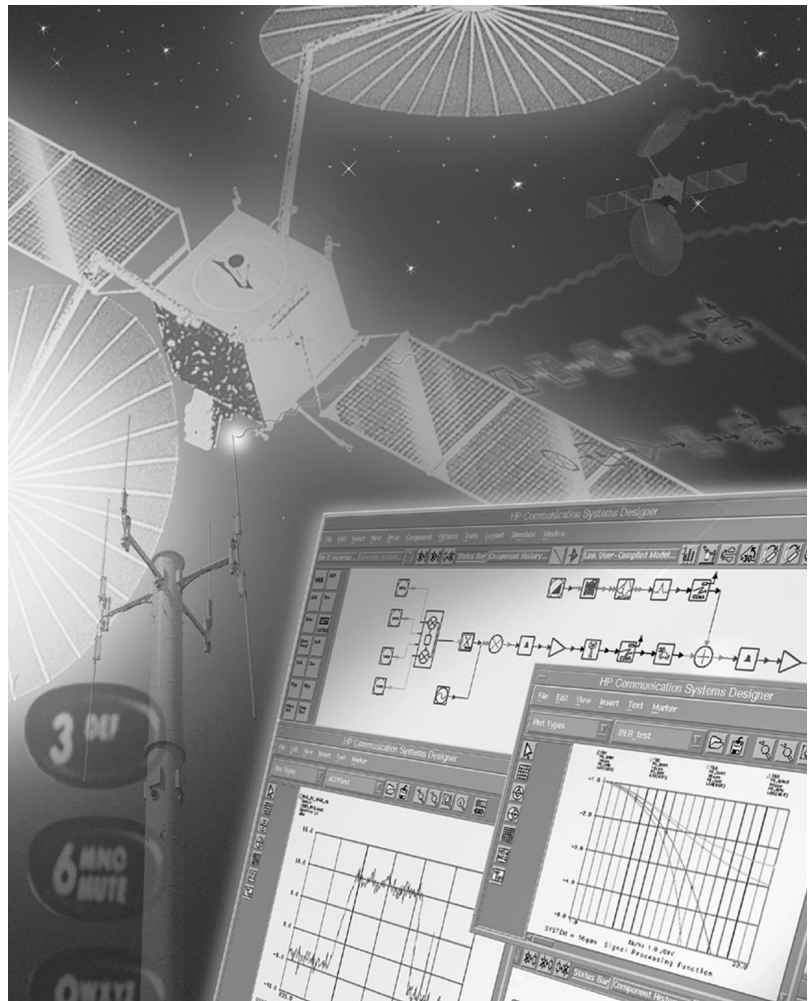




**AN-1298**      **Agilent EEsof EDA**

## Generating Custom, Real-World Waveforms for 3G Wireless Applications



## Introduction

As a system designer, have you ever needed to know the system specification at the input or output of specific components along the design flow, only to be thwarted by the inability to either measure the specification through instrumentation or simulate the specification with software? Suppose, for example, that you have an ACPR specification for the entire transmission chain and you want to know the allowable ACPR specification before the input of the power amplifier. The system has been simulated in software, you know the simulated ACPR up to the input of the power amplifier, and the specific power amplifier has been chosen, but is it the right power amplifier for the system? Before continuing on with the design you want to send the simulated signal, with known ACPR, through the actual power amplifier to measure at the output of the power amplifier this very important specification.

A few years ago, your only option would have been to continue with the design, with no way of knowing whether the system design met the ACPR specification until after the prototype was fully built and measured. Today, it is possible to integrate the testing of partially completed software and hardware designs by combining the signal simulation capabilities of Advanced Design System, EDA software from the Agilent EEsof product group with the signal generation capabilities of the Agilent ESG-D series signal generator.

In our example, the signal is created in Advanced Design System and sent to the arbitrary waveform generators of the ESG-D to create a real-world signal for input into the power amplifier. The ACPR is then measured with a vector signal analyzer such as the Agilent 89440 Series Vector Signal Analyzer (VSA). If the ACPR specification is not met, then the parameters or system components in the transmission chain can be changed to alter the ACPR of the signal at the input of the power amplifier. Or, as alternatives, a power amplifier with different ACPR characteristics can be selected or the power amplifier itself can be modified.

Using our example, other types of system specifications could also be measured, such as Error Vector Magnitude (EVM), Bit Error Rates (BER), and Frame Error Rates (FER) on the receiving chain, and also spur analysis. The signal created by Advanced Design System can also include real-world impairments such as multiple scattering noise, IQ offset errors, filter group delay, and multipath fading. Using the same signal in the simulation and on the actual hardware component removes the uncertainties associated with correlating measured and modeled results.

