The digital paradigm for test and measurement

A modular solution combining next-generation digital converters and gigabytes of fast memory takes on the task of digital amplifier testing.

By John DeMott and Jim Reeves

Today's power amplifier designers are confronted with new design challenges involving the industry's move to 2.5 G and 3 G systems. The proposed hybrid systems permit service providers to shift to the 3G systems while supporting the existing infrastructure. These systems combine multi-carrier and multi-standard in an effort to reduce system cost, accommodate data services, and expand market penetration.

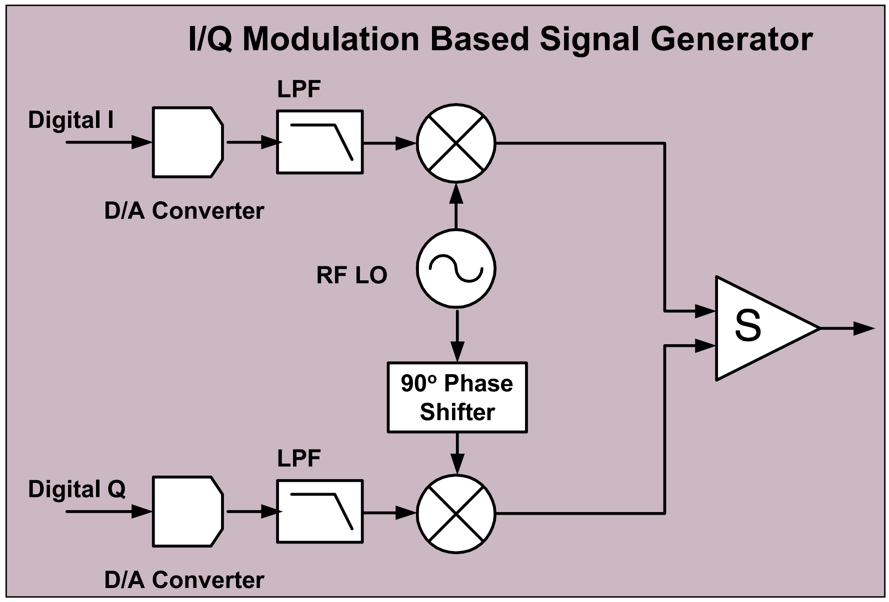

Figure 1. I/Q modulation-based signal generator.

Defining next-generation radios

The software-defined radio (SDR) is the enabling technology driving these changes. Amplifier designers find themselves confronted with the additional challenge of characterizing performance under multiple-carrier and multiple-modulation schemes. This too requires a new paradigm in test and measurement.

To implement SDR as a solution for 3G deployments, amplifiers must be thoroughly characterized in the designer's test lab. To efficiently accomplish this, the latest modular test and measurement configurations must be applied. A modular solution takes advantage of highly linear digital-to-analog (D/A) converters coupled with gigabytes (GB) of solid-state memory and broadband RF up-and down-conversion. This provides for real-world conditions both in the lab and in production test. Using these new test methods, real-world comprehensive cumulative distribution functions (CCDF's) can be simulated; multi-carrier and multi-standard signals can be generated; and spectrally pure signals can be created. New digital linearization techniques can be tested to prove the latest algorithms used to exceed power amplifier performance. The industry's move to these new amplifier designs requires more complex signal test sets with modular adaptability to characterize performance.

Testing the amp

Power amplifiers are typically tested using a signal generator based on an in-phase and quadrature (IQ) modulator. These instruments were initially optimized for single-carrier generation, and have been extended to address the multi-carrier requirements of today. They feature dual D/A converters and analog IQ modulation circuits, waveform memory and adequate capability for single-standard test scenarios. These generators (see Figure 1) inherently have the same limitations that have forced base station designers to

