NEW TRANSCEIVER IC EASES mmWAVE 5G FRONT-END DESIGN

Dual Channel IF Transceiver ICs

New levels of integration and flexibility

Anokiwave Is Now

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In 2024, Anokiwave was acquired by Qorvo. The combination of the two company's unique capabilities enables Qorvo to supply highly integrated complete solutions and SiPs for defense, aerospace and network infrastructure applications.

Anokiwave's innovative portfolio of active antenna ICs, combined with Qorvo's complementary products, global scale and significant market reach, provide new options for high integration and high-performance that will democratize phased array active antennas.

The following whitepaper was written to provide an overview of the latest IF transceiver IC family that, together with the beamformer ICs, enable new levels of integration and flexibility to develop 5G radios with significantly smaller size, lower cost and higher power efficiency. References to Anokiwave have been updated throughout the paper to reflect this acquisition.

The new IF transceiver ICs along with Qorvo's 4th generation beamformer ICs, enable new levels of integration and flexibility allowing 5G radios that are greener, lower cost and smaller form factor for every 3GPP mmWave 5G band.

Transceiver IC Eases 5G mmWave Front-End Design

Large fifth generation (5G) cellular wireless networks will rely on many small cells to reach subscribers with service at millimeter-wave (mmWave) frequencies. Due to small wavelengths, mmWave signals require many closely spaced cells to transmit and receive signals at frequencies above 24 GHz. Fortunately, a 5G small cell with multi-band frequency coverage can be assembled with just two integrated circuits (ICs) from Qorvo.

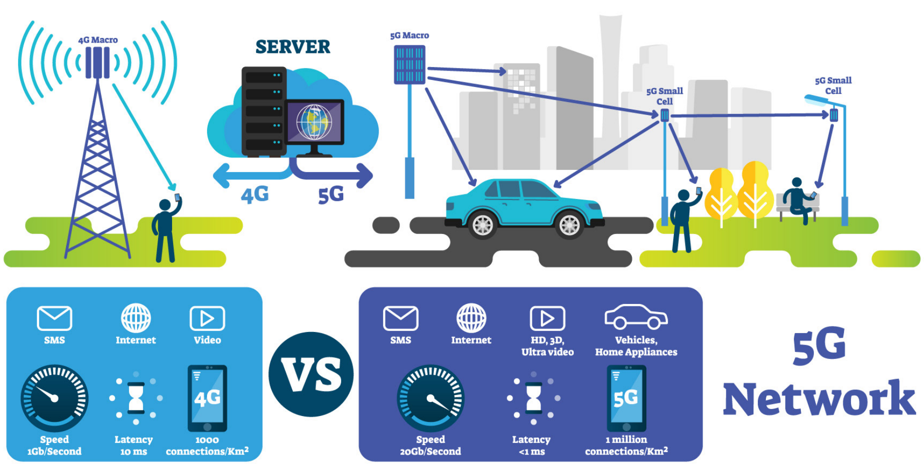
These ICs comprise a dual channel, transmit/receive frequency upconversion/downconversion transceiver IC paired with a dual quad 4x2 beamformer IC. Together they seamlessly enable the realization of dual polarized antennas in a single active array. The high integration and component density of these ICs speed and simplify the design and development of radio front ends for 5G small cells with the excellent power efficiency expected from an advanced silicon CMOS semiconductor process.

As wireless users turn to an increasing number of “data-consuming” activities, mmWave 5G networks provide increased speed and capacity especially in densely populated areas as service providers search for ways to provide faster upload/download speeds without glitches or delays.

As the number of use cases of wireless cellular networks has grown, the networks have evolved to require more frequency spectrum to handle the exponential growth of demand for bandwidth and data. To support this influx in demand and surge in use cases, critical mmWave infrastructure, powered by IC platforms that support intelligent arrays, are required in abundance.