Another challenge facing RF and DSP system designers at the forefront of technology is to be able to create the needed signal formats and modulation schemes for tomorrow's standards. Advanced Design System can interface with ESG-D to create custom test signals. Linking electronic design automation (EDA) tools with measurement equipment decreases the time needed to evaluate and troubleshoot the system. This link between the design environment (ADS) and test and measurement environment (ESG-D and VSA) bridges the gap between conceptual design and prototype/test phases.

The Advanced Design System/ESG-D link, when used with Design Libraries from Agilent EEsof EDA, such as W-CDMA, GSM, or cdma-2000-compliant, can greatly reduce your system design time.

Features include:

- Enabling subsystem evaluation prior to system completion
- Allowing measured data to be used in system simulation serving as flexible waveform generators
- Allowing complex and real-world signals to be generated or used in simulation
- Providing precise frequency and level control with modulation using the HP ESG-D
- Creating signals with real-world impairments such as multipath fading and noise.

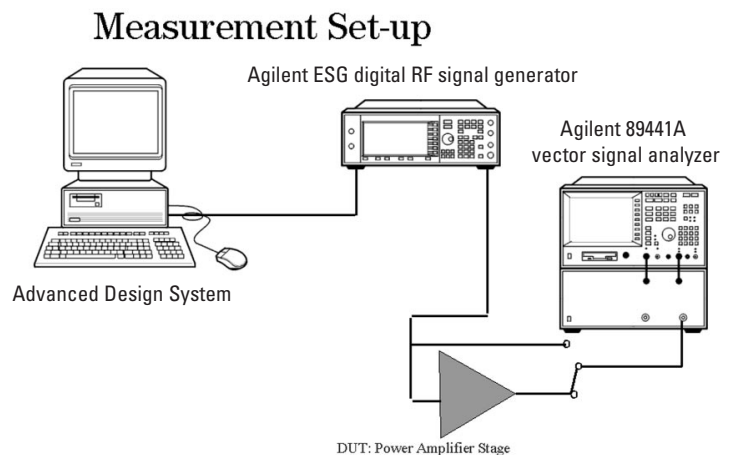
This product note describes software and hardware requirements and how they should be configured for a successful link.

These sections include:

- An overview of the basic structure of the ADS to ESG-D link
- An introduction to Advanced Design System and the ESG-D interface component
- An introduction to the ESG-D signal generator capabilities
- An example of W-CDMA and cdma2000 signal generation
- A configuration guide for software and hardware components
- A list of related literature

### Basic Structure of Advanced Design System ESG-D Link

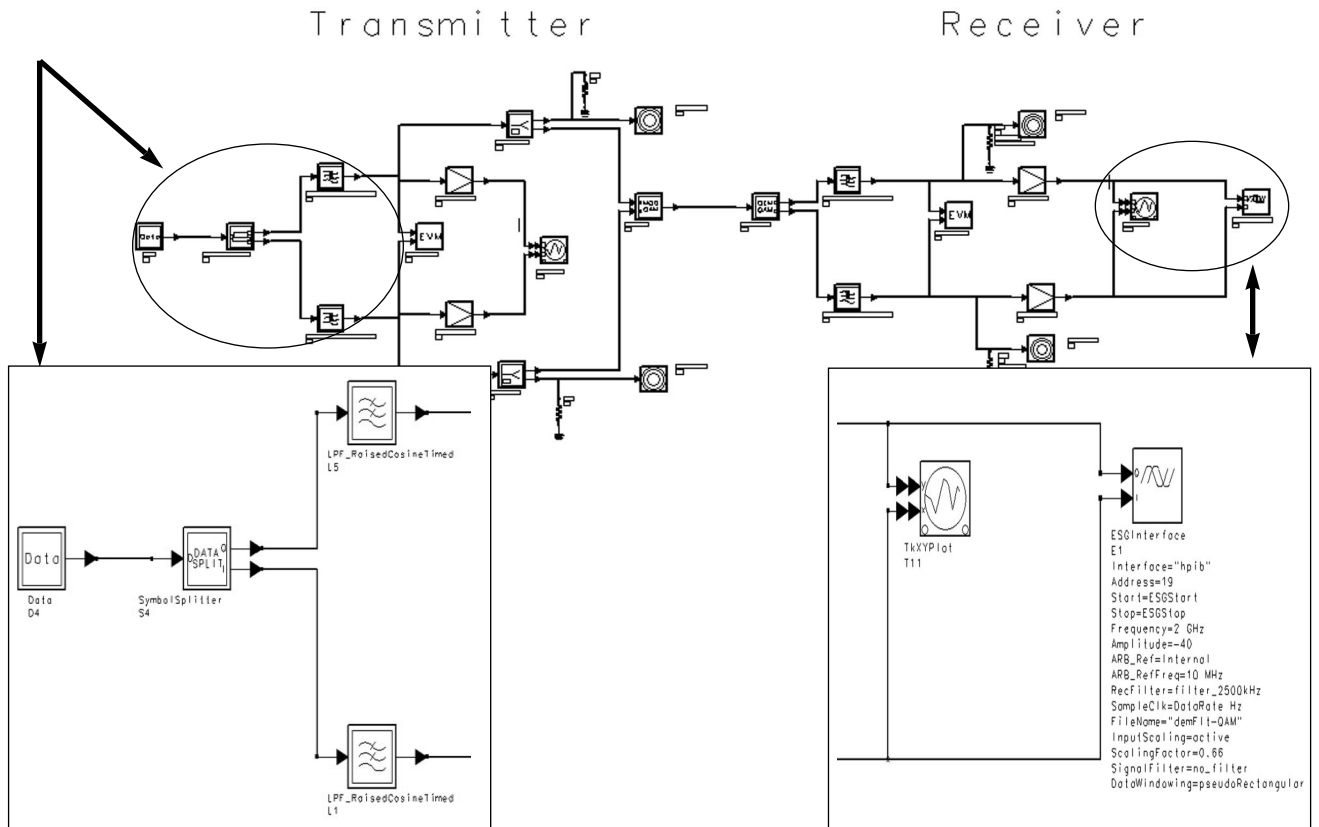
As shown in Figure 1, the data generated by an Advanced Design System simulation is transmitted to the ESG-D through an HPIB interface. By using the arbitrary waveform generator in the Agilent ESG-D Signal Generator, the analog I and Q waveforms of the simulated signal (modulated to radio frequency) are generated. The RF signal can be put into the prototype amplifier stage first, or measured by the HP89441A Vector Signal Analyzer directly.



