RF Signal Generators Face an Expansion in Wireless Communications

Selecting the appropriate signal generator is critical to the success of wireless communications projects.

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The wireless communications world is making demands on the RF signal generator never envisioned a decade ago. It must deliver higher-bandwidth baseband and improved dynamic range, provide more arbitrary waveform-generator memory, and run at greater speed. Some formats require capabilities such as multiple-carrier generation, frequency hopping, fading, and signal impairments such as drift and additive noise.

The past decade has seen an extraordinary expansion in the field of wireless communications technology. This is fueling competition for spectral bandwidth and moves to higher frequencies and faster data rates. These changes necessitate ever more complex and sophisticated wireless terminals, and base stations that are smaller, cheaper, use less power, and cover a smaller area.

Naturally, this wireless expansion challenges those who design wireless products as well as those in manufacturing and quality control. To stretch your test equipment budget as far as possible, and get your wireless products to market as soon as possible, you must carefully examine the testing requirements for your products, and select the most cost-effective equipment, including signal generators. The two principal applications for signal generators in the wireless communications field are component testing and receiver testing.

Component Testing

Components in this context are subassemblies of a transceiver or base station for which full coding is not required, so a spectrally correct signal source is sufficient. These components include preamplifiers, combiners, and high-power amplifiers.

As an example, power amplifiers are complex components requiring a variety of test techniques to confirm their performance. They play an essential role in the wireless communications infrastructure: The growth of digital communications systems has increased the demand for highly efficient linear amplifiers. One metric of power amplifier quality is the absence of nonlinear behavior, which exhibits itself by producing undesirable, spurious products, both in band and out of band. These spurious products are not present in the signal applied at the input to the power amplifier. Nonlinearities in an amplifier cause adjacent-channel interference and reduced spectral efficiency. Testing for distortion caused by nonlinearity helps ensure proper in-band and out-of-band power amplifier operation.

Signal Generator Attributes for Component Testing

A signal generator to be used for component testing must cover the full frequency range of the component, including any out-of-band regions requiring testing. A component cannot output a signal that is cleaner than the one it received, so a signal generator being used for testing a component must produce a signal that is at minimum of higher quality and performance than is specified for that component. If it receives a low-quality signal, the component cannot be proven to maintain a clean signal at the specified performance level. Thus the signal generator must not contribute excessive spurious products, in band or out of band.

Several component measurements need a more complex stimulus than a simple CW frequency. For example, in power amplifiers employed in CDMA (Code Division Multiple Access) service, a CDMA signal is needed for accurately measuring output channel power, occupied bandwidth, and distortion performance. Another requirement is the ability to generate multicarrier and multitone signals, especially for multichannel power amplifiers (MCPAs). For multicarrier applications, the ability to clip signals to control distortion is an important consideration.

For amplifier testing, an RF signal generator is required to simulate statistically correct forward and reverse link signals. It is important that configuring multiple channels and switching between different test configurations are fast and easy. Control over the individual channel parameters is also important, as they contribute to the CCDF or peak-to-average ratio of the signal. Finally, ACPR performance is critical. Modern power amplifiers are approaching the limits of test equipment with their own ACPR performance. Every dB of margin is important to reduce uncertainty in the final product specifications.

Receiver Testing

The requirements for receiver testing are distinct from the component testing requirements in that for most tests a fully coded signal source is required. When testing receivers it is typically necessary to demodulate the arriving signal down to baseband and evaluate the accuracy of the recovered information. This requires that one or more channels be fully coded (interleaving, convolutional encoding, rate matching, and power control), simulating the actual data that would occur in a real-world operating environment.

Several receiver tests are common to most formats. BER is the ratio of the number of erroneous bits to the total number of bits received. A workable solution for measuring BER during the R&D phase is to use a signal generator and a vector signal analyzer. Later in the development cycle, a more efficient solution for testing mobile phones would be a dedicated single-enclosure tester with transmit, receive, and BER capability.

