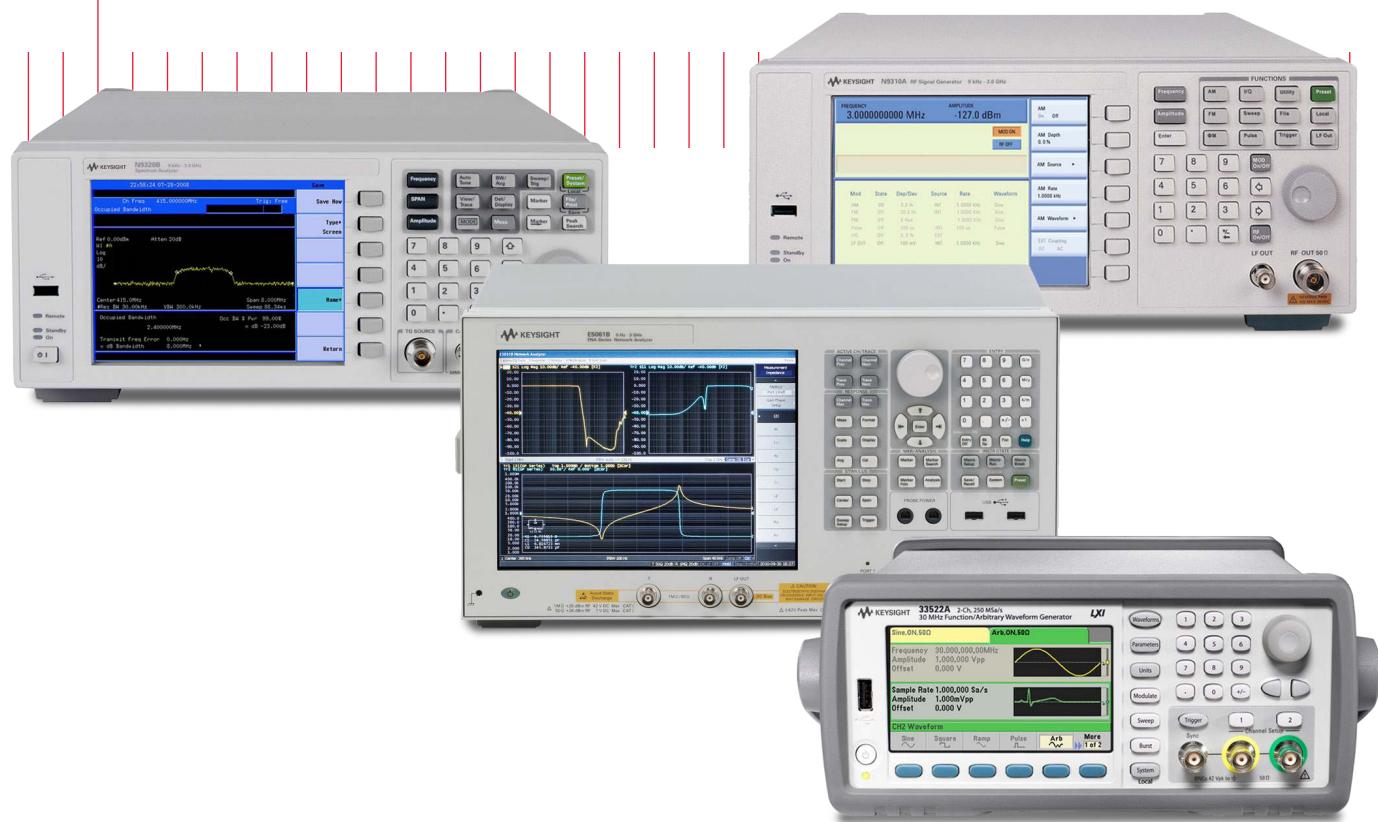


# Keysight Technologies

## Complete Digital RF Design and Test Process Fundamentals



*The demand for ubiquitous wireless communications stresses the physical limitations of modern wireless systems. Such systems must operate in a very limited area of the radio spectrum and cannot interfere with other systems. Rather than employ analog modulation, wireless systems rely on digital modulation and, as a result, are able to realize several significant advantages, including: bandwidth efficiency, superior immunity to noise, low power consumption, privacy, and compatibility with digital data services. These advantages, coupled with advances in digital signal processing and analog-to-digital conversion, have spawned the current migration to digital RF communications formats.*

*The fundamental stages included in the design and test of digital RF systems are outlined below. For each individual stage, the theory behind it is explained, along with its reasoning and a suggestion as to what equipment may be used.*

## Step 1. Generate a Baseband Signal

In this stage, digital bits are transferred onto an RF carrier by varying the carrier's magnitude and phase such that at each data clock transition, the carrier occupies any one of several specific locations on the I versus Q plane. Each location encodes a specific data symbol that consists of one or more data bits (Figure 1a).