## Advanced Design System System Basics

This section describes some basics about Advanced Design System that are relevant to the ESG-D interface. Figure 2 shows the schematic of a Quadrature Amplitude Modulation QAM, scheme. The I and Q bit streams are transmitted through a 990 MHz modulator and demodulator. The demodulated/received signal at the demodulator output is automatically downloaded to the ESG-D instrument immediately after the ESGInterface component has collected all the required data. The transmitted signal at the modulator input could also have been downloaded to the ESG-D instrument. The ESGInterface component will collect the desired segment of a time domain signal, download the time-limited simulation data to the ESG-D instrument, and set all the necessary controls and parameters of the ESG-D instrument. Some important component parameters on the ESGInterface component include:

- DataRate, to set the desired data transmission rate
- NsamplesPerInputSym, to set the number of simulation points per input symbol
- Tstep to set the simulation time step



## Using the ESG-D in the Schematic

As the Dual Arbitrary Waveform Generator module of the ESG accepts only a finite number of data points, the downloaded signal becomes a time-limited signal. In general, a time-limited signal cannot be bandlimited. There will always be frequency spectrum overlap between repeating frequency spectrum sections of the sampled version of the original time-limited time-domain signal. Even with the use of an ideal lowpass filter, some unwanted high-frequency components, of aliasing errors, will be present in the reproduced physical signal.

This effect can be minimized by using a Repeat component (NumTimes=3) in front of the ESG to provide end-point signal continuity (see Figure 3). The filtered and downloaded data to the ESG is the middle third of the generated data. The ESGInterface Start parameter must also consider the filter length (number of taps and interpolation or decimation parameters) so that only the steady-state filter output is taken by ESGInterface.



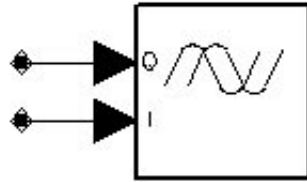
For example, in Wideband Code Division Multiple Access (W-CDMA) with a chip rate of 3.84 MHz and 10 msec of information (one traffic frame) of interest, the Repeat component output is connected to a FIR filter that has 200taps with an upsample and interpolation value of 4. The FIR filter output is connected to the ESGInterface component.

$$\text{BlockSize of Repeat} = (2.84 \text{ x MHz}) \times (10 \text{ msec}) = 38400 \text{ samples}$$

$$\begin{aligned} \text{Start of ESGInterface} \\ &= \text{Interpolation of FIR} \times (\text{BlockSize of Repeat} + \#\text{FIR taps} + 1) \\ &= 4 \times (38400 + 200 + 1) = 154404 \end{aligned}$$

$$\begin{aligned} \text{Stop of ESGInterface} \\ &= 2 \times \text{Interpolation of FIR} \times (\text{BlockSize of Repeat} + \#\text{FIR taps} + 1) \\ &= 2 \times 4 \times (38400 + 200 + 1) = 308808 \end{aligned}$$

