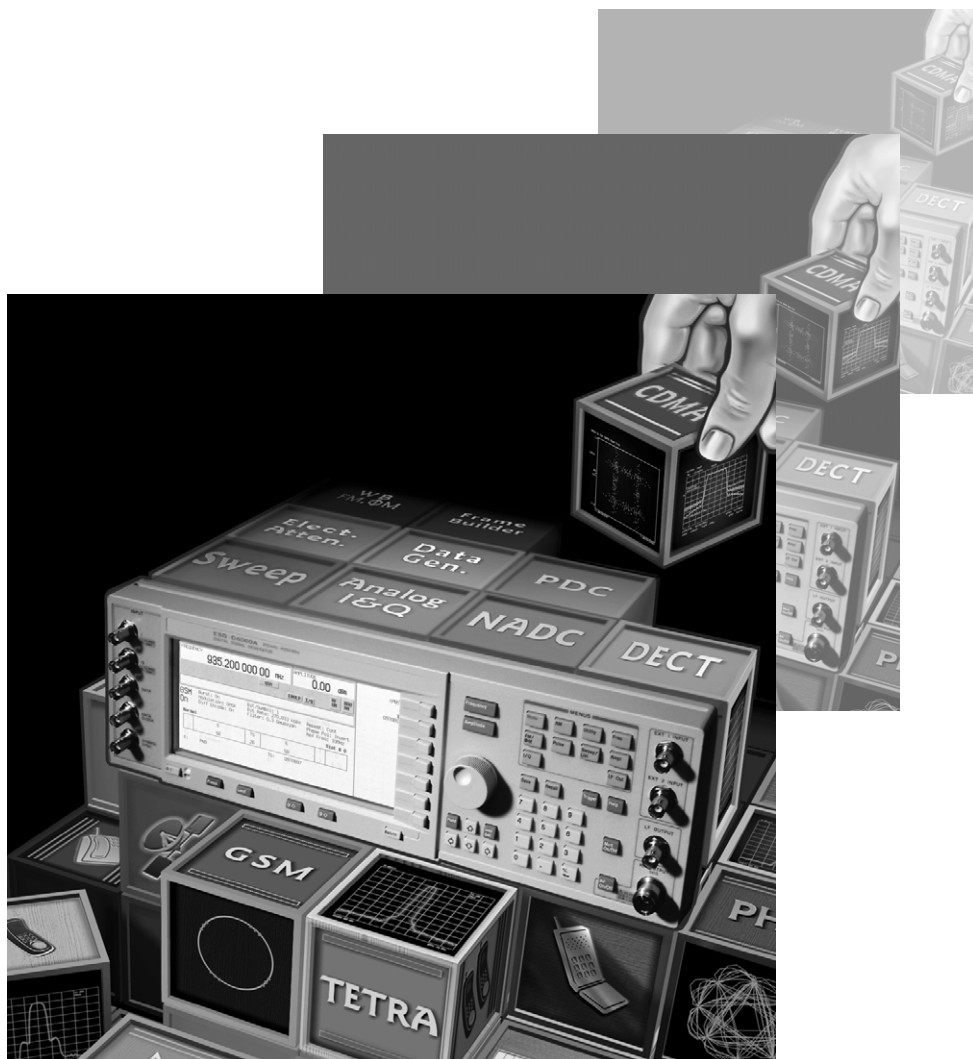


Agilent ESG-D Series, Option UN5

Using the ESG-D RF Signal Generator's Multicarrier, Multichannel CDMA Personality for Component Test

Product Note



Agilent Technologies

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Introduction

The Agilent Technologies multichannel CDMA personality, Option UN5, is ideally suited for adjacent-channel-power (ACP) and code-domain power measurements for CDMA base-station and mobile component test for single and multiple carriers. This personality offers preconfigured settings for pilot, 9-channel, 32-channel, 64-channel, and reverse channel. For additional control of CDMA signals, a channel editor provides the power to define up to 256 Walsh-coded channels per carrier with selectable channel type, Walsh code, power, PN offset, and data. Four IS-95 filters are provided as well as user-defined FIR filtering. To test CDMA variants, the chip rate is selectable from 10 chips/second to 20 megachips/second. All these capabilities are combined with superior ACP performance to test high performance active components.