In addition to the novelty of working at higher-than-traditional cellular frequencies, radio designers developing front ends at mmWave frequencies are faced with the many challenges of working with high-frequency signals through all kinds of propagation media. At mmWave frequencies, the shortest distance is the wisest, and highly integrated transceiver components help minimize signal losses while miniaturizing a radio front-end solution that is a good fit for many 5G small cells.

To support the wireless cellular networks influx in demand and surge in use cases, critical mmWave infrastructure, powered by IC platforms that support intelligent arrays, such as Qorvo's newest IC family, will be required in abundance.



5G network performance improvements are due to new mmWave antenna configurations with active beam steering

For networks using the mmWave frequency range, small cells are the solution. They must be capable of sending and receiving signals above 24 GHz within a defined dynamic range while performing the frequency translation of those signals to a lower-frequency IF for practical conversion by high-speed RF analog-to-digital converters (ADCs) and digital-to-analog converters (DACs). Although filtering requirements at mmWave frequencies may be minimal compared to lower, more-congested parts of the frequency spectrum, interference above 24 GHz may exist in the form of higher-order harmonic and spurious signals generated by lower-frequency signals within range, so the receiver and transmitter layouts within a 5G small cell must consider such factors as transmit spurious content and transmit signal leakage that can reach mmWave receiver input ports.

Achieving mmWave transmitters and receivers in a housing the size of a shoebox with suitable performance to operate reliably within a full-time 5G wireless network is not trivial and requires components built to military standard (MIL-STD) electrical, mechanical and environmental levels and an understanding of the nuances in developing commercially deployable mmWave antennas.

Finding the best spots for 5G small cells to provide extensive coverage at mmWave frequencies may be as challenging as building the small cells. Those small cells must include multiple receivers and transmitters as well as directional antennas with sufficient gain to overcome signal losses when reflected from building materials and other light posts. The 5G small cells must be closely spaced for continuous coverage for as many users as possible but not so closely spaced as to form an inefficient topology. Often, a mesh network of small cells is designed such that alternate signal paths can be formed through the network should one or more of the small cells fails.

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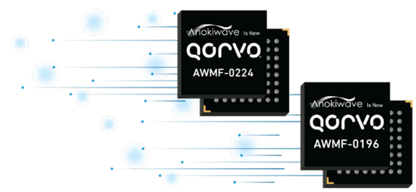
An Integrated Solution

Anokiwave, now Qorvo, recently introduced the industry's first single-chip dual channel IF up/down converter family with fully integrated LO synthesizer, delivering a single-chip multi-band solution that enables network operators to design smaller, lower cost, higher performance 5G radios across the entire 3GPP mmWave frequency range. The new AWMF-0224 is a half-duplex mmWave to IF transceiver covering multiple 5G bands between 24 GHz to 30 GHz, while the corresponding AWMF-0196 covers the higher 37 to 48.2 GHz 5G bands. The ICs integrate the entire mmWave to IF signal chain for 5G radios, including dual up/down converters, driver amplifiers, multipliers and LO synthesizer into a single silicon IC, without compromising performance.

Frequency downconversion is a result of mixing mmWave signals in an RF range with signals from a tunable local oscillator (LO) to create lower frequency IF signals. Frequency upconversion occurs in reverse, with IF signals mixed with LO signals to produce RF signals in the mmWave frequency range. The LO signals can come from an on-chip voltage-controlled oscillator (VCO) teamed with an on-chip phase-locked-loop (PLL) frequency synthesizer or an external LO source feeding the same PLL circuitry.

The frequency-converter/transceiver ICs feature the fast switching between transmit and receive functions (typically 250 ns) needed for time-division-duplex (TDD) operation used in the mmWave 5G frequency bands. The fast-switching speed of the transceiver IC includes tight amplitude control of its many integrated amplifier stages, with typical gain settling time of 50 ns during TDD operation. The broad bandwidth allows the transceiver ICs to operate under 5GNR or 802.11 ac/ax/be waveforms.

