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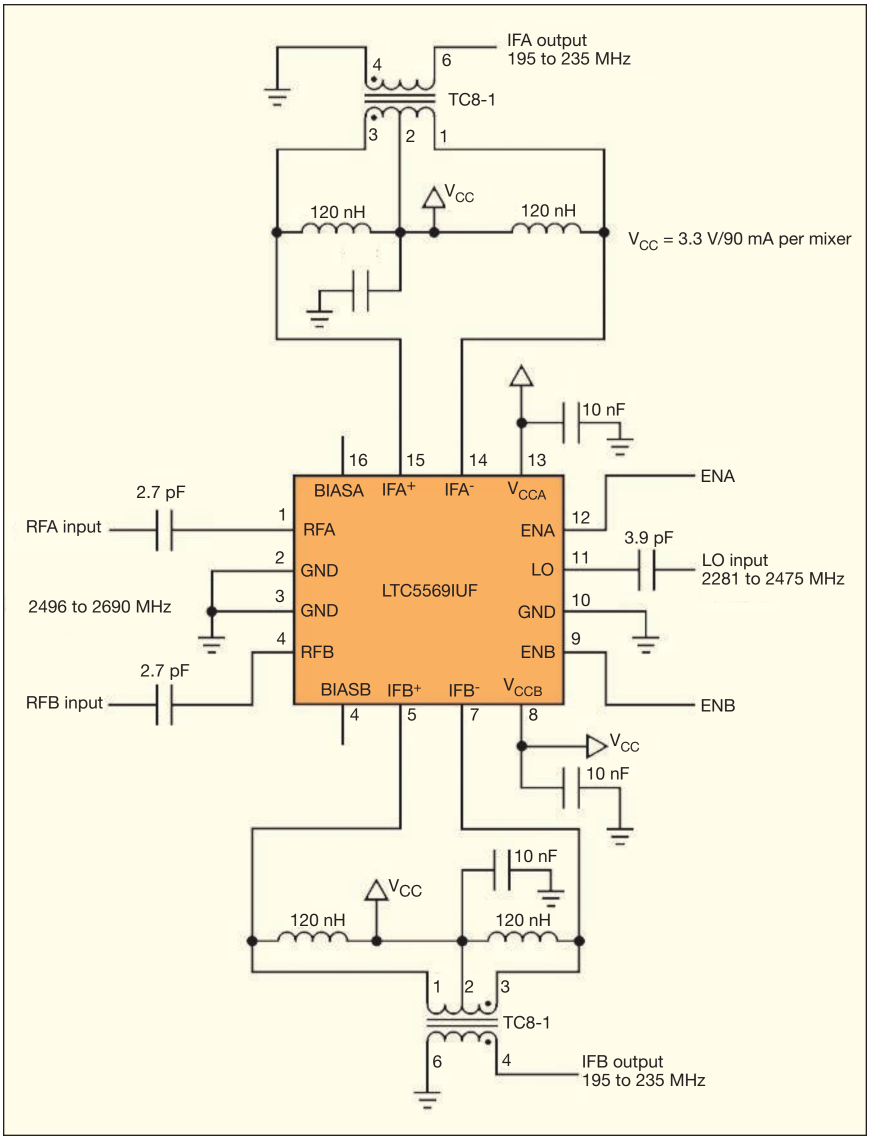
Making MIMO Receivers Smaller

Smaller MIMO base-station hardware is only attractive if it can also deliver improved performance across multiple communications channels, while also keeping power consumption in check.

FOURTH-GENERATION (4G) wireless communications networks are predicted to lean heavily on multiple-input, multiple-output (MIMO) receiver technologies. Compared to 3G systems, 4G operators and customers are expecting faster data rates and wider bandwidths, both of which place demands on new receiver designs. Fortunately, available mixer technology, including a dual-mixer integrated-circuit (IC) solution, supports flexible receiver architectures that can provide excellent wideband performance with low power consumption.

Wireless base stations in cellular's 4G evolutionary stage are undergoing transformations, keyed by lessons learned from earlier generations. Efforts are underway to make network deployment more effective for these newer networks that promise faster and faster wireless data rates. Challenges facing 4G equipment designers include developing radios with as many MIMO channels as possible, in smaller housings, and with operational compatibility with other frequency bands and multiple communications standards.

Hence, next-generation base stations are likely to take on a different look from those of the past. The man-sized equipment rack that sits inside an air-conditioned shack at the base of the transmission towers is being replaced by small, weather-sealed housings known as remote radio heads (RRHs) or remote radio units (RRUs). These enclosures are the size of a desktop personal computer (PC) and are designed to mount on the tower top, fully exposed



This sample implementation of a MIMO TDD LTE band spans the frequency range from 2496 to 2690 MHz based on the use of the LTC5569 dual mixer.

to the elements. Each box is packed with many channels of radio electronics, but lack the baseband modulation or demodulation processor. Instead, the modulated signals are piped in and out through either multi-100-Gb/s fiber-optic cables, or by point-to-point microwave links. These signals are sent to a single base unit that can be tens of kilometers away, and feed multiple cell towers at a time. This type of base station architecture scales easily and is potentially more economical to deploy.

Another trend for the new generation are multiband-capable and—in many instances—multimode-operational radios. These systems can be easily configured by software to adapt to any carrier's service requirements, regardless of frequency bands or standards.

The most important goal for any new generation base station is, of course, to deliver a higher data rate to increase capacity. MIMO transceivers help to achieve higher data rates by enabling two or more orthogonal receive channels operating in parallel. Their data bit streams are combined to increase the effective data rate.