Option UN5 requires the dual arbitrary waveform generator, Option UND, to be installed.

The two baseband generators in the Agilent ESG-D

The Agilent ESG-D family of RF signal generators offers two optional baseband architectures with complementary features for generating complex digitally modulated signals. These are Option UN8, real-time I/Q baseband generator and Option UND, internal dual arbitrary waveform generator. These options provide the flexibility to simulate existing communications standards, modify existing digital protocols, define and create digitally modulated signals, and intentionally impair these digital signals. Both baseband generators are programmable so new digital modulation formats can be added by simply loading new firmware into the Agilent ESG-D.

Option UN8 simulates a single communications channel with a variety of modulation types, FIR filters, and symbol rates. Data sources are external serial data, internally generated data, or downloaded data patterns.

Option UND provides completely arbitrary I/Q waveform generation capability, but does not provide modulation of real-time data. Typical applications with Option UND include:

- simulating digitally modulated signals with up to 20 MHz bandwidth

- generating two or more CW tones with just one ESG-D
- simulating multiple communications channels
- simulating noise or other impairments.

How to use this note

This product note discusses using Option UN5 for CDMA base station and mobile component test. It begins with the steps involved in generating a multichannel CDMA signal, followed by a description of the IS-95 physical layer and statistical nature of that signal. Next is a description of some common CDMA component measurements for one or more carriers and techniques for getting the most out of those measurements. Finally, this note concludes with a discussion of the various parameters available to the user who wants to test non-standard IS-95-like signals.

The minimum instrument configuration used in the examples in this note is:

Agilent ESG-D signal generator, equipped with Option UND (internal dual arbitrary waveform generator), Option UN5 (multichannel CDMA personality), and Option H99—recommended for improved adjacent channel power (ACP).

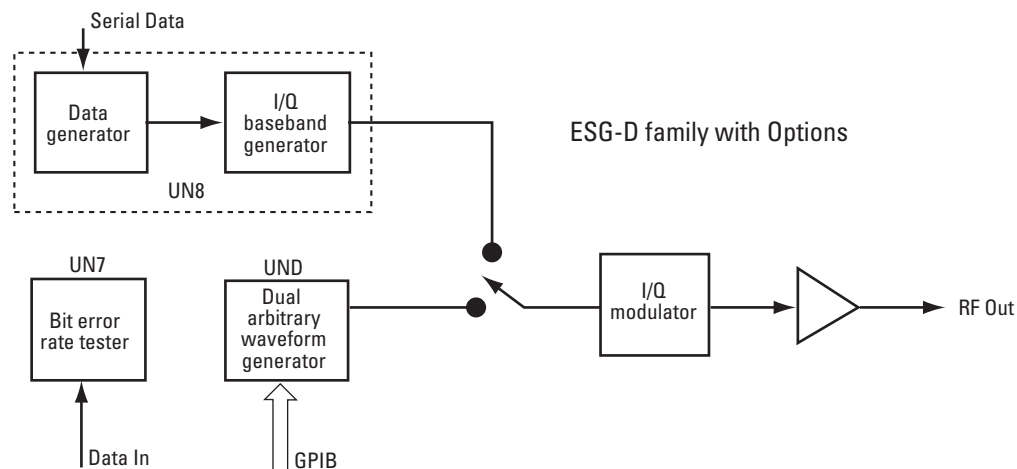


Figure 1. Complementary digital baseband generation in the ESG-D family

The examples in this product note use the following convention: softkeys (redefined by context) are denoted by **bold** type. Hardkeys are denoted by underlined type.