**Electronic Signal  
Generator Interface  
ESGInterface**



ESGInterface  
E 1

**Parameters:**

Interface	=	name of HPIB / GPIB interface or IP address
Address	=	address of ESG on interface
Start	=	sample to start waveform recording specify when to start and stop data collection. The number of samples collected, Stop - Start + 1, must be in the range 16 to 1,048,576. The ESG requires an even number of samples; the last sample will be discarded if Stop - Start + 1 is odd.
Stop	=	sample to stop waveform recording
Frequency	=	RF output frequency
Amplitude	=	RF output power level
ARB_Ref	=	waveform clock reference option: The ARB_Ref parameter specifies an internal or external reference for the ESG clock generator. If set to External, the ARB_RefFreq parameter sets the frequency of this clock. Acceptable values range from 250 kHz to 20 MHz. Internal or External
ARB_RefFreq	=	reference frequency for the external clock generator
RecFilter	=	reconstruction filter between DAC output and ESG output: through (no filtering), filter_250kHz, filter_2500kHz, filter_8MHz. The RecFilter parameter specifies the cutoff frequency for the reconstruction filter that lies between the DAC output and the Dual Arbitrary Waveform Generator output inside the ESG.
SampleClk	=	sample clock rate for sequencer and DAC converter range from 1 Hz to 40 MHz.
FileName	=	waveform file name to be stored in ESG
InputScaling	=	specifies whether to scale inputs. If set to active, inputs are scaled to +/- ScalingFactor; if set to inactive, any data with an absolute magnitude larger than 1V will be interpreted as 1V. In general, use only a fraction of the full scale (set ScalingFactor <<1V) for better adjacent channel power ratio performance. Driving the I/Q modulator of the Dual Arbitrary Waveform Generator at the 1V maximum level can cause non-linear distortion leading to spectral regrowth.
ScalingFactor	=	input scaling factor
SignalFilter	=	parameter is used to select a root raised cosine filter that will filter data before it is sent to the ESG. The filter options are for W-CDMA signals at specified chip rates and include compensation for appropriate ESG reconstruction filter and D/A sin(x)/x roll-off. The WCDMA 4096 MHz Chiprate option is for signals that have a chip rate of 4096 MHz and 4 samples per symbol. The internal FIR filter has 200 tap coefficients. Set the RecFilter option to 2500 kHz when using this filter. The WCDMA 8192 MHz Chiprate option is for signals that have a chip rate of 8192 MHz and 4 samples per symbol. The internal FIR filter has 112 tap coefficients. Set the RecFilter option to 8 MHz when using this filter. The WCDMA 16384 MHz Chiprate option is for signals that have a chiprate of 16384 MHz and 2 samples per symbol. The internal FIR filter has 64 tap coefficients. Set the RecFilter option to 8 MHz when using this filter. The ESG can sense when the signal has less than 4 samples per symbol and apply sin(x)/x compensation for the D/A automatically. These tap coefficients thus do not include this compensation.
DataWindowing	=	type of input windowing: Hamming, pseudoRectangular, threePtAverage, Hann, or Blackman
EventMarkers	=	The EventMarkers parameter specifies which ESG Event markers are enabled: Event1, Event2, Both, or Neither. Event markers are useful for synchronizing other instruments to the ESG. Refer to the HPESG-D Series Options UND and UN5 Signal Generators manual, Chapter 2, for more information.
ARB_On	=	turn ESG on immediately after data is downloaded:manual or automatic
<b>Range of Usage:</b>		16 < Stop - Start + 1 > 1,048,576 (or less, if limited by available RAM in ESG) 250 kHz < ARB_RefFreq > 20 MHz 1 Hz < SampleClk <= 40 MHz ScalingFactor > 1

**Inputs:**

I	=	I (real) part of a quadrature input (signal type: floating point)
Q	=	Q (imaginary) part of a quadrature input (signal type: floating point) I and Q must be of equal length.

## Agilent ESG-D Series Signal Generator Basics

The Agilent ESG-D Series of RF signal generators with option UND, dual arbitrary waveform generator, provides extremely flexible baseband generation for the most complex RF waveforms. With the capability to drive the ESG-D's I/Q modulator, the internal dual arbitrary waveform generator provides the power to simulate complex, nonstandard or proprietary modulated RF signals. These modulated waveforms are easily generated with Advanced Design System software.

