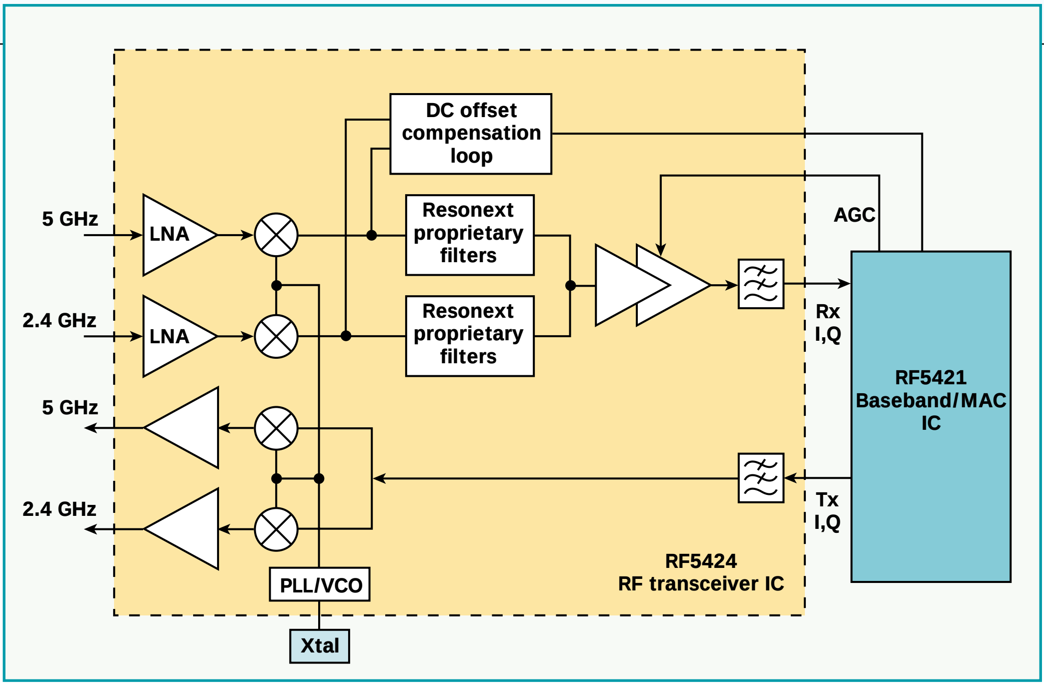
The other RF effects of zero-IF CMOS transceivers are mitigated by a combination of RF design techniques and baseband algorithms. A DC offset loop operates in conjunction with the baseband to dynamically correct for DC offset. Similarly, in-phase/quadrature (I/Q) mismatch is measured and corrected by the baseband at time of system initialization or channel changes. Close coupling of the RF5421 and RF5425 provide optimal performance for the zero-IF WLAN radio implementation.

The RF5421 baseband/MAC IC provides the baseband, MAC, security and host functions for the RF5425 radio **(Fig. 3)**. It is designed with proprietary RF Micro Devices algorithms to achieve maximum IEEE 802.11a/b/g system performance, using AccuChannel Equalization technology, advanced hardware security and a flexible MAC. The IC incorporates the following functional blocks:

1. An ARM9 processor with 16-kB cache memory for MAC software execution supported by external SDRAM, SRAM, or Flash memory.
2. An 802.11a/g OFDM modem.
3. An 802.11b CCK modem.

4. A programmable encryption/decryption engine.
5. Internal timers with microsecond resolution.
6. PCI/CardBus/Mini-PCI interface support.
7. Power-management circuitry.

The decision to use a software MAC has obvious benefits for the flexibility to support the IEEE 802.11a, b, and g protocols as well as the quality-of-service and security standards soon to be ratified by the IEEE standards body. The RF Micro Devices' Flexible MAC is software controlled, written in C++ language, and runs under the ThreadX real-time operating system (RTOS). On-chip dedicated hardware is provided to offload various low-level operations for performance optimization. Implementation of the MAC in software provides a *future-proof* implementation for original-equipment manufacturers (OEMs). With the software based MAC, OEMs can track changes in the developing