This product note assumes a basic knowledge of digital modulation concepts, CDMA, and instrument programming with Standard Commands for Programmable Instruments (SCPI). It describes how to set up multichannel CDMA signals, technical details of signal generation, and advanced techniques for using the full potential of the ESG's multicarrier, multichannel CDMA capability.

For additional information about these and other topics, the following Agilent application and product notes are available through your local Agilent sales office or at www.agilent.com:

Creating Digitally Modulated Signals with the Agilent ESG-D and Option UND, Dual Arbitrary Waveform Generator, literature number 5966-4097E.

Customize Digital Modulation with the Agilent ESG-D Series Real-time I/Q Baseband Generator, Option UN8, literature number 5966-4096E.

Digital Modulation in Communication Systems – An Introduction, literature number 5965-7160E.

Agilent application note 1307, *Testing CDMA Base-station Amplifiers*, literature number 5967-5486E.

CDMA component test with multichannel CDMA

CDMA active components are tested best by actual multichannel CDMA signals. The Agilent ESG-D can generate a variety of customizable signals that accurately test active components. The nonlinearities of active components in CDMA base stations and mobile stations make them susceptible to effects such as gain compression, spectral regrowth and phase distortion. These effects degrade in-channel characteristics like code-domain power and out-of-channel characteristics such as adjacent-channel power ratio (ACPR). CDMA component test involves measuring in-channel and out-of-channel characteristics to determine whether an accurate signal is transmitted while interference with other signals is minimized.

The phenomena that cause in-channel and out-of-channel distortion are highly dependent on both the amplitude and phase of a transmitted signal. Measuring distortion requires a signal that closely resembles a fully coded CDMA signal to characterize CDMA components. The ESG-D with Option UN5 generates a wide variety of statistically correct multichannel and multicarrier waveforms for CDMA component test. For component test, the “statistical correctness” of the test signal is vital. This concept is explained more completely under the section describing the complementary cumulative distribution function (CCDF) of a multichannel CDMA signal.

Generating multichannel CDMA waveforms

The Agilent ESG-D multichannel CDMA personality uses the onboard digital signal processor (DSP) to compute up to 256 CDMA channels on each of up to 12 carriers. A user can simulate the signals of everything from a single mobile station to one or more fully loaded base stations. Methods to perform these simulations include one-button configurations as well as custom setups, and the ability to modify basic CDMA parameters to test emerging technologies, such as wireless local loop.

To simplify the task of configuring the highly flexible CDMA signal parameters, the user interface is segregated into **CDMA Select** and **CDMA Define**.

The **CDMA Select** menu gives the user a “one button” choice of default or user-defined channel setups. The **CDMA Define** menu allows tremendous flexibility in defining the CDMA signal parameters. For convenience, CDMA channel information is preloaded into the CDMA channel editor for modification.

Predefined channel configurations

To simulate a CDMA forward link, use the soft keys to provide configurations for pilot, 9 channels, 32 channels, and 64 channels. For a reverse link, a single offset quadrature phase shift keying (OQPSK) channel is generated. The **CDMA Select** menu is shown in Figure 2. The preconfigured channel setups are shown in Table 1.