The ESG-D series with Option UND provides users the flexibility to create completely arbitrary I/Q waveforms. Using ADS to generate I and Q waveforms externally, the ESG-D can be expanded to include the following applications:

- Simulating digitally modulated signals with up to 20 MHz bandwidth
- Generating two or more CW tones with one HP ESG-D
- Generating multichannel and multicarrier signals such as orthogonal frequency division multiplexing (OFDM).
- Generating a signal that includes noise or other impairments
- Creating multiple modulated RF carriers, such as mixed NADC and CDMA carriers for base-station amplifier testing

### **Example 1** **Multi-Channel with** **Fading Channel in Forward** **Link** **Example Design Name:** **MultiChannel\_fading.dsn** **Features:**

- Dedicated physical channels (DTCH) with multiple symbol rate
- Perch channel
- Soft quadrature phase shift keying (QPSK) modulation
- Orthogonal multiple spreading factors (SF) codes in forward link
- Long random sequence with chip rate of 4.096 Mcps
- Radio frequency (RF) with 2 GHz in PCS band
- W-CDMA spectrum with bandwidth of 5MHz
- FIR filter designed by HP Microwave Instrument Division used in transmission
- Signal wrapped around before transmission
- Power of each channel adjusted independently
- An IMT2000 channel is applied after the transmit filter

### **Description**

This example generates the W-CDMA transmitting signal with bandwidth of 5MHz at carrier frequency band of 2 GHz for code domain measurement in W-CDMA-ESG link testing. The design itself generates the multi-channel W-CDMA transmitting signal passing a fading channel. By using this fading signal, performance of the mobile receiver can be tested. The fading of the signal envelope is a Raleigh distribution fading type. The Doppler spectrum and multi-paths propagation are also included. The path loss due to the distance between base station and mobile station is not included in the characteristic of the channel.

The 29 code channels include:

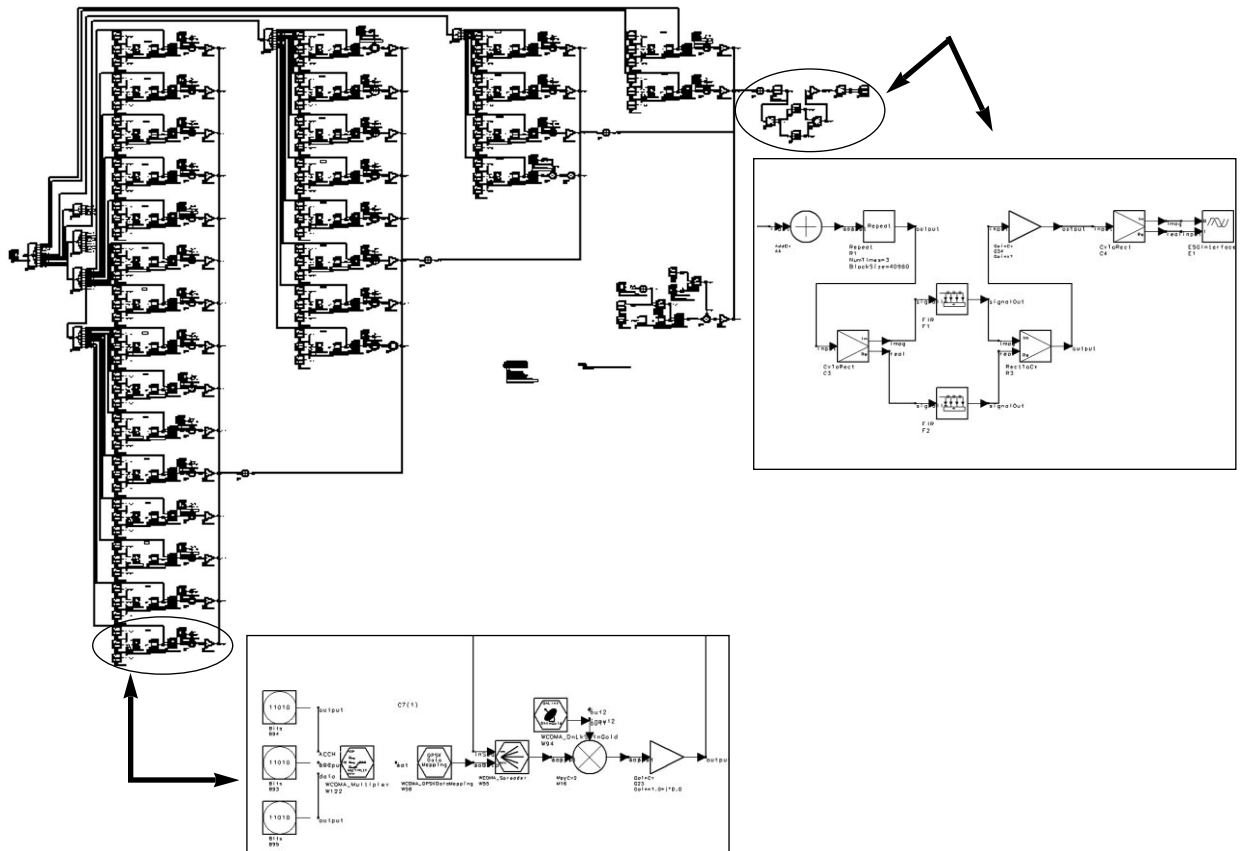
- A Perch channel spread with short code C8(0)
- Fifteen 32ksps dedicated physical channels (DTCH) spread with short codes C7(1) to C7(15)
- Eight 64ksps DTCHs spread with code C6(16) to C6(23)
- Four 12 ksps DTCHs spread with code C5(16) to C5(19) and two 256ksps DTCHs spread with code C4(12) and C4(13)

None of the 29 DTCHs consist of channel encoder. Random bit stream source components are used as the framed and channel-coded data.