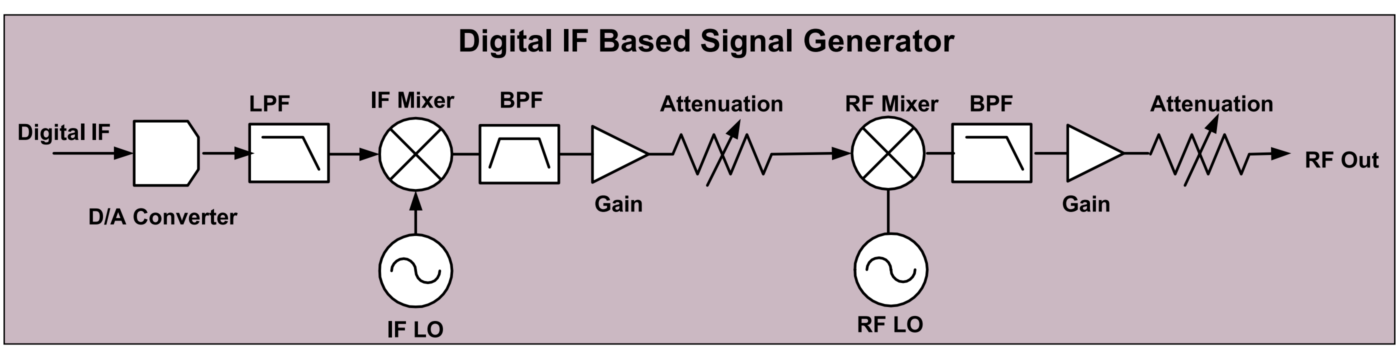

Figure 2. Digital IF-based signal generator.

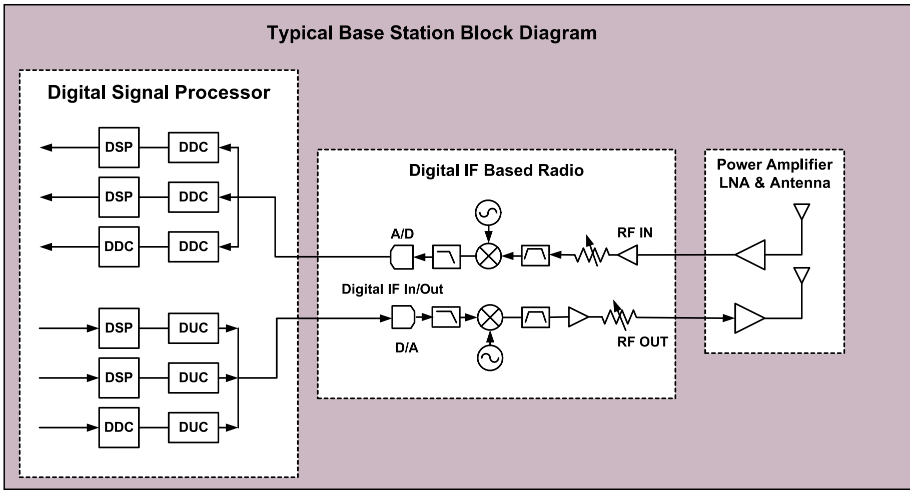

Figure 3. Base station block diagram.

migrate toward the SDR concept.

The IQ architecture is historically susceptible to channel impairments originating in the I and Q baseband sections, phase offsets, amplitude imbalance and DC offset. The IQ architecture becomes particularly difficult to optimize when the multi-carrier spectrum is not symmetric about the RF carrier. These are manual adjustments and signals tend to drift, which requires continual resetting by the operator. All of these impairments produce perturbations on the output and result in less than optimum adjacent carrier power (ACP) measurement. Optimizing the adjacent carrier power ratio (ACPR) performance is key to testing the power amplifier.

The platform

Using the SDR concept as the architectural basis of a vector signal generator, many shortcomings of today's IQ-based generators can be eliminated. This concept makes use of a single D/A converter and an IF to RF up conversion chain (see Figure 2). It also mimics the latest base station architectures. The addition of gigabytes of solid state memory behind the D/A converters permits nearly unlimited flexibility in generating test scenarios. This provides for multi-carrier/multi-standard signal generation, along with the ability to record and play actual field spectral recordings. This hardware, coupled with intuitive "Vector Signal Simulation" software (VSS), allows the test engineer and product developer an endless array of multi-carrier/multi-standard spectrums for evaluation. This VSS software suite enables the designer to develop proprietary algorithms and custom modulation schemes independent of the equipment vendor. Long period simulations can be generated, allowing statistically significant CCDF measurements. Multi-carrier/multi-standard signals can also be generated to test the performance of amplifiers for the latest 2G, 2.5G and 3G base station configurations.

In the current I/Q-based test platform, rejection of the carrier frequency local oscillator (LO) is based on the fidelity of the I/Q modulator. This design demands critical phase/amplitude matching and DC rejection to optimize performance.