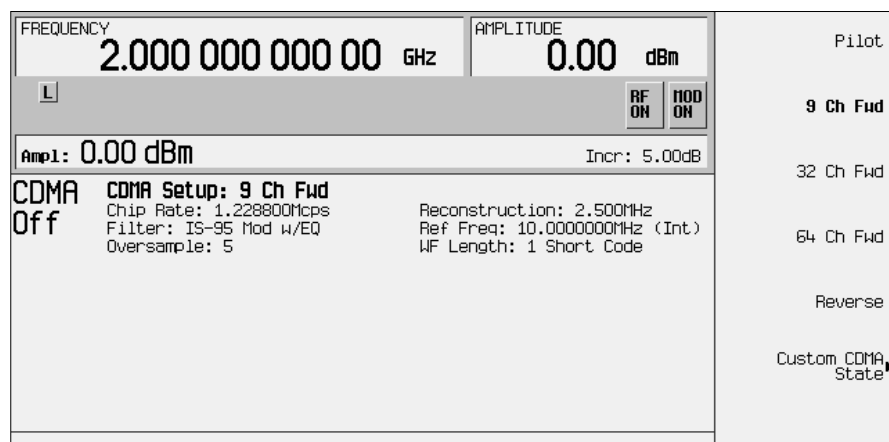


Figure 2. CDMA Select menu

Table 1. CDMA channel configuration defaults

	Channel Numbers				FIR Filter
	Pilot	Paging	Traffic	Sync	
Pilot	0	-	-	-	IS-95 filter modified for ACP with equalization
9 Channel	0	1	8 to 13	32	IS-95 filter modified for ACP with equalization
32 Channel	0	1	8 to 31, 33 to 37	32	IS-95 filter modified for ACP with equalization
64 Channel	0	1	8 to 31, 33 to 63	32	IS-95 filter modified for ACP with equalization
Reverse	-	-	-	-	IS-95 filter modified for ACP

Custom channel configurations

The CDMA define menu gives the user maximum flexibility to modify the CDMA signal. The user can either modify a preconfigured CDMA selection (the 9-channel default, for example) or, starting from a blank screen, define a multichannel signal configuration with the multichannel CDMA table editor shown in Figure 3.

The variables for each channel that the user can control are:

- Channel type: pilot, paging, traffic, synchronization
- Walsh code for each channel: 0 to 63

- Power for each channel: 0 to -40 dB, independently
- PN offset: 0 to 511
- Data feeding Walsh code: random data or binary data 00000000 to 11111111

The ability to define a custom channel configuration is especially useful for tuning the complementary cumulative distribution function (CCDF), a measure of the stress on a component.

Code-domain power display

To verify power levels or enabled Walsh codes, Option UN5 offers a code-domain display based on the channel and power levels specified by the user, shown in Figure 4. To look at channel configurations at additional PN offsets, rotate the knob on the signal generator.

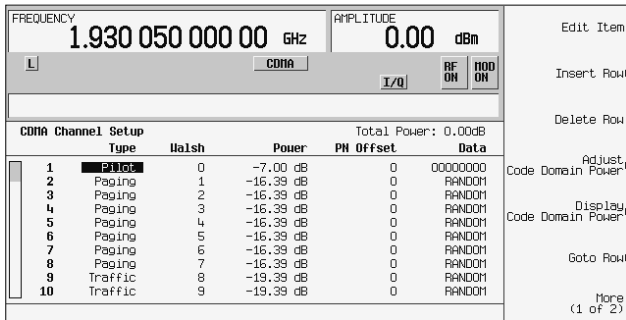


Figure 3. CDMA channel-table editor preloaded with 64-channel configuration

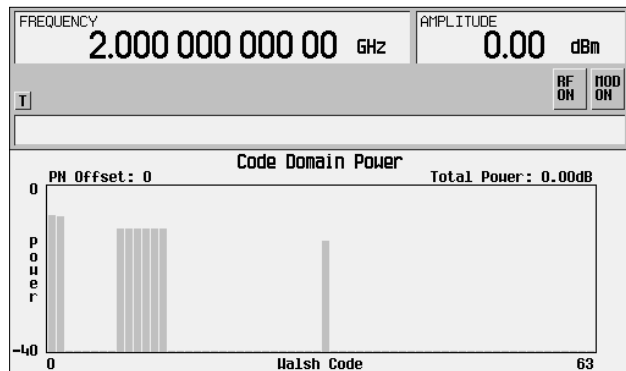


Figure 4. Code-domain power display for a 9-channel configuration

Signal generation details

For multichannel CDMA waveforms to be played back by the dual arbitrary waveform generator, they must be generated and then stored in RAM. This is done in the DSP and is controlled by the UN5 personality's firmware algorithms.