Dual Channel IF Transceiver ICs



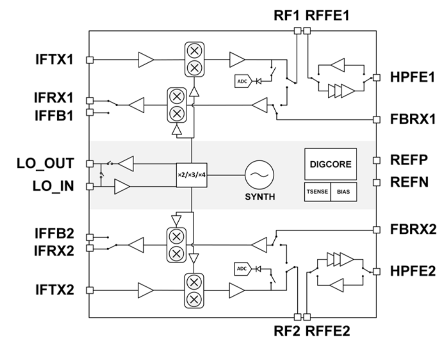
New levels of integration and flexibility

The IF Transceiver, AWMF-0224, integrates functionality of up to 5 ICs into a single IC covering 24 to 30 GHz, while the AWMF-0196 covers the 37 to 48.2 GHz bands with the same levels of integration.

For protection and ease of handling, the IF transceiver ICs are supplied in a flip-chip chip-scale package (FC-CSP). Despite the small size, they pack two channels of frequency upconversion and downconversion, translating input and output signals efficiently, with low loss and wide dynamic range. The packaged ICs contain a host of components on a single semiconductor die, with its integrated VCO and PLL frequency synthesizer at the heart of the circuitry. The internal LO can be bypassed for an external LO signal source used for the mixing, allowing for a great deal of flexibility when configuring and interconnecting small cells within a 5G network.

To minimize damage during handling, the IF transceiver's FC-CSP package includes electrostatic-discharge (ESD) protection on all package pins. The package incorporates thermal compensation to simplify the IC's thermal management and provide thermal protection from internal and external sources of heat. The package's inverted-chip mounting style also simplifies (and shortens) connections to planar antenna layouts to contribute to 5G small cell miniaturization.

Signal energy is difficult to generate and preserve at mmWave frequencies; the transceiver ICs take an active role in minimizing mmWave signal losses and maintaining high dynamic range with well-placed amplifier stages throughout the IC layout. For example, amplifier stages are included within the frequency upconverter/transmit signal paths where integrated driver amplifiers contribute to the gain and output power of transmitter antenna arrays. Implemented with separate components, such amplification is not trivial in terms of size and cost and the addition of mmWave amplification in discrete-component forms can hamper opportunities for miniaturization or for meeting size, weight and power (SWaP) goals in military electronic systems. The generous integration of multiple driver and power amplifier stages serves to overcome path fading and interconnection signal losses such as at antenna to board interfaces.



The half-duplex Transceiver ICs integrate dual Tx single-sideband up-conversion, dual Rx image-reject down-conversion functionality, and an on-chip synthesizer that enables 2T2R applications within a single die.

An on-chip frequency multiplier simplified board-level integration for use with either an internal frequency synthesizer or an external PLL.

Along with its RF, LO and IF amplification stages, the transceiver ICs integrate a LO with several frequency multipliers, a frequency synthesizer and multiple power detectors for monitoring and control, frequency generation and signal routing throughout the IC. For example, RF power detectors for the RF, LO, and IF stages are all designed and checked for their capabilities to characterize 0 dBm signal power with ±1 dB accuracy at their respective test points. Timing can be synchronized with a single-ended or differential reference clock. Noise can be minimized with the aid of a digital-predistortion (DPD) feedback path.

When the integrated LO is activated/enabled, it works with the integrated PLL frequency synthesizer to produce stable, low-phase-noise signals. The internal LO produces about -5 dBm typical output power and is supported in the frequency conversion process by about 12 dB average IF gain, which can be controlled in 0.25 dB steps across a 15 dB IF gain control range. For 5G small cells or network interconnections where an external LO might make more sense, when an external LO source is connected to the IC, the internal LO is disabled, and the external LO signals are fed into the IC's LO port. The transceiver IC's LO multiplexing capability minimizes the need for external switches when operating in multiple-in, multiple-out (MIMO) antenna configurations.