**Why?** The quadrature relationship between I and Q signals means they are truly independent. Therefore, while changes of the Q input alter the composite output signal, they do not change the I component at all. Similarly, changes of the I input have no effect on the Q signal.

In digital communications, I-Q modulation puts the encoded digital I and Q baseband information onto the carrier. I-Q modulation receives the I and Q baseband signals as inputs and mixes them with the same local oscillator (LO). These two orthogonal modulated carrier signals are then summed together (Figure 1b). An example of equipment that may be used for this step is the Keysight Technologies, Inc. 33522A Function/Arbitrary Waveform Generator, shown in Figure 1c.

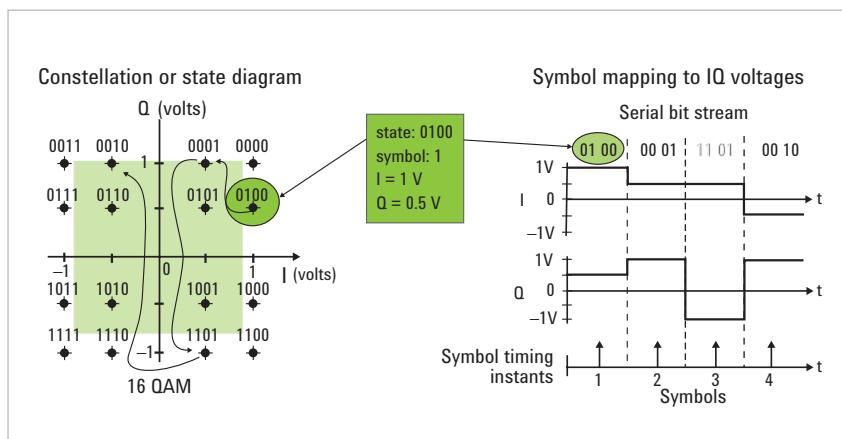


Figure 1a. IQ baseband mapping

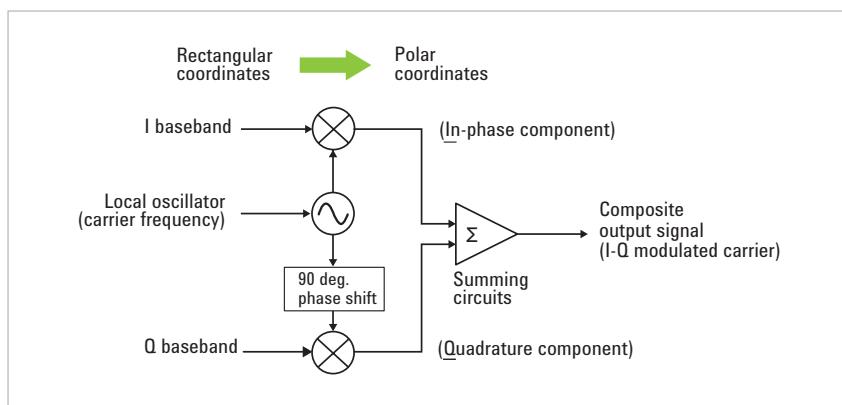


Figure 1b. IQ signal generation



Figure 1c. The Keysight 33522A Function/Arbitrary Waveform Generator is capable of IQ baseband generation

## Calculate Error Vector Magnitude

At any moment in time, the signal's magnitude and phase can be measured. At the same time, a corresponding ideal or "reference" phasor can be calculated, given knowledge of the transmitted data stream. The differences between these two phasors form the basis for error vector magnitude (EVM) measurements.

**Why?** EVM is an ideal measurement tool for troubleshooting communication system problems at the baseband, IF or RF sections of the radio.