The Agilent ESG-D with Option UN5 does not generate fully coded multichannel CDMA signals. Instead, it generates partially coded signals that are statistically equivalent to fully coded signals, with equivalent power spectral density, peak-to-average power statistics, and phase response. However, certain elements of real CDMA signal generation are not performed, such as long coding, 64-ary modulation, interleaving, and convolutional encoding.

This level of coding is sufficient to achieve the appropriate CCDF, as well as correlation of the Walsh-coded channels in a code-domain power measurement. This means this signal will stress amplifiers and other components exactly as a fully coded multichannel signal. The stress applied to a CDMA component can be described by a signal's CCDF.

The channel coding structures for both forward and reverse channels are shown in Figure 5. For this discussion, we use the phrase "forward channel" to include the forward traffic channels, pilot channel, sync channel, and paging channels, all of which are transmitted from the base station to the mobile station. For forward channel generation, random data, or a defined sequence of repeating data, is supplied to a Walsh code modulator. The output of the Walsh coder undergoes short-code scrambling (with the appropriate PN offset) for both I and Q channels, and baseband filtering.

In the case of reverse-channel (mobile station to base station) coding, data is supplied directly to the I and Q short-code scramblers. After scrambling, the Q channel is delayed by 1/2 chip to effect OQPSK modulation.

After individual channels are generated, they are summed (forward link only) for a complete multichannel CDMA waveform and scaled for optimal adjacent channel power, or spurious emissions. Finally, the I and Q waveform data is stored in RAM to be played back and modulated on an RF carrier.

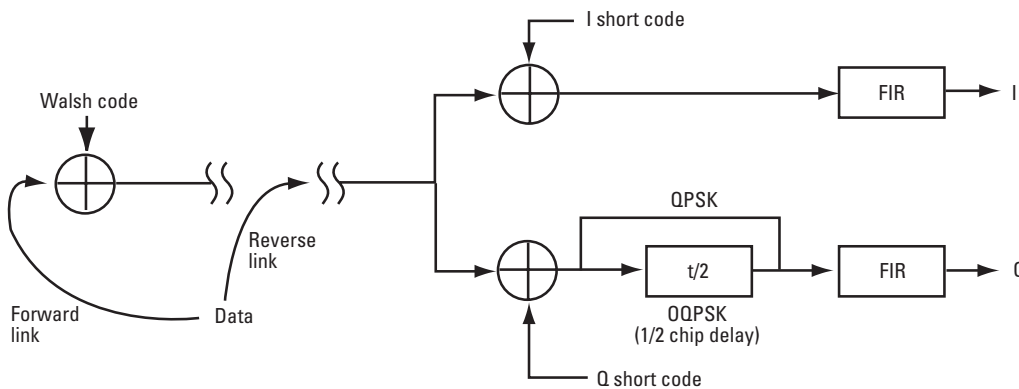


Figure 5. Physical layer implementation for forward and reverse CDMA channels

Complementary cumulative distribution function

The instantaneous power level of a signal is an important factor in the distortion it will induce in a nonlinear component like an amplifier. As the instantaneous power level of a signal increases, it is more likely to exceed the 1 dB compression point of an active device, causing an increase in intermodulation distortion (IMD) and degrading adjacent channel power (or spurious emissions) performance. With highly dynamic input signals, such as CDMA, active component distortion can occur even if the average power level is well below the compression point of the component. Figure 6 demonstrates this effect.