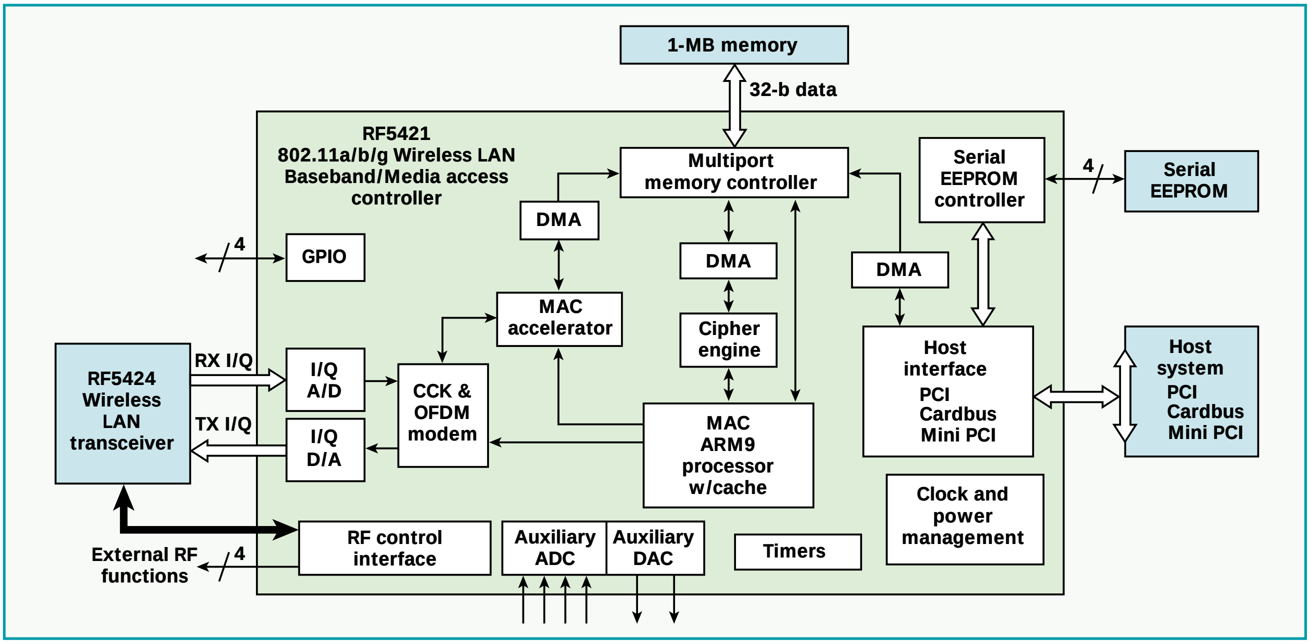
2. The RF5425 RF transceiver IC employs a zero-IF architecture to minimize mixers, filters, and other components in the downconversion of 2.4- and 5-GHz signals to lower-frequency baseband signals.

IEEE 802.11 standards and provide feature upgrades to installed hardware via software-update packages. All flexible MAC features can be downloaded to clients using remote software-update procedures controlled from a central management database. This feature offers OEMs the capability to provide software updates and revenue-generating software enhancements to end customers.

This software-based MAC implementation is referred to as the RFMD Flexible MAC architecture. RF Micro Devices has used the Flexible MAC architecture to track IEEE standard developments (e.g., IEEE 802.11i,e,h,k, and j) and to implement extensions to the basic service set defined by the IEEE such as WiFi Protected Access and Cisco CCX in addition to providing a vehicle for customers to provide product differentiation through implementation of their own protocol extensions. The RF5421 has been implemented with a programmable encryption/decryption engine that is managed by the on-chip ARM processor in order to implement Flexible MAC Enhanced Security (IEEE 802.11i). This flexible architecture allows the RF5421 solution to be aligned with the developing IEEE 802.11-TGi Working Group proposals. In addition to supporting TGi standards based security proposals, the programmable encryption/decryption engine can be used to support proprietary security systems such as Cisco CCX. Current security modes supported by the RF5421 include: *Wired Equivalent Protection* (WEP) 1 and 2, *WiFi Protected Access* (WPA) and *Advanced Encryption Standard* (AES). These security modes are implemented in hardware for maximum system performance. TKIP and AES/CCM modes are also supported for future compatibility with evolving TGi proposals. The RF5420 chip set also provides support for 802.1x authentication.