The output of bit source is multiplexed with the fast transmit power control (TPC) bits before being transformed into a soft QPSK modulation. Then an orthogonal multiple spreading factor code sequence and a single long random scrambling code sequence are applied to spread the narrow band of digital signal into the wide band of digital signals. Spread signals from all channels are combined after being amplified with power amplifiers. The Wrap Around method is used. That is, the combined signal is repeated three times in the length of a frame to make the phase between the first chip of a frame and the last one consecutive. The signal of the second (middle) frame is generated after going through a transmission filter.

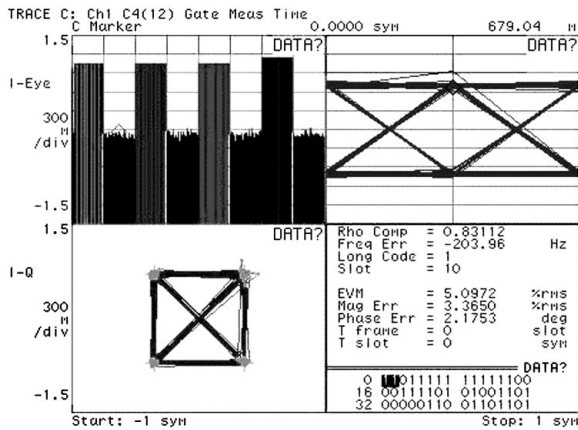
There are two transmission filters applied. One is a square root raised cosine filter with factor of 0.22 and the other is an FIR filter. The FIR filter is designed by Agilent Technologies. The coefficients are stored in a data file called fir.txt. Since all code channels are of one base station, a unique long code is used. The index of the long code is defined in the variable of Longcode.

This example can also generate the multi-channel W-CDMA transmitting signal passing a fading channel. By using this fading signal, performance of the mobile receiver can be tested. The fading of the signal envelope is a Raleigh distribution fading type. The Doppler spectrum and multi-paths propagation are also included. The path loss due to the distance between base station and mobile station is not included in the characteristic of the channel.



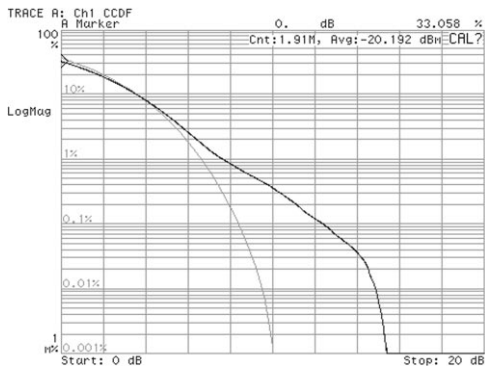


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### Complementary Cumulative Distribution Function (CCDF)

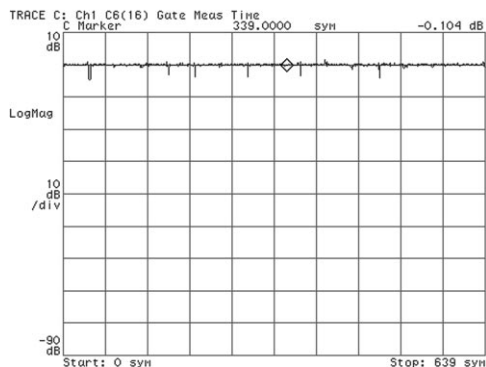
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The left curve is CCDF of white Gaussian noise signal; the right curve is that of W-CDMA without channel coding. Theoretically, the Peak-To-Average ratio of W-CDMA signal is greater than that of white Gaussian noise signal.

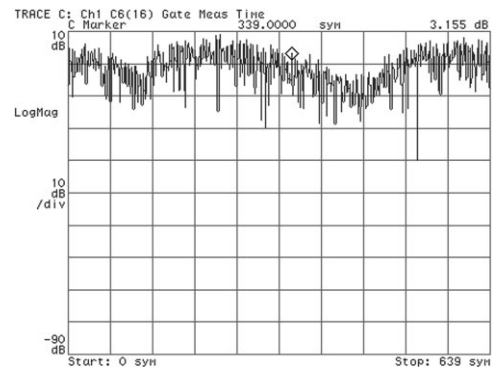
### Time Domain Power

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This figure shows the time domain power of signal before the fading channel.

