How Digitally Generated Faded Signals Reduce Cost of Test

Application Note

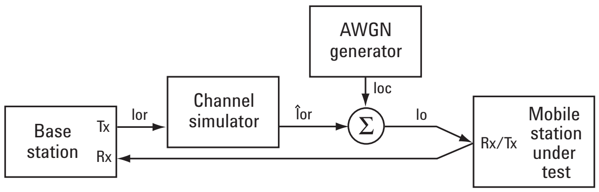
Agilent Technologies

Cost effective testing of wireless devices' receiver performance requires fast, accurate generation of the forward channel signal. Implementation of test processes that instill confidence in device design becomes much more challenging when testing specifies the addition of fading profiles combined with a noise source.

This paper presents an innovative approach to digitally integrating calibrated noise and fading patterns in one piece of test equipment designed to emulate a cellular base station. Performing these functions within the test equipment's baseband circuitry simplifies test setup by eliminating a large portion of the time spent calibrating system level faders. Comparisons with standard fading systems and correlative data will position the Agilent Technologies fading solution as the high performance, low-cost leader in this important test area.

Fading Fundamentals

To understand the advantages of the Agilent Technologies solution it is important to make comparisons with the system level fading solutions. First, let's take a look at the setup specified in the TIA test standard:

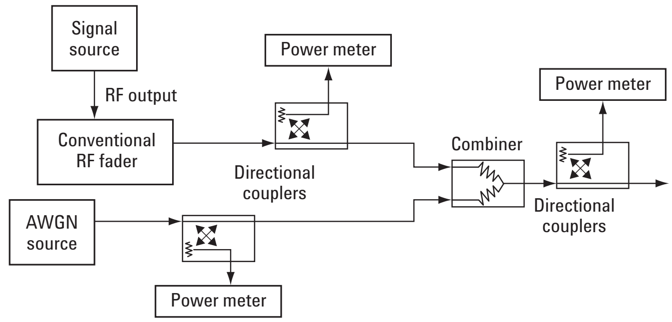


The base station emulator must provide a forward channel with all of the necessary modulation formatting and signaling protocols including code channels with calibrated levels. The channel simulator then adds fading patterns according to user- or standard-defined parameters. Finally, the additive white Gaussian noise (AWGN) generator sums in noise to completely emulate channel conditions under which a mobile station under test may need to operate.

Several fundamental issues must be resolved to provide useful faded signals using this approach.

First, calibrated levels must be transmitted to the mobile station under test. This requires periodic calibration of each transmitter in the system. Calibration routines may need to be performed frequently if the range of measurement levels or frequencies is large or if temperature drift is present. Loss through test system's cabling, couplers, mixers, and connectors must be compensated throughout the test operating range.

To verify that these requirements have been met, power measurements at three stages should be made. These measurements should be repeated for each power level or frequency change. This is illustrated below:



Each setting change can take minutes to measure, adjust, and settle. Consider the time for performing this function multiplied over the length of a fading test plan and the number of devices that can be tested is very limited.

Besides level accuracy, timing issues arise when multiple pieces of test equipment are combined with the goal of working together in a synchronized system. Path delays must be calculated and applied to measurement algorithms so that signal timing offset measurements are not skewed by signal propagation delays.

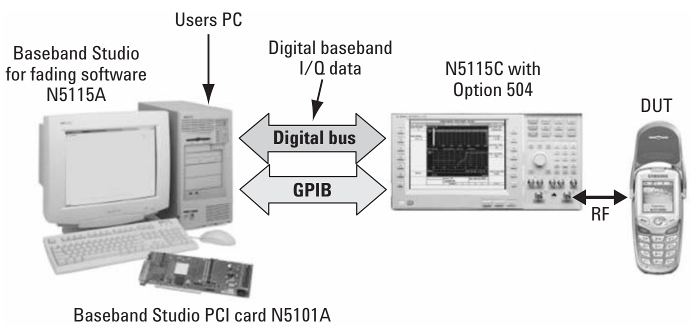
If faded tests are performed under system software control, delays for events like level switching and power meter measurement settling must also be compensated.