Sensitivity is a measure of the lowest signal level that can be received with an acceptable error rate. It is the most significant in-channel receiver test, as it demonstrates at what signal level the receiver can receive, demodulate, and decode.

Signal Generator Attributes for Receiver Testing

A signal generator for testing receivers should provide the required channels, fully coded to produce a true physical-layer signal. The signal generator should have sufficient DSP processing power to generate the necessary channels at high-enough data rates to generate all standardized test setups. Other valuable features include adequate low-level power accuracy and the ability to provide settable Eb/No and fading simulation.

A signal generator should provide easy channel setup. Many of the wireless formats are very complex and easily misconfigured, so this can have a significant effect on the time required to conduct receiver tests.

Special Requirements for the Different Wireless Formats

Many wireless formats have special characteristics that place extra demands on signal generation for wireless testing. These are described below.

GSM / EDGE

GSM and EDGE have demanding specifications for the envelope of the time slot. For GSM, the amplitude envelope exhibits a dynamic range of greater than 70 dB, yet flatness must vary no more than ±1 dB over the active part of the time slot. This must hold true throughout the 577-ms interval of every time slot.

An EDGE signal exhibits the same spectral characteristics as GSM. However, to achieve its higher data rates, EDGE makes use of both amplitude and phase modulation. The addition of amplitude modulation translates into more stringent requirements for the power amplifier than GSM, as well as a different approach for measuring modulation quality and power.

With the appropriate down converter, the signal generator can perform loopback BER tests of sensitivity. For receiver testing it must create fully coded ETSI-compliant time slots that simulate real-world GSM/EDGE signals. It should also have a fast-switching, full-range attenuator that provides ETSI-compliant alternate-time-slot power-level control up to 130 dB. Another useful feature is the ability to generate mixed EDGE/GSM time slots.

Component testing for GSM/EDGE requires high dynamic range between adjacent channels. The signal generator must be able to generate multi-carrier signals with deep valleys of over 80 dBc between the carriers. It is useful for the signal generator to be able to provide mixed types of carriers.

CDMA

The CDMA system is an example of a wireless format that places heavy demands on an RF signal generator. It is an access method in which many terminals are authorized to transmit simultaneously and in the same frequency band, with each user sequence employing a unique code. The CDMA technique is based upon spread-spectrum modulation, a system in which the transmitted signal occupies a wider bandwidth than the baseband signal. Spread spectrum works by spreading the baseband signal using a specialized code. At the receiver end, the same code, which must be synchronized with the transmitter, is employed to “despread” the received signal so that the original data can be recovered. **Figure 1** shows an example of how this works.