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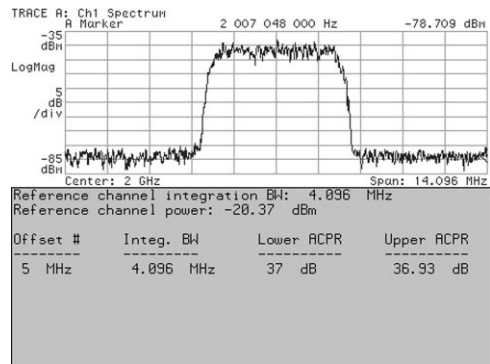


This figure shows the time domain power of the fading signal.

### The graphic outputs are:

- **Code Domain Power** (upper left grid)  
The powers of code channel C7(1) to C7(15) (first bar at the left); C6(16) to C6(23) (second bar from the left); and C5(16) to C5(19) (third bar from the left) are -15 dB.  
The power of C8(0) is -18 dB, which is exactly 3 dB below the power of other code channels. The powers of C4(12) and C4(13) are -12 dB, which is exactly 3 dB greater than other code channels.  
The power of interference is -50 dB
- **Eye Diagram** (upper right grid)
- **I-Q diagram** (lower left grid)  
The dots at each corner are the de-spread and normalized symbols. The crosses at each corner are QPSK modulation ideal points. The lines are the symbol traces.
- **EVM** (lower right grid)  
The value of EVM is 5%, which is reasonable.

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Adjacent Channel Power Ratio (ACPR).  
The spectrum and test result of ACPR.

## Example 2

### Five channels in Reverse Link without Channel Coding

Design Name:

EsgCDMA\_RevSR1Hpsk.dsn

Features:

- 5 channels (Pilot, Fundamental, Supplemental1, Supplemental2 and Dedicated Control channels)
- Orthogonal Walsh code spreading
- HPSK modulation
- Masked long PN code used to distinguish mobiles
- FIR filters for SR1 and SR3 respectively according to cdma2000 standard

### Description

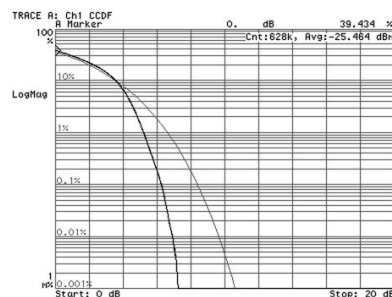
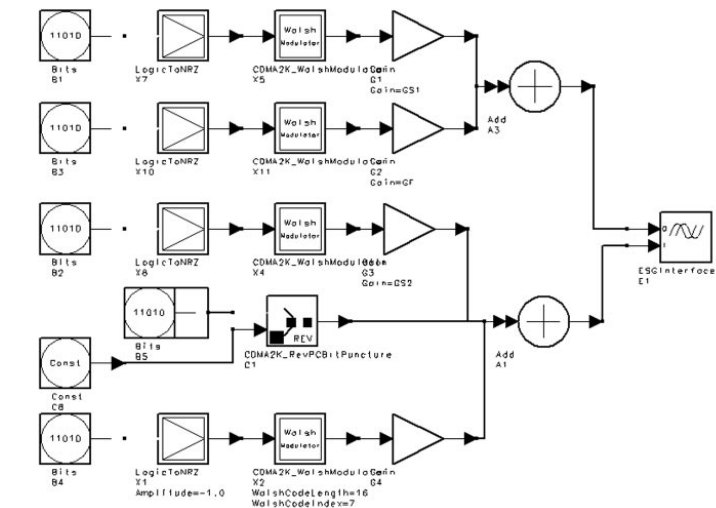
This example generates the cdma2000 transmitting signal in reverse link for ESG link testing. The power level of the R-FCH is about 7.5dB below the power level of the R-Pilot. On pilot channel, a power control group is divided into 4 blocks and Pilot signal (all '0' s) occupy the first three blocks and the power control bits occupy the last one. For other channels, random bit sources are used as the signal sources. Data on Fundamental and Dedicated Control Channels are spread by 16-bits Walsh codes, and on Supplemental channels are spread by 8-bits Walsh codes, then HPSK modulated with PN codes. The final chip rates are 1.2288Mcps and 3.6864Mcps respectively for SR1 and SR3.

The spread and modulated signal is passed through a FIR filter before input into the ESGInterface component.

