This highly integrated SiGe BiCMOS transmitter and receiver chipset clears the way for low-cost, high-data-rate applications in the millimeter-wave frequency spectrum centered at 60 GHz.

DATA AND BANDWIDTH ARE TWO AREAS where wireless communications customers have seemingly insatiable needs. No matter their wireless device of choice—be it a cellular telephone or a personal computer (PC)—users want faster data rates and thus require more bandwidth. Unfortunately, bandwidth is finite. But, thanks to a 7-GHz millimeter-wavefrequency block from 57 to 64 GHz set aside by the United States’ Federal Communications Commission (FCC; www.fcc.gov) in 2001, bandwidth is still available for wireless services. In general, throughout the world a 5-GHz millimeter-wave band is available for wireless services.

Of course, this assumes the development of practical transceiver components for radios at those frequencies. Fortunately, the model HMC6000 transmitter integrated circuit (IC) and the model HMC6001 receiver IC, both from Hittite Microwave Corp. (www.hittite.com), are those practical transceiver component solutions. Hittite’s HMC6000/6001 chipset not only solves many of the key technical challenges encountered at millimeter-wave frequencies, but also enables turnkey multi-Gb/s communication links at 60 GHz.

A 5-GHz portion of that millimeter-wave bandwidth, 59 to 64 GHz, is available for unlicensed applications in the US and in many locations around the world. The large block of spectrum enables the use of simple modulation schemes to achieve multi-Gb/s communication links, working with simpler transceiver designs at lower power levels than required for wireless applications at lower, more crowded frequencies.

The small wavelengths at 57 to 64 GHz also allow for extremely small antennas and overall miniaturization of radio system solutions. The short wavelengths support direct line-of-sight communications with low interference. At 60 GHz, signals propagate in an oxygen absorption band with approximately 15 dB/km attenuation; signals in that band also do not penetrate walls, which can be an aid in densely deployed short-range applications and in smaller wireless communications cell deployments.

1. This low-cost solution for license-free 60-MHz wireless communications consists of the model HMC6000 transmitter IC and a model HMC6001 receiver IC.
enabling significant frequency reuse. At 60 GHz, the short wavelength means that, for a given antenna aperture, a very narrow beam is transmit, with such beams capable of high isolation even in dense signal environments.

Because of the high isolation, the FCC allows for high transmit powers in this frequency band (to 500 mW) and an effective isotropic radiated power (EIRP) level to +40 dBm. This is 10 dB more than allowed at 900 MHz outdoors, 2.4 dB more than allowed at 5 GHz indoors and 6 dB higher than the 5-GHz UNII band outdoors. The limits set by the European Telecommunications Standards Institute (ETSI; www.etsi.org) allow for a power density of +13 dBm/MHz and a maximum EIRP of +40 dBm for wireless-local-area-network (WLAN) and wireless-personal-area-network (WPAN) applications and +55 dBm maximum EIRP for outdoor point-to-point fixed wireless systems.

The signal propagation properties, along with the wide bandwidth and high available EIRP, make the 60-GHz band an attractive frequency range for short-range applications requiring multi-Gb/s data rates. These include outdoor point-to-point radio solutions for metrocell/picocell backhaul and indoor datalink applications such as wireless Gb/s cable replacement (HDMI, USB 3.0, Thunderbolt, etc.), wireless docking stations and video/magazine kiosks. The bandwidth also holds great promise for millimeter-wave wireless sensor applications. Several standards and industry groups have emerged to address the use of these millimeter-wave frequencies, including the Institute of Electrical and Electronics Engineers (IEEE; www.ieee.org) with their IEEE 802.11ad and IEEE 802.15.3c standards, as well as the WirelessHD and Wireless Gigabit Alliance (WiGig; www.wirelessgigalliance.org) consortia.

| The 60-GHz transceiver solution at a glance. |
|--------|-----------------|-----------------|
| Parameter | HMC6000 transmitter | HMC6001 receiver |
| Operating frequency range | 57 to 64 GHz | 57 to 64 GHz |
| Linear output power | +12 dBm | --- |
| Noise figure | 38 dB | 67 dB |
| Maximum gain | 17 dB | 65 dB in 1-dB steps |
| Gain control range | -86 dBc/Hz | -86 dBc/Hz |

Of course, millimeter-wave signal processing poses many challenges. Achieving low-loss performance on printed circuit boards (PCBs) and with interconnections can be difficult without the use of advanced materials and sophisticated topologies. For low-cost solutions, millimeter-wave interconnections (to give one example), must be incorporated into the ICs themselves or into their packages. Hittite, a contributing member of the WiGig consortium, developed the HMC6000/6001 chipset to translate low-frequency baseband signals directly to and from 60 GHz, minimizing the need for expensive or complex millimeter-wave interconnection components on the PCB.

For example, the HMC6000 transmitter IC [Fig. 1] can translate baseband in-phase (I) and quadrature (Q) signals to a selected channel in the 60-GHz band, requiring only an external reference oscillator to execute the frequency translation. Model HMC6000 is fabricated with silicongermanium (SiGe) BiCMOS semiconductor process technology. It provides analog I and Q (differential) input ports with DC coupling for cancellation of DC offsets and carrier feedthrough. The transmitter IC includes a low-noise frequency synthesizer for tuning across the 57- to 64-GHz band using 500- or 54-MHz steps (a quarter of the IEEE channel spacing) depending on the reference input frequency. It features as much as 38-dB gain (with 17-dB gaincontrol range) to achieve as much as +12 dBm linear output power and as much as +17 dBm saturated output power. The differential RF output provides a low-loss RF transition with high output efficiency.