It is susceptible to drift, causing spectral and constellation impairments that can severely limit the quality of the test results. This drift is directly related to the statistical variability inherent in any component.

In contrast, the digital IF-based test platform rejects the RF carrier LO by using RF bandpass filtering and optimal selection of frequency offsets between the IF and LO inputs. The digital IF-based test platform eliminates impairments introduced by the I/Q drift (phase, amplitude and DC offset). In the digital IF-based test set, the highest performance is achieved with the fundamental frequency generated in the D/A process. This signal is then up-converted to preserve a high fidelity output. The performance of this new architecture exceeds the currently available equipment by 10dB. It offers unparalleled fidelity in the realm of test flexibility, modularity and signal purity. The digital IF-based concept matches the current base-station architecture for new designs.

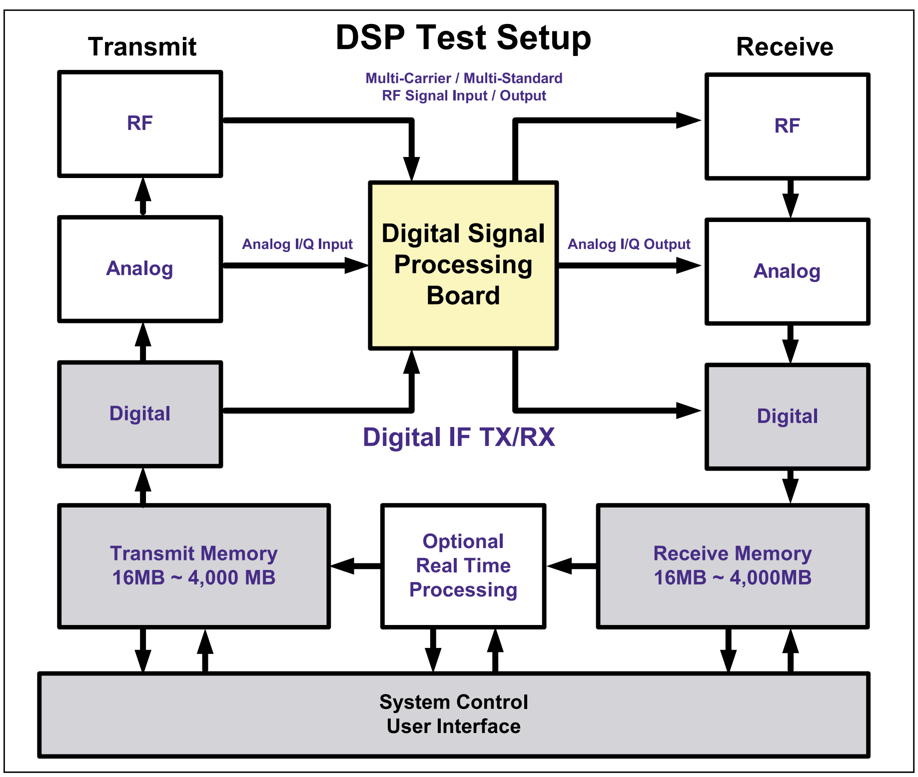

Figure 4. DSP test setup.

The big picture

Extending the capability of the vector signal generator to a full digital radio architecture allows construction of a modular, end-to-end test set that offers both transmit and receive paths for test simulation. This test set incorporates multi-domain testing with the ability to simulate and generate the digital, analog and RF portions of a wireless device. Adding application-oriented software to the hardware permits testing in the logic, time, spectrum, modulation and code domains. This new architecture allows replication of wireless radio functionality with "test equipment grade" performance for lab and production use.

Bidirectional functionality

The ability to simulate both transmit and receive paths in a single test instrument enables radio, digital signal processor and amplifier designers to work in parallel rather than in sequence. The layered sub-assemblies that comprise typical wireless communication infrastructures must be tested as a system at the composite, modular and component level. This can mean significant improvement in time-to-market as design analysis and interface issues surface early in the design process. Figure 3 illustrates a typical base station. The test layout shown in Figures 4, 5 and 6 indicates the various iterations for combined digital, analog or RF generation and analysis. Through the modular interfaces, any single input or output can be implemented through software to provide for unique or typical test scenarios from a single chassis. This traditionally required seven independent pieces of equipment: pattern generator, logic state analyzer, arbitrary waveform generator, deep memory digital storage oscilloscope, signal generator, modulation analyzer and a spectrum analyzer. All of these can be replaced with the digital radio architecture for wireless testing.