Finally, to maintain accurate forward channel modulation (in CDMA this is referred to as rho) there are several areas of concern. For example, quantization errors could degrade signal quality considerably with each A/D conversion. In addition, the crest factor inherent in wideband modulation can contain amplitude excursions that exceed the limits of test equipment. The fading patterns themselves must not cause signal levels that over-stress the output stages, particularly power amplifiers. The wideband signal's crest factor can increase 12 to 18 dB under standard test conditions!

Fading Test Made Easy

The Agilent N5115A Baseband Studio for fading is a powerful channel simulation tool for verifying communications receiver designs, such as cellular phones and PC cards under real-world signal conditions. You can achieve realistic channel simulation by adding multi-path fading or AWGN to a forward or downlink channel base-to-mobile station signal. Through software menus this tool provides preconfigured fading profiles for W-CDMA, cdma2000, and 1xEV-DO, or you can specify fading profiles to meet your test needs.

The complete fading solution is comprised of the Baseband Studio for fading software that runs on a PC equipped with the N5101A Baseband Studio PCI card and the Agilent E5515C wireless Communications Test Set running a firmware lab application. The test set is equipped with an optional digital bus connector that allows the digitized baseband I/Q signal to be routed to the PC for faded signal generation. The faded baseband signal is routed back to the test set and converted to RF to be output to a device under test (DUT.)



The E5515C transmits accurate, repeatable faded channel signals with minimal effort during setup and operation, and it is priced well below most existing solutions on the market.

Level Accuracy

The Agilent Technologies' fading solution does not require external compensation for signal loss through external couplers and mixers because none are required due to the digital signal format. Loss through cabling and connectors to the DUT are compensated by the amplitude offset function built into the test set's system configuration feature set.

The E5515C has standard calibration routines that are performed on regular calibration cycles, usually at six-month intervals or if the internal temperature changes more than 5 °C. The only internal calibration specific to fading with the Agilent solution is a calibration routine that generates calibration factors for a special ALC (automatic level control) mode. This mode disables (opens) the ALC loop. This mode is necessary to prevent the test set's ALC loop from canceling out the amplitude variations that result from fading patterns added to the digital baseband signal. ALC open loop calibration is only required if the internal temperature changes more than 5 °C compared with the temperature during the last calibration.

Timing and Synchronization

All signal routing is performed over a high speed digital bus. Timing delay introduced by the signal path through the PC is compensated for by adding a latency factor. As a result, the modulation presented to the DUT is synchronized with the rear panel clock signal, the same as in the case of unfaded signals.

Fading tests can be fully automated through the GPIB interface on the test set and the fading software's .NET application program interface (API.) The complexity of synchronizing the controller with the test equipment and the test equipment with the device being tested is greatly reduced because only one GPIB interface is involved.

Signal Modulation Quality

Modulation quality is ensured with the Agilent Technologies approach because AWGN is generated digitally, along with the fading patterns. By eliminating unnecessary digital-to-analog conversion, errors that could introduce quantization error are eliminated. One characteristic of wideband signals, which is exacerbated by fading, is the fast change in amplitude, related to the crest factor. This is handled by the fading solution with scale factors that are calculated and applied based on the characteristics of the current test settings.

With analog fading systems, adding AWGN to a faded signal can create problems in setting the desired energy-per-bit to noise power spectral density ratio (Eb/Nt). Traditional faders typically do not include a built-in AWGN generator, resulting in the need to combine two different RF signals to achieve the overall ratio. Baseband Studio for fading seamlessly integrates the signal and noise, eliminating calibration issues associated with traditional fading simulators. The baseband signal from the E5515C is sent to Baseband Studio for fading as a 16-bit digital signal. The multipath fading and AWGN are added to the original baseband data, all in the digital format. The entire channel simulation process remains digital right up to the point where it is up-converted to RF. This results in exceptional Eb/Nt ratio accuracy because the uncertainty associated with adding analog signals has been eliminated.