The multiple channels also help mitigate wireless receivers that are subject to fading and multipath interference that can result in performance degradation and data loss. High-frequency mixers capable of supporting multiple channels, such as the model LTC5569 dual mixer from Linear Technology (www.linear.com), help to minimize the component count in the design of 4G equipment. The LTC5569 enables simultaneous receive channels by configuring each mixer circuit's local oscillator (LO) to be driven from a common input, maintaining phase coherency across the two channels.

While it is possible to implement the same using two discrete mixers, having both mixers built on a monolithic die provides a far superior and consistent match on a part-by-part basis. Such a dual mixer provides for a higher degree of signal integrity by allowing it to mate with two physically separate antennas or patch elements. Thus, a good degree of spatial diversity can be accomplished. The two mixers' internally independent LO buffers provide excellent isolation between the two channels to support concatenating two or more data bit streams into a single, much higher data rate stream.

MEASURING MIMO FACTORS

A smart antenna can be used in a MIMO implementation by beam steering the signal in the direction of its reception. This can be done by using two or more MIMO receive channels to measure the angle of the incident signal. LO phase coherency between MIMO measurement channels is essential to ensuring the accuracy of these measurements. Expectations for 4G wireless systems are not only for higher data rates than in 3G systems, but wider operating bandwidths in support of multimode operation. Engineers are being asked to develop systems and components with bandwidths of 40, 65, and 75 MHz with acceptable gain flatness across the full bandwidths.

As an example of an application circuit for 4G systems, the LTC5569 dual mixer was used in an uplink receiver for Long Term Evolution (LTE) time-division-duplex (TDD) operation from 2496 to 2690 MHz **(see figure)**. The mixer's intermediate-frequency (IF) outputs must cover from 195 to 235 MHz. The IF outputs were optimized for the best possible return loss at higher IFs to improve the IF output frequency response flatness. The measured IF output return loss is 20 dB at 235 MHz and 14 dB at 195 MHz. Over the 40-MHz IF output bandwidth, this results in a ±0.3-dB IF output frequency response flatness.

In this application, the dual mixer's IF outputs employ 120-nH pull-up inductors from Coilcraft (www.coilcraft.com). These inductors are from the 0603HP series with 2% tolerance. Also, an 8:1 impedance ratio IF output transformer, a TC8-1+ from Mini-Circuits (www.minicircuits.com) is used on the differential IF outputs to present a single-ended, 50-Ω output impedance to the following stage in the LTE system.

The 120-nH pull-up inductors in parallel with the LTC5569 mixer IF output capacitance (1.3-pF differential) and other parasitic circuit elements form a wide-bandwidth, single-pole bandpass filter at the IF outputs. Each IF output pin conducts 28 mA of DC current from the V_{cc} supply. The total IF DC current of 56 mA is split between the secondary winding of the TC8-1 IF transformer and the two 120-nH IF output inductors. The junction between the two pull-up inductors and the center tap of the TC8-1 transformer requires a good AC ground, which is provided by the 10-nF bypass capacitors.

In this application circuit, the mixer's local oscillator (LO) port matching was optimized for low-side LO injection of 2281 to 2475 MHz. The mixer circuit's measured performance for an RF input sweep from 2496 to 2690 MHz yielded conversion gain of 1.5 dB, flat within ±0.3 dB, and output third-order intercept point (OIP3) of +26.0 to +27.2 dBm. The same performance was also measured for an IF output sweep from 195 to 235 MHz.

DUAL MIXERS FIT SMALL PACKAGE

The small size of the QFN-packaged LTC5569 (4 x 4 mm) helps in miniaturizing MIMO receiver designs. Each mixer's RF input and the common LO input have integrated balun transformers rendering external transformers unnecessary. External transformers can often take as much printed-circuit-board (PCB) area as the mixer itself. In addition, on-chip RF balun transformers can offer other advantages over external units. Since the patterns, thickness of the metallic traces, and the dielectric material for a built-in balun are well controlled as a part of the semiconductor process, they produce consistent impedance behavior that cannot be matched by discrete, mechanically wound transformers.

The 50-Ω impedance match of the LTC5569's RF and LO input ports helps minimize external impedance matching requirements. From 1.4 to 3.3 GHz, RF and LO return losses are better than 12 dB, so only a DC blocking capacitor is required at these ports. Since the dual mixer operates as low as 300 MHz, its RF input ports can be matched for the 700-MHz LTE band and 800-MHz GSM bands.

The generous conversion gain (2 dB)

of the LTC5569 dual mixer may eliminate the need for an additional IF gain stage (amplifier). The mixer also offers wide dynamic range, with +26.8-dBm input IP3 at an IF of 190 MHz. In addition, the mixer also fares well in the presence of blocker signals, with its noise figure only degrading slightly from 11.7 to 17.0 dB for a 1.95-GHz RF signal with in-band blocker signal of +5 dBm at the RF input port.

The mixer's outstanding performance comes without the expense of high power consumption. The LTC5569 is optimized for a supply of +3.3 VDC. At this supply voltage, each mixer draws only 90 mA DC current, for power consumption of only 300 mW/channel. With such low power consumption, an eight-channel MIMO receiver consumes only 2.4 W power.

When the dual mixer is soldered down on a PCB, care should be taken to ensure that the underside exposed center pad is completely soldered to the circuit board. This is important not only to provide the most efficient heat conduction away from the mixer, but also to achieve optimum RF signal ground contact and to ensure the best possible RF signal-to-noise performance. The LTC5569's package has a very low junction-to-case thermal resistance (εjc) of 8°C/W. With both channels operating (600 mW total power) and a PCB temperature of +105°C, the junction temperature for the dual mixer is only +110°C, well below the absolute maximum rating of +150°C.

In summary, The LTC5569 dual mixer delivers exceptional performance over a very wide bandwidth, operating within a compact housing and with low power consumption. It provides the performance and features needed for implementing next-generation LTE MIMO RRU requirements. MWRF

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