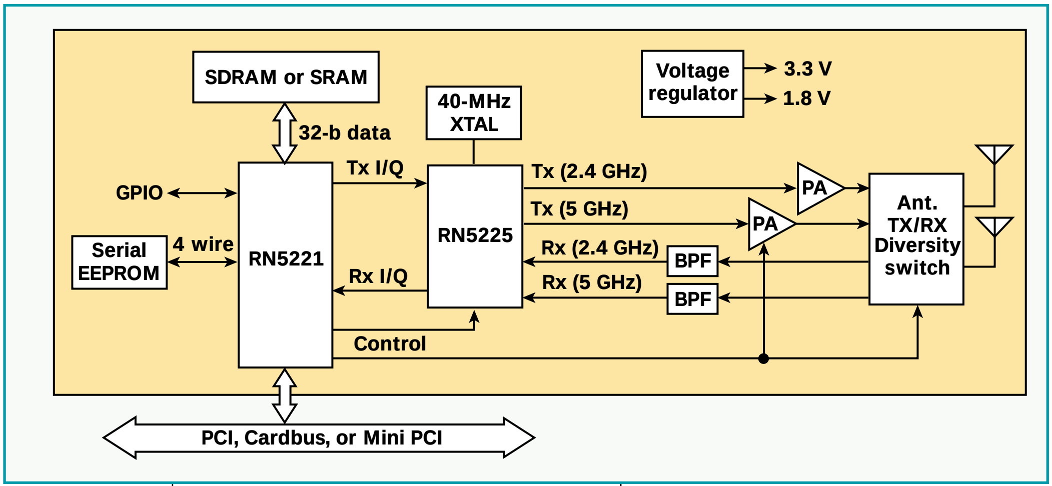
Multimedia applications are increasing the need for managed quality of service (QoS) in many applications. In accordance with the IEEE 802.11e standard, the RFMD Flexible MAC has provisioned for eight independently managed packet queues to support implementation of QoS dependent services. With the software-based architecture the Flexible MAC can be used to implement standards-based approaches to QoS or proprietary approaches in advance of full standard ratification.

The IEEE 802.11 specifications allow for reserved and optional fields in beacon and other management frames within the IEEE 802.11 protocols. OEMs have taken advantage of these fields to implement network-management features commonly referred to as “SuperMAC” extensions. RFMD’s Flexible MAC



3. The RF5421 baseband/media-access-controller (MAC) IC works with a flexible software MAC to support the IEEE 802.11a/b/g WLAN standards.

4. This functional block diagram shows a typical client CardBus or Mini-PCI WLAN design based on the RF5425 transceiver and the RF5421 baseband/MAC ICs.



allows OEMs to take full advantage of these SuperMAC extensions. Examples of these features include dynamic data-rate selection, client roaming support, and a host of network-management features, such as link status reporting, and radio-link calibration.

With the Flexible MAC software and the two-chip CMOS implementation, the RFCS5420 chip set can be embedded into a variety of WLAN devices. As an example, **Fig. 4** shows a functional block diagram for a basic client CardBus or Mini-PCI WLAN solution based on the RF5425 and RF5421. This application illustrates the level of system integration achievable with the chip set resulting in a high-yield, low-BOM cost, small form-factor design. In addition to the pair of ICs, the solution requires dual-band diversity antennas, an antenna switch for transmit/receive mode and diversity functions, 2.4- and 5-GHz PAs, low-dropout regulators to supply the +1.8 and +3.3 VDC needed by all devices, a low-cost band-select filter/diplexer for selecting 2.4- or 5-GHz band, 2-kb serial EEPROM for storing device configuration data and MAC address, and 1-MB SDRAM or SRAM for MAC code and data.

In addition, the RFCS5420 chip set can be used to develop USB2.0 client devices, Ethernet Client Bridge devices, low-cost Access Points and Wireless routers, as well as embedded multimedia WLAN NICs. In summary, the RFCS5420 is an ideal solution to provide cost-effective IEEE 802.11a/b/g network connectivity while at the same time providing a platform that will change along with the continuously evolving IEEE standards activities. **RF Micro Devices, 7628 Thorndike Rd. Greensboro, NC 27409; (336) 664-1233, FAX: (336) 931-7454, Internet: www.rfmd.com.**