The HMC6001 receiver IC [Fig. 2] works with input signals from a selected channel in the 60-GHz band and downconverts them to lower-frequency differential analog I and Q baseband signals. The receiver chip includes all necessary frequency generation, filtering and gain control, including a programmable highpass filter that helps remove residual DC offset and local-oscillator (LO) feedthrough signals. The HMC6001 exhibits a 6-dB noise figure at the maximum gain setting; it provides a 65-dB gain control range in 1-dB steps (see table). A simple four-wire digital serial interface provides full control and status reporting for these ICs, including frequency channel selection, gain control, circuit bias and filter bandwidths.

Because reference and voltage-controlled-oscillator (VCO) signals (and their noise) are multiplied to achieve 60-GHz signals, phase noise can be a limiting factor for a millimeter-wave receiver. To
avoid degrading the HMC6001’s receiver noise figure, its integrated phase noise is maintained at typically 10 dB below the required signal-to-noise ratio (SNR) of the applicable modulation format. Fortunately, with the faster symbol rates used at 60 GHz, the integrated phase noise of concern is much further from the carrier. Both the HMC6000 and HMC6001 have integrated phase noise of roughly −25 dBc at 1.76-GHz WiGig symbol rates, enabling modulation formats to 16-state quadrature amplitude modulation (16QAM). Both the HMC6000 and HMC6001 exhibit phase noise of typically −86 dBc/Hz offset 1 MHz from the carrier.

To assist customers with 60-GHz system solutions, Hittite offers both connectorized and antenna-in-package (AiP) solutions based on the HMC6000 and HMC6001 millimeter-wave transceiver ICs. The model HMC6000LP711E solution, which combines a 60-GHz antenna with the HMC6000 transmitter IC in a low-cost, 7 x 11 mm QFN plastic package. This surface-mount-compatible solution supports low-cost PCB assembly and requires no experience in handling millimeter-wave devices. Similarly, the HMC6001LP711E combines a 60-GHz antenna with the HMC6001 receiver IC, also in a 7 x 11 mm QFN plastic package.

A typical point-to-point 60-GHz microwave radio link (Fig. 3) might transport one or more Gigabit Ethernet data streams. These are full-duplex connections so a diplexer is commonly used to provide the necessary isolation between the transmit and receive channels while sharing a common, high-gain antenna. In contrast to earlier system designs with numerous discrete components, a design based on the HMC6000 and HMC6001 ICs reduces the radio portion of the system to a pair of chips and a crystal reference oscillator; in addition, the interconnect challenge is reduced to two short transmission lines to the diplexer. The block diagram includes compatible analog-to-digital-converter (ADC) and clock-generator products from Hittite.

Figure 4 shows the block diagram for a multi-Gb/s indoor link adhering to the WiGig standard that is based on the HMC6000 and HMC6001. A variety of high speed digital interfaces can be used for such a link, including GigE, USB, HDMI or even PCIe. But to compete in consumer markets, this design integrates all network processing, Media Access Control (MAC), and Physical Layer functionality into a single application-specific integrated circuit (ASIC). The ADCs and digital-to-analog converters (DACs) in this system design typically operate at multi-Gb/s sampling rates, or at least twice the symbol rate of the modulation format. To minimize power and cost in a consumer application, the ADCs and DACs might even be integrated as part of the ASIC. Since WiGig employs time-division-duplex (TDD) multiplexing, this system can operate without a diplexer. Since its communications path distance is limited to the size of a room, the high-gain antenna used with outdoor millimeter-wave point-to-point links can typically be replaced by a much smaller, lower-gain antenna. To minimize transmission-line losses at 60 GHz, the radio chipset might be placed as close to the antenna as possible. The differential baseband interface for the transceiver ICs simplifies this placement by allowing separation between the ASIC and the ICs.

To try out these 60-GHz ICs, evaluation kits are available with coaxial connectors and in AiP configurations. For example, model HMC6450 is a 60-GHz AiP Transceiver Evaluation Kit (Fig. 5) comprised of two boards, the model HMC6000LP711E with the transmitter and the model HMC6001LP711E with the receiver. With its configuration software, a user has everything needed to set up a bidirectional millimeter-wave link at 60 GHz with a universal analog I and Q interface. For those preferring coaxial connectors, model HMC6451 is a 60-GHz MMPX Transceiver Evaluation Kit with the same functionality and software but with snap-on MMPX 60-GHz connectors.
New Highly Integrated IC Radio Solution for Low Cost 60 GHz Applications!

HMC6000 & HMC6001
Supports WiGig & IEEE 802.11ad
Multi-Gbps Solutions!

- High Output Power Silicon Germanium
- Covers 57 - 64 GHz Frequency Band
- Complete Analog Baseband to RF Solution
- Integrated Frequency Synthesizer
- Universal Analog I/Q Baseband Interface
- Up to 1.8 GHz RF Bandwidth

HMC6000 Transmitter

<table>
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<th>Frequency (GHz)</th>
<th>Function</th>
<th>P1dB (dBm)</th>
<th>Max Gain (dB)</th>
<th>Gain Control Range (dB)</th>
<th>Phase Noise @ 1 MHz Offset (dBc/Hz)</th>
<th>Power Dissipation (W)</th>
<th>Part Number</th>
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<tbody>
<tr>
<td>57 - 64</td>
<td>60 GHz Integrated Transmitter</td>
<td>12 dBm</td>
<td>38</td>
<td>17</td>
<td>-86</td>
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<tr>
<td>57 - 64</td>
<td>60 GHz Integrated Receiver</td>
<td>6 dB</td>
<td>67</td>
<td>65 @ 1 dB Step</td>
<td>-86</td>
<td>0.61</td>
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