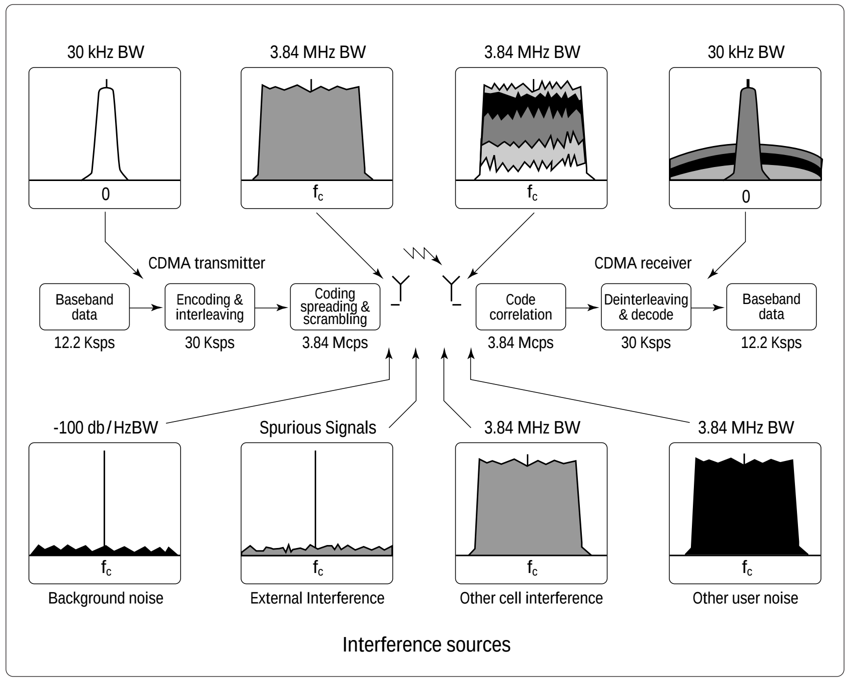

Figure 1. CDMA transmission and reception process

As with other wireless platforms, CDMA receiver tests quantify the performance of a receiver in the presence of degradation in the signal path between the transmitter and the receiver. In CDMA the receiver demodulation process is more complex than in formats that are solely based on TDMA. The base-station receiver must use correlation and descrambling algorithms to receive bits from the signal transmitted by the user equipment (UE). Furthermore, CDMA places unique requirements on the signal stimulus used to make measurements. A real-world CDMA signal is superficially noise-like and can exhibit extreme peak-to-average ratio (or crest factor) variability. Depending upon the data and specific traffic channels selected, a signal with a crest factor of up to 15 dB is possible.

CDMA also has unique timing issues. For any direct-sequence, spread-spectrum radio system to function, all mobiles and base stations must be precisely synchronized. In the IS-95 CDMA system, synchronization is based upon GPS time. Therefore each CDMA base station incorporates a GPS receiver to provide exact timing information for the cell.

The base station sends this information to each mobile via a dedicated coded channel, enabling all radios in the system to maintain near-perfect synchronization.

Therefore precise synchronization is also essential for testing. A valuable characteristic of a signal generator is to provide a frame timing reference (also called the "even-second standard") in addition to a precise reference frequency. Feeding an even-second clock to the base station and test equipment speeds up synchronization, thereby reducing overall test time. **Figure 2** shows the interconnections for CDMA receiver tests.

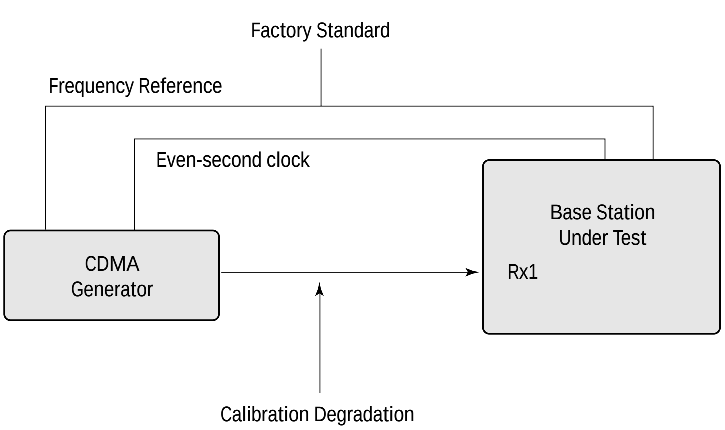

Figure 2. Interconnections for CDMA receiver tests

Another useful signal generator feature is the ability to simulate the interference environment by providing calibrated noise (Eb/No), phase and frequency errors, and interfering signals (CW or modulated).

For component tests, the primary requirement is excellent adjacent-channel power performance. To meet the stringent spectral-regrowth specifications placed upon CDMA amplifiers, the signal generator must not contribute any adjacent-channel interference to the measurement. To test an amplifier under real-world conditions, the signal generator must provide a realistic CDMA signal. A generator that provides a selection of different Walsh-coded channels, power levels, and uncorrelated data is essential for fully characterizing the base-station amplifier.

The specification in IS-97 states that an appropriate signal for emulating real-world CDMA includes one pilot, one synch, and one paging channel, and six traffic channels with specified power levels. Preloaded waveforms speed up CDMA signal generation. For example, the specified nine-channel waveform with pilot, paging, sync, and six channels could be already preloaded into the generator, avoiding unnecessary waiting for a waveform to regenerate. Adequate memory is necessary for storing these preloaded waveforms.