Using this modular digital radio approach to wireless test allows the DSP designer to test his code and hardware by having the equipment emulate

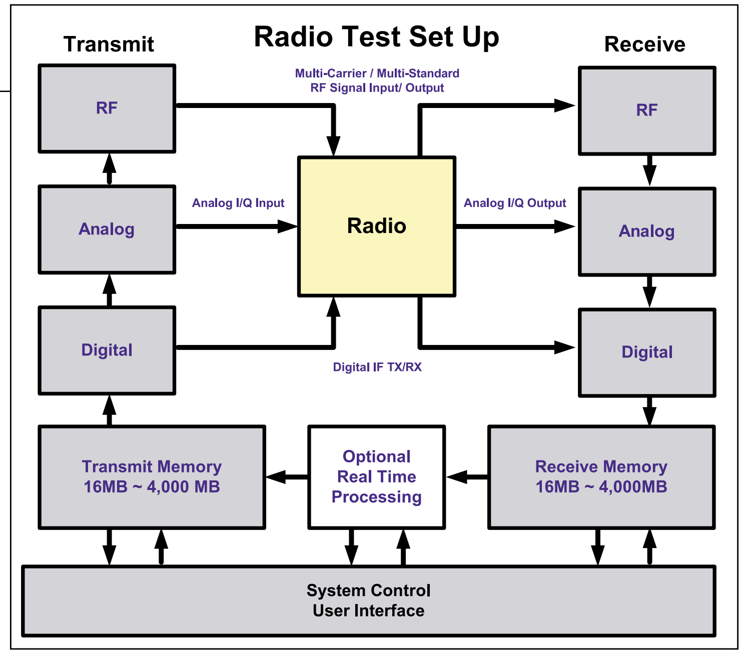

Figure 5. Radio test setup.

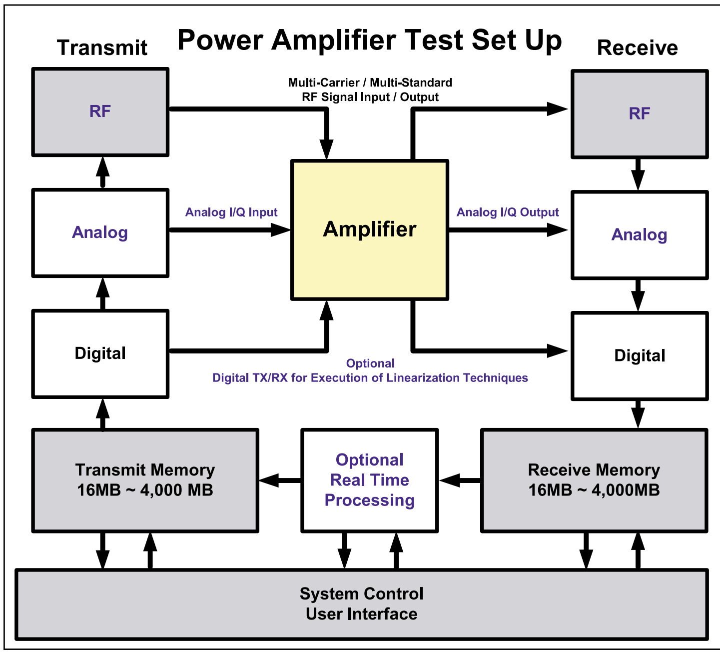

Figure 6. Amplifier test setup

the digital IF transmit-and-receive data streams. The radio designer can have both the channel processors and the RF input simulated. This digital and RF combination allows for the radio, as a module, to be validated independently. The amplifier designer can test designs by simulating the multi-carrier/multi-standard output of the radio. This test signal emulates the broadband spectrum of the proposed 3G systems.

The package

The consolidation of many separate pieces of test equipment into an instrument with ever-higher levels of integration is appealing. There is an immediate demand for an integrated instrument that specifically addresses the needs of the wireless industry. The simulation of both the transmit and receive paths in one instrument is the new paradigm in test and measurement. These tools are just beginning to take their place as industry standards. **RF**

About the authors

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