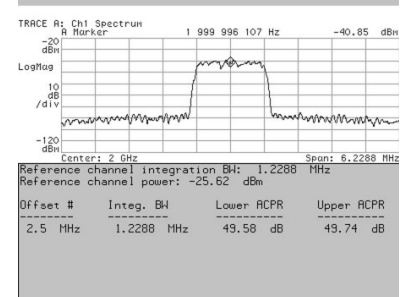
### Schematic

- Multiple channels(Subnetwork: HPSKChannel)

### Test Results



CCDF



ACPR

## Configuration Guide

### Design Tools Requirements

#### Advanced Design System

##### Required Suites (Select at least one)

- DSP Designer Pro (Agilent E8821A/AN)
- Communications System Designer Pro (Agilent E8851A/AN)
- Communications System Designer Premier (Agilent E8852A/AN)

##### Required Options (depending on applications)

- W-CDMA design library (Agilent E8855A/AN)
- CDMA design library (Agilent E8857A/AN)
- CDMA2000-Compliant Design Library (Agilent E8877A/AN)

#### Platform and Interface Requirements

- HP B/C/J - Class Workstations
  - HPUX 10.2      LAN/HPIB      HP E2050A
  - PCI            HP E2078A
  - ISA/EISA      HP E2071D
  - ISA/EISA      National Instruments GPIB-HP700-EISA
  - HPUX 11.0      LAN/HPIB      HP E2050A<sup>1</sup>
- SUN Microsystems
  - Solaris 2.5, 2.6    LAN/HPIB      HP E2050A<sup>1</sup>
  - SBus            National Instruments GPIB-SPRC-B
  - PCI            National Instruments PCI-GPIB Sun SPARCstation
- Windows NT
  - NT 4.0            LAN/HPIB      HP E2050A
  - ISA/EISA      HP 82341C/D
  - PCI            National Instruments PCI-GPIB for Windows NT
  - PCMCIA      National Instruments PCMCIA-GPIB for Win NT
  - EISA/ISA/AT    National Instruments AT-GPIB/TNT for Win NT
- Windows 98/95
  - LAN/HPIB      HP E2050A
  - ISA/EISA      HP 82341C/D
  - PCI            National Instruments PCI-GPIB for Windows 98/95
  - PCMCIA      National Instruments PCMCIA-GPIB for Win 98/95
  - EISA/ISA/AT    National Instruments AT-GPIB/TNT for Win 98/95

## Test Equipment

#### Agilent ESG-D and ESG-DP series digital RF signal generator (Select at least one)

- Agilent E4432B 3 GHz digital RF signal generator
- Agilent E4433B 4 GHz digital RF signal generator
- Agilent E4436B 3 GHz digital RF signal generator with high spectral purity
- Agilent E4437B 4 GHz digital RF signal generator with high spectral purity

##### Required Options

- Option UND internal dual arbitrary waveform generator
- Option 1E5 high-stability timebase

##### Recommended Options

- Option UN8 real-time I/Q baseband generator with TDMA standards and 1M RAM
- Option UN5 multicarrier, multichannel CDMA personality
- Option 100 multichannel W-CDMA personality
- Option 101 multichannel cdma2000 personality
- Option 202 EDGE personality
- Option H99 improved ACP performance for TETRA, CDMA, and WCDMA

#### HP 89400 series vector signal analyzer

- Agilent 89441A vector signal analyzer

##### Required Options

- Option B73 W-CDMA code domain power measurements
- Option AYA vector modulation analysis
- Option AY9 extended time capture
- Option UTH 20 Mbytes extended RAM

##### Recommended Options

- Option AYJ adaptive equalization to AYA
- Option XXX ARIB 1.0-1.2 or 3GPP W-CDMA (Available x/x/xx)
- Option XXX EDGE (Available x/x/xx)

1. Requires Advanced Design System release 1.3

## Literature

- Technical brief, "Connected Solutions for 3G," literature number 5968-5031E.
- Product note, "A Flexible Waveform Generator Using OmniSys and Instrumentation," (describes how to create baseband signals using HP Eesof's SeriesIV Omnisys software and the HP1445 Arbitrary Function Generator), literature number E4600-9.
- Brochure, "HP ESG Series RF Signal Generators," literature number 5968-4313E.
- "Profile of options for the HP ESG family," literature number 5968-2807E.
- "Configuration guide," literature number 5965-4973E.
- "Technical specifications," literature number 5965-3096E.
- Product note, "Generating and Downloading Data to the ESG-D RF Signal Generator for Digital Modulation," literature number 5966-1010E.
- Product note, "Generating Digital Modulation with the ESG-D Series dual Arbitrary Waveform Generator," literature number 5966-4097E.
- Product note, "Customize Digital Modulation with the HP ESG-D Series Real-Time I/Q Baseband Generator," literature number 5966-4096E.
- Brochure, "CDMA Solutions from HP," literature number 5966-3058E.
- Brochure, "GSM Solutions from HP," literature number 5966-1550E.
- Brochure, "WCDMA Solutions from HP," literature number 5967-6349E.
- CD-ROM, "W-CDMA Solutions from HP, Workshop '98," literature number E8900-10025.
- Brochure, "HP Communications Systems Designer," literature number 5966-0670E.



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