For multicarrier power amplifiers, a generator that offers multicarrier signals or multiple tones provides an excellent test stimulus.

W-CDMA

Testing W-CDMA receivers requires many specialized tests such as verification of demodulation, despreading, control-channel recovery, and TFCI decoding. User control of the variables and parameters for these tests is important. The RF signal generator for W-CDMA should enable user control of parameters such as the TPC, FBI, and pilot fields, and the bit pattern in the data field.

In the 3GPP standard, the important metrics for receiver quality are BER and BLER (block error rate). Therefore, the key requirement is to have fully coded traffic and control channels. It is also useful to be able to generate compressed-mode signals and to simulate discontinuous transmission (DTX). Other valuable features include transmit diversity, fading, and impairments such as calibrated noise (for Eb/No tests).

For W-CDMA component testing, the signal generator must be able to produce statistically correct uplink and downlink W-CDMA signals. It should be possible to select from predefined W-CDMA channel configurations including all the DL test models for transmitter conformance tests. It is also important to produce multicarrier signals for MCPA testing. A signal generator that allows the user to easily configure a W-CDMA signal to meet specific requirements is desirable. Finally, superior adjacent and alternate channel performance (ACLR) in the signal generator is crucial.

CDMA2000

CDMA2000 requirements are similar to those for W-CDMA, but there is no compressed mode or DTX. For receiver testing, it is also essential to be able to generate every required CDMA2000 channel configuration from a single signal source. As with W-CDMA, these channels should be fully coded to permit BER and BLER types of tests.

1xEV

To test a receiver's modulation capabilities, a signal generator with full channel coding is essential to verify that each stage is working properly, and to permit BER tests. 1xEV signals require complex setups that are prone to error. Software with an easy-to-use interface can be a great aid to defining a specific channel configuration. A good set of default values is helpful to get going, with easy adjustment of the specific setup as the need arises.

For component testing, it is useful to generate burst signals, as components such as power amplifiers behave differently under burst conditions than they do with continuous signals.

WLAN IEEE 802.11

In addition to standard signal generator requirements for wireless communications such as mentioned for 1xEV above, essential requirements for IEEE 802.11 are wide I/Q bandwidth and high sample rates, to generate the high data rates required by these standards. Once again, fully coded signals are required for BER testing.

Bluetooth™

As with the other formats, *Bluetooth* testing benefits from ease of setup and the ability to create fully coded signals. You must also be able to generate packets easily and without errors. A wide array of packet types and data sources further expands your testing abilities. To generate the longer (multi-slot) packet data files, there must be sufficient resident RAM.

Another important feature of a signal generator for *Bluetooth* applications is BER testing. The signal generator must have some means of accounting for the delay through the device under test; it is a definite advantage if this can be automated.

Frequency-hopping capability is beneficial for thorough testing, but is required for only one test. You must also be able to create the required signal impairments, such as frequency drift and symbol timing error.

Selecting an RF Signal Generator

In addition to the format-specific requirements described above, you must evaluate a signal generator's total cost of ownership. This includes interoperability with design tools such as Agilent's ADS, MATLAB, Ansoft, Signal Builder, and other third-party tools, a universal programming language (SCPI), the availability of software drivers, and adequate service and support. Another significant aspect of the total cost of ownership is the length of time required to use the signal generator. An instrument that is easy to set up and can quickly switch functions will reduce operating costs. Connectivity to a LAN to share data easily and the ability to move data into Microsoft® applications for test-procedure documentation further reduce the cost of operation. Finally, a signal generator should have provisions for upgrade as new and revised format specifications are issued.

Regardless of the special requirements of each particular format, an RF signal generator for wireless communications testing must provide the spectral environment to simulate the conditions a receiver will encounter when installed. A cellular receiver operating in the real world will receive a cascade of signals, not just an ideal version of the signal of interest. The transmitter with which the receiver is communicating may output a marginal signal, and other carriers along with their out-of-channel power and interference products may all converge on the receiver. RF signal generators play an important role in simulating this chaotic signal environment, so selecting a capable one is critical to the success of your wireless communications projects.

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