## Step 2. Perform RF Modulation

The next stage is to perform RF modulation. Modulation is defined as the amplitude, frequency or phase modification of the carrier in direct proportion to the amplitude of the modulating (baseband) signal. In digital modulation, the baseband modulating signal, and not the modulation process, is in digital form.

**Why?** Communications systems use modulation to superimpose or "piggyback" low-frequency voice or data signals onto an RF wave (high-frequency carrier) that can be transmitted long distances (Figure 2a). An example of equipment that may be used for this step is the Keysight N9310A RF Signal Generator, shown in Figure 2b.

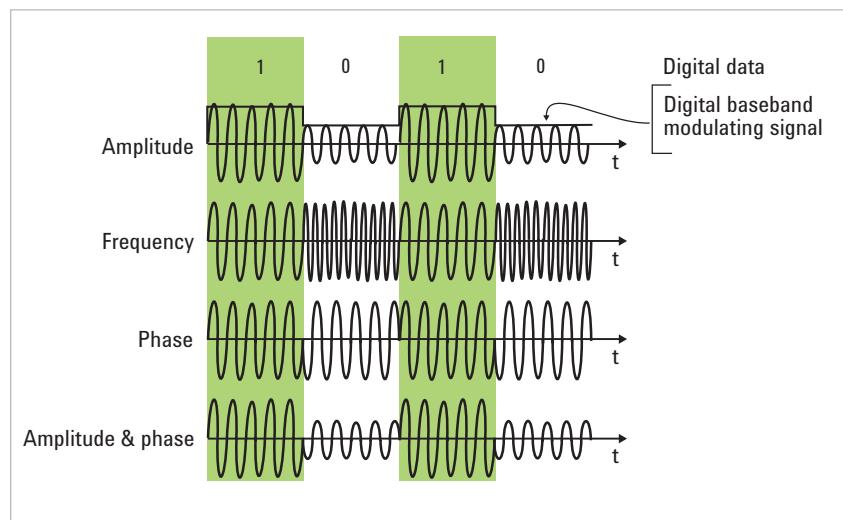


Figure 2a. RF modulation

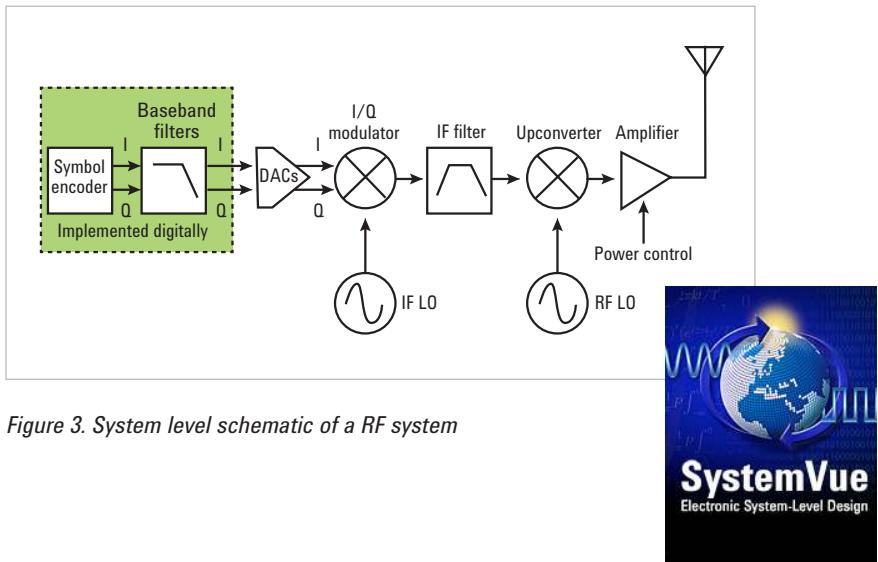


Figure 2b. The Keysight N9310A RF Signal Generator is capable of generating modulating RF signals

## Step 3. Simulate the RF system

During this stage, a “model-based design” workflow with multi-domain modeling for RF and baseband is created. Link-level analysis of Layer 1 systems is also performed, and baseband and RF architectures are linked together with implementation and test.