Conclusion

This paper has shown that system-level fading solutions can be complex in structure, relying on the user to invest significant effort to ensure the system remains accurately calibrated. Even then, the results are subject to numerous variations due to cable, connectors, and temperature drift. Adding to the high cost of individual fading components are the costs of user maintenance, calibration time, and test development time.

The Agilent fading solution, using the 8960 wireless communications test set and N5115A Baseband Studio for fading, provides a much simpler fading solution and delivers the highest level of accuracy, repeatability, and throughput at the lowest price in the industry.

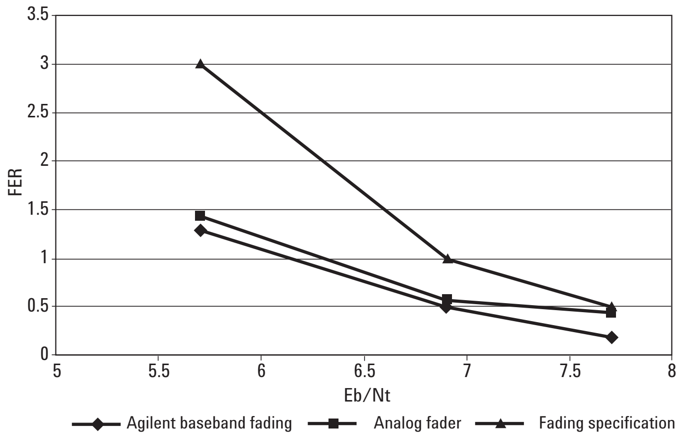
To validate the accuracy of the Agilent Technologies fading solution Wireless Test Services (WTS), a leading CDMA test and certification software corporation, performed faded tests on a CDMA phone with both the analog system level solution and the Agilent Technologies solution.

The correlation data included in this document will provide the confidence needed to select the Agilent fading solution for use in product development through conformance test verification.

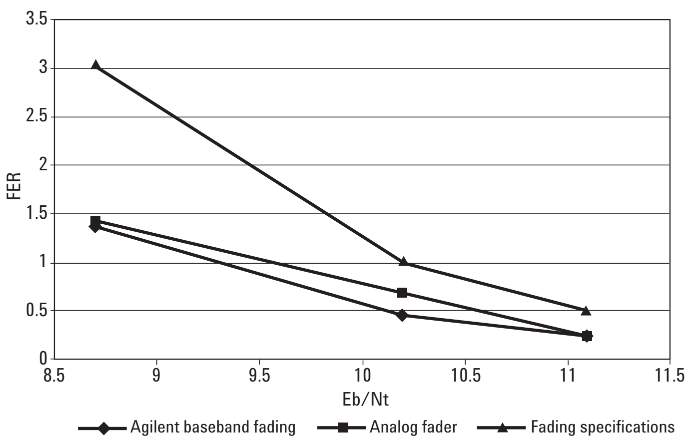
Appendix A

The graphs that follow show 30 kM and 8 kM cases at the PCS and US cellular frequency bands.

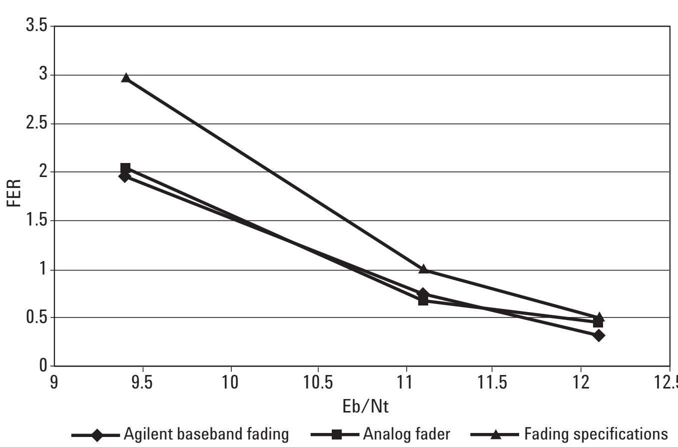
Graph 1: US PCS channel 25 – 8 Km/hr – 2 path fading comparison