The transceiver ICs are equipped with on-chip LO feedthrough calibration capability from the Digcore to maintain precision frequency, phase and timing during frequency upconversion/downconversion whether within a single 5G small cell or across a portion of a 5G network. With on-chip LO frequency multiplication, the ICs can function with a wide range of external LO sources, ensuring proper operation with the aid of the Digcore calibration process. Multiple transceiver ICs can be synchronized with their integrated PLL synthesizers enabled by using a phase synchronization signal to achieve synchronization. One IC serves as a form of lead signal generator, with its frequency synthesizer enabled and generating LO signals for distribution to the other transceiver ICs.

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The Air Interface

The highly integrated and simplified frequency conversion provided by the IF transceiver family requires an air interface for connection to a 5G wireless network and Qorvo's beamformer ICs (AMWF-0221, or AWMF-0236) provide the perfect fit. They are dual-polarized quad 4 × 2 beamformer ICs that can guide signals to and from the transceiver to multiple antenna elements and form the beams from those elements needed for sending and receiving mmWave 5G signals from base stations and small cells. Using discrete antenna elements or arrays of elements, these beamformer ICs enable the design and development of compact multiple-element antennas that can fit around the outside of those shoebox-sized 5G small cells. As with the IC transceivers, the beamformer ICs are supplied in a rugged FC-CSP package. The packages share many common electrical and mechanical interfaces for ease of interconnection within a larger circuit or system.

The beamformer ICs represent the company's fourth-generation beamforming ICs, built on Anokiwave's (now Qorvo's) proven quad channel, dual polarization CMOS platform, covering the same 3GPP 5G frequency bands as the IF transceiver ICs. The BFICs contain two circuits each with four antenna-element control sections connected by power-combining networks. The circuits are designed to provide tight command of EM beams generated by antenna elements, with 6-bit phase control and 5-bit gain control.

Qorvo's patented Zero-Cal® technology eliminates the need for performing phase or gain calibration on the control circuits. The beamformer ICs also include automatic temperature compensation to correct for the effects of operating temperature on phase and gain. They can form electronically steered antennas with either four dual-polarized or eight single-polarized antenna elements and supports half-duplex transmit/receive operation in conjunction with the TDD operation of the IF transceiver ICs.

The IF Transceiver ICs used in conjunction with the beamformer ICs, allow OEMs build the entire mmWave 5G radio front end with just (2) two IC types, while offering the industry's highest linear power and efficiency.

Together, this family enables a new level of form factor reduction, a single unified design across the mmWave 5G bands in play and industry leading performance than ever seen before.

Conclusion

Together, the transceiver and the beamformer ICs are just two ICs, but they can go a long way to the design and development of 5G small cells that may fade into the background but won't fade in terms of signal strength. Most 5G users don't want to be reminded of the network infrastructure but do want to rely on their 5G service. Qorvo continues its commitment to offer system level solutions to the 5G market to enable mmWave radios with leading performance, smallest form factor, low cost and simpler designs for faster time to market.

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About Anokiwave

In 2024, Anokiwave was acquired by Qorvo. Anokiwave's innovative portfolio of active antenna ICs, combined with Qorvo's complementary products, global scale, and significant market reach, provide new options for high integration and high-performance that will democratize phased array active antennas.

The two companies' technologies enable a unique combination of innovation + commercial scale + reputation to deliver with proven commercial success across mmWave 5G, SATCOM and D&A markets.

- mmW Silicon ICs
- Intelligent Array IC Solutions®
- mmW Algorithms to Antennas®

Industry's Trusted Choice for mmW 5G Systems, Built Green

- Silicon Beamformer ICs
- IF Up/Down Converter ICs
- IF Transceiver ICs
- mmWave Antenna Kits

qorvo.com/Active Antenna Systems

Highest efficiency and linear power ICs

Enabling greener radios for a net-zero emissions future

Multi-band ICs for fewer SKUs

Just 5 total ICs for a complete mmW to IF, including LO, solution for all 5G bands from 24 to 50 GHz

Smallest form factor radios

More than 70% size reduction over 4 generations for ease of deployment

Production assurance

Assured supply to support all mmW 5G market demand

Qorvo is dedicated to enabling OEMs succeed in the mmWave 5G market with key mmWave 5G innovations that provide critical market solutions.