**Why?** A modular approach to the design environment enables a virtual system to be verified from the first day of a project, beginning with simulation models and gradually incorporating more measurements. An example of equipment that may be used for this step is shown in Figure 3.



## Step 4. Perform Network Analysis to Calculate S-Parameters

At this point, S-parameters must be calculated. Network analysis is the technique used to accomplish that goal. Common network analyzer terminology has the incident wave measured with the R (reference) receiver, the reflected wave measured with the A receiver and the transmitted wave measured with the B receiver. With amplitude and phase information of these three waves, engineers can quantify the reflection and transmission characteristics of their device-under-test (DUT), as shown in Figure 4a.

**Why?** It is hard to measure total voltages and currents at the RF DUTs ports. Also, S-parameters are analytically convenient as they allow for calculations of system performance by cascading individual components. An example of equipment that may be used for this step is the Keysight E5061B ENA Series Network Analyzer, shown in Figure 4b.

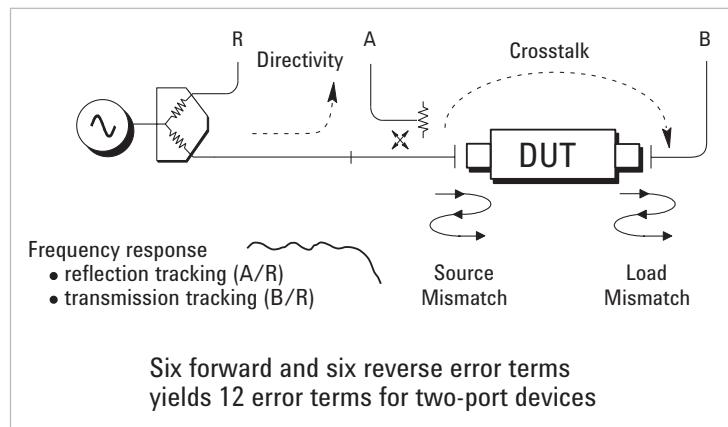


Figure 4a. Direction of a transmitted signal across a DUT

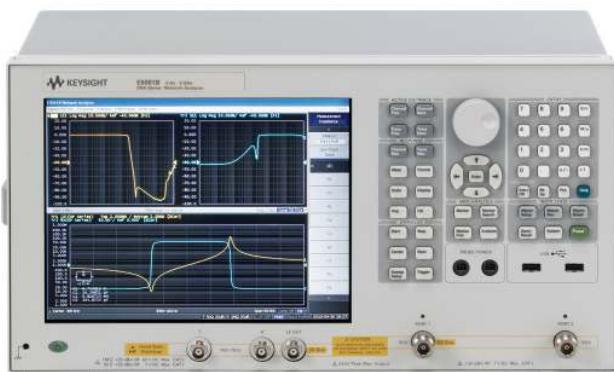


Figure 4b. The Keysight E5061B ENA Series Network Analyzer measures S-parameters

## Step 5. Observe the RF Signal in the Frequency Spectrum

Next, the engineer must observe the RF signal. This can be accomplished with spectrum analysis, the measurement of raw, unprocessed signal information such as voltage, power, period, wave-shape, sidebands, and frequency.

**Why?** Transmitter problems (or impairments) can cause signal power splatter thus, occupying more bandwidth than allowed and causing interference with adjacent channels. Adjacent channel power measurements can be very important in this regard because they tell the engineer how well their device will perform under real-world conditions (Figure 5a). An example of equipment that may be used for this step is the Keysight N9320B RF Spectrum Analyzer, shown in Figure 5b.