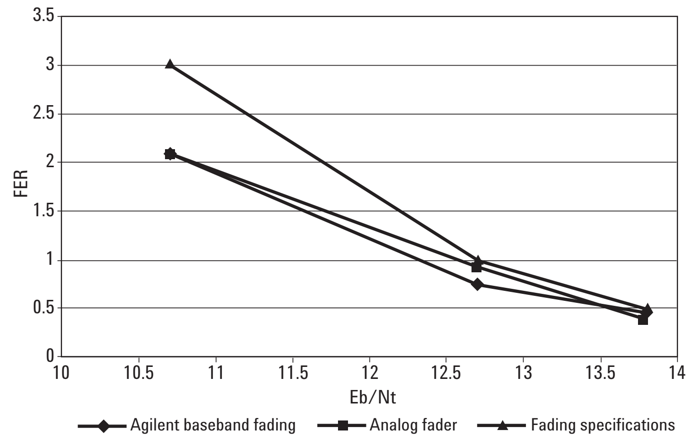
Graph 2: US PCS channel 1175, 30 Km/hr – 1 path – eighth data rate fading comparison



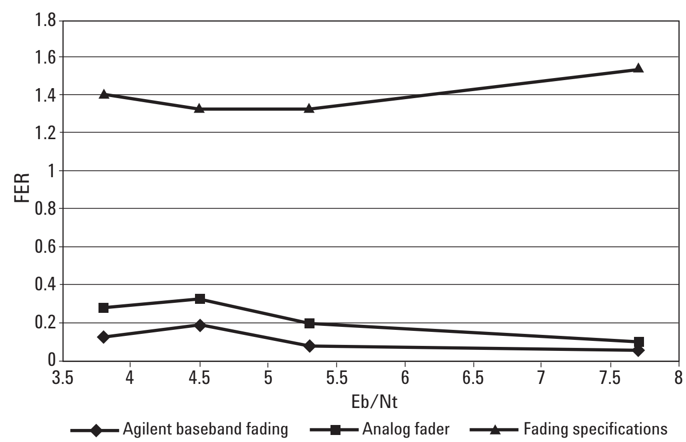
Graph 3: US PCS channel 25 – 30 Km/hr – 1 path – half data rate fading comparison



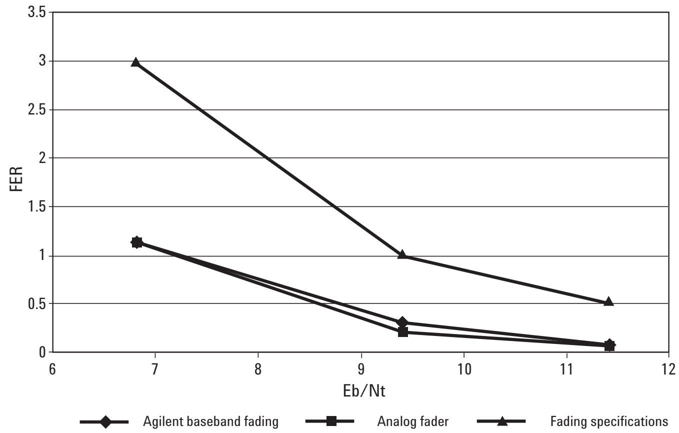
Graph 4: US PCS channel 600 – 30 Km/hr – 1 path – full data rate fading comparison



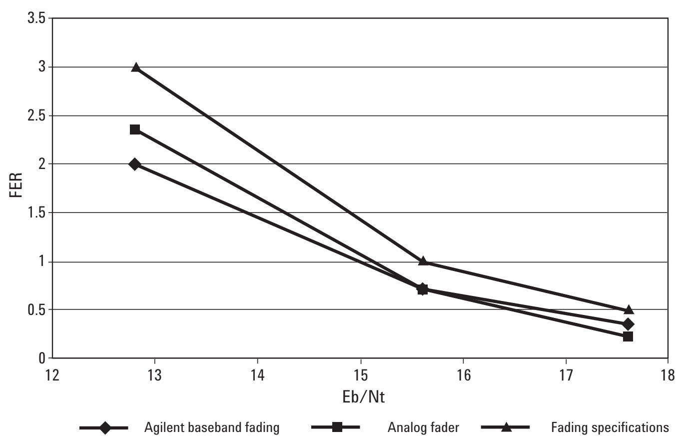
Graph 5: US PCS channel 1175 – 100 Km/hr – 3 path fading comparison



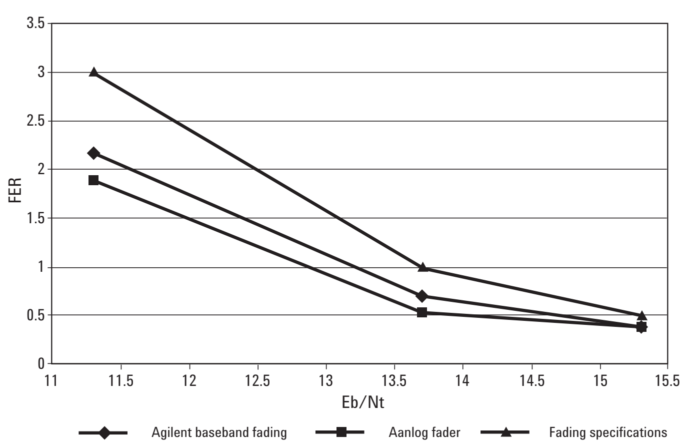
Graph 6: US Cellular channel 384 – 8 Km/hr – 2 path – fading comparison



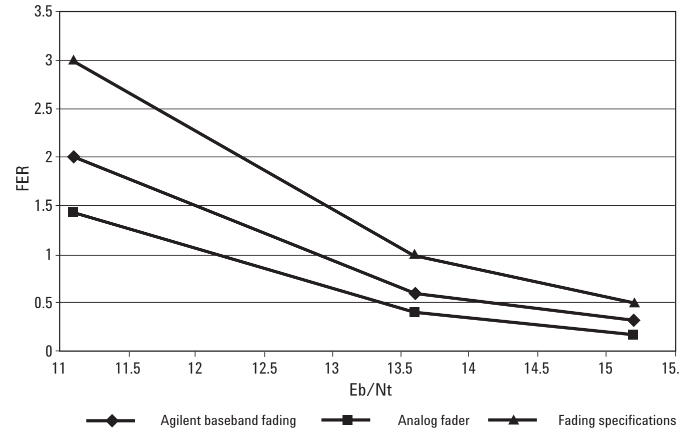
Graph 7: US Cellular channel 384 – 30 Km/hr – 1 path – full data rate fading comparison



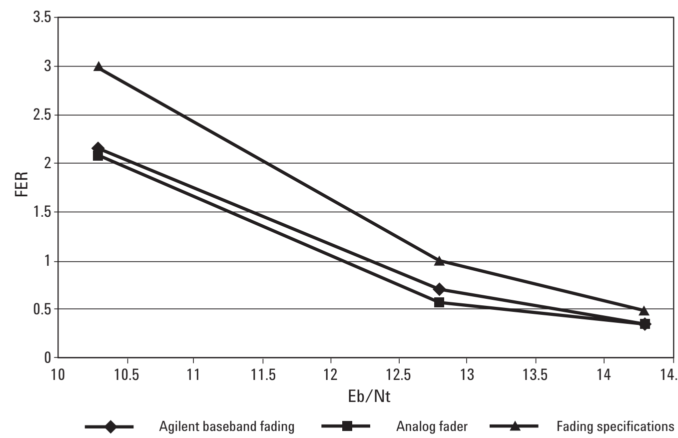
Graph 8: US Cellular channel 384 – 30 Km/hr – 1 path – half data rate fading comparison



Graph 9: US Cellular channel 384 – 30 Km/hr – 1 path – quarter data rate fading comparison



Graph 10: US Cellular channel 1013 – 30 Km/hr – 1 path –eighth data rate fading comparison



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