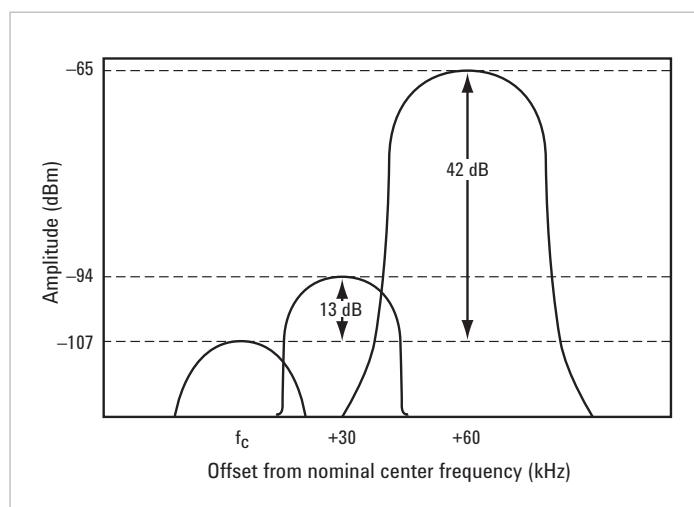


Figure 5a. Adjacent channels in frequency spectrum

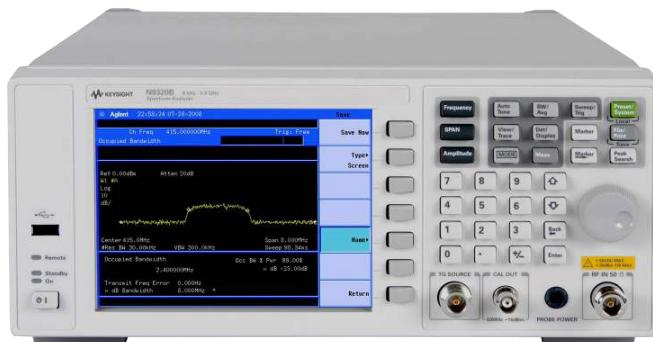


Figure 5b. The Keysight N9320B RF Spectrum Analyzer is capable of measuring power across the frequency spectrum

## Step 6. Perform Electromagnetic Compatibility Tests

The final stage involves performance of electromagnetic compatibility (EMC) tests. Electrical or electronic equipment that uses the public power grid or has the potential for electromagnetic emissions must pass EMC requirements. Conducted emissions testing focuses on signals present on the AC mains, which are generated by the equipment-under-test (EUT). Radiated emissions testing searches for signals being emitted from the EUT through space.

**Why?** EMC tests are conducted to simulate antenna structures and their placement within the EUT, in conjunction with the presence of real-world proximity effects of other devices emitting radiation. An example of equipment that may be used for this step is the Keysight EMPro 3D Electromagnetic Simulation software, shown in Figure 6.

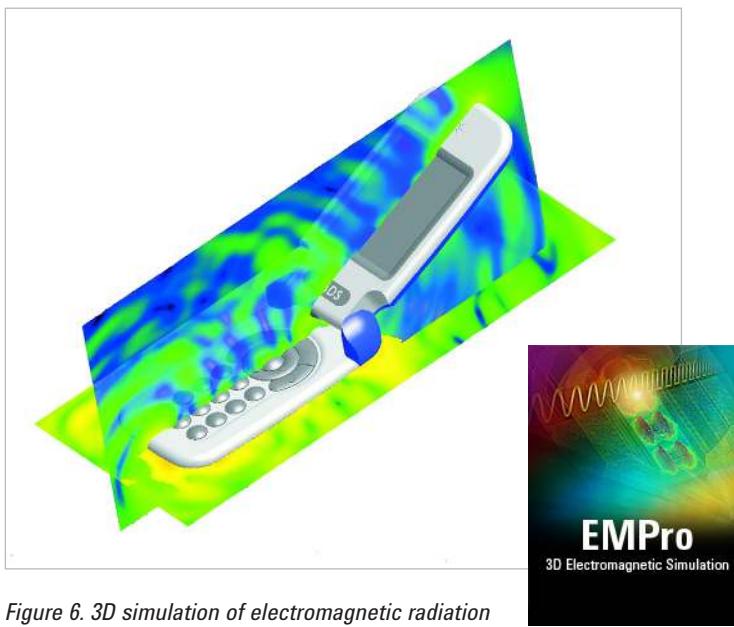


Figure 6. 3D simulation of electromagnetic radiation emitting from a mobile phone

## Summary

As wireless communication signals become more complex, the design and verification techniques must also evolve. It is now crucial for the engineer to understand the intricacies of using a flexible verification and signal processing environment to merge virtual design with real world measurements. An integrated solution of Electronic Design Automation (EDA) and instrumentation not only can accelerate the product development cycle, but also extend the test and EDA capabilities. This knowledge can help the designer to use the appropriate tool in each design stage.

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