There are several measures of peak-to-average power that are common in the wireless industry today:

- Instantaneous peak-to-average power ratio
- Crest factor

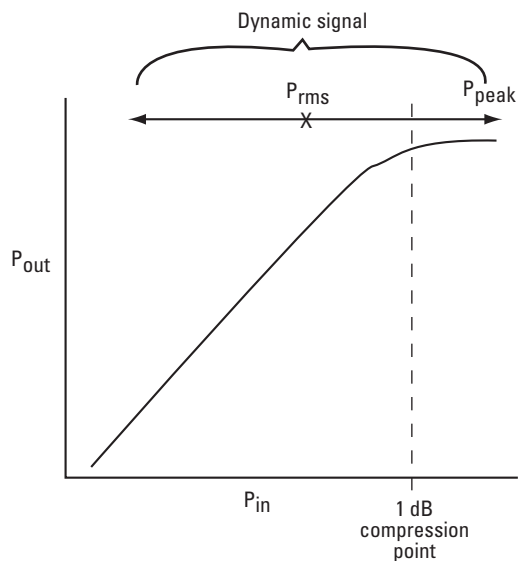


Figure 6. Effect of high peak-to-average power levels on an active component

- Complementary cumulative distribution function (CCDF), also known as probability distribution function (PDF), or cumulative distribution function (CDF).

Peak-to-average power is a measure of the instantaneous power relative to the time-averaged power in a signal. Instantaneous peak-to-average power changes over time (depending on number of Walsh-coded channels, data on each channel, and relative power levels in each channel), and is a poor indicator of a signal's ability to push a component into compression. The crest factor of a signal is a ratio of the peak power versus the average level over some interval. Unfortunately, instantaneous peak-to-average power and crest factor do not completely describe the percentage of time the peak exceeds the average power by a given amount.

The CCDF gives a more complete statistical picture of the peak-to-average power ratio for a given signal. Expressed as a ratio with a given probability, the CCDF illustrates the chance of any instantaneous power measurement being at a certain level relative to the average power of the signal. A sample CCDF curve for a 9-channel CDMA signal generated on the Agilent ESG-D with Option UN5 is shown in Figure 7.

The CCDF of a signal is an especially important metric for multichannel CDMA. Multiple forward channels are summed together before a basestation output amplifier, and can add constructively or destructively. The peak power (completely constructive combination) increases at a higher rate than the average power as more channels are turned on (Figure 8). The average power is subject to destructive and constructive combination. This results in higher peak-to-average power ratios.

Increasing active component stress is visible in a CCDF curve as it moves outward to the right, cor-

responding to higher probabilities of higher peak-to-average power ratios.

IS-97 requires the use of nine forward channels for base-station test, but does not mention specific channel setups or CCDF requirements. This leads to a potential discrepancy among CDMA base-station component tests.

Since independent pairs of Walsh codes are correlated in portions, certain channel setups, for the same number of channels, result in higher CCDFs than others. For example, the peak-to-average power that characterizes the largest 0.01 percent of samples in two different 9-channel configurations can vary by more than 2 dB. To determine the appropriate level of stress to place on components under test, the predicted traffic should be evaluated. Experimentation with multiple channel configurations is the best method of achieving one that optimally stresses the component under test or matches system requirements. CCDFs for a pilot channel and three different 9-channel configurations are shown in Figure 9.

The next section describes some tests that a user might perform on mobile- or base-station components.

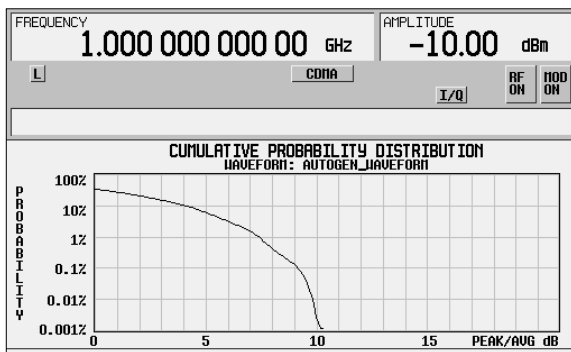


Figure 7. A CCDF plot for the default 9-channel CDMA configuration in the Agilent ESG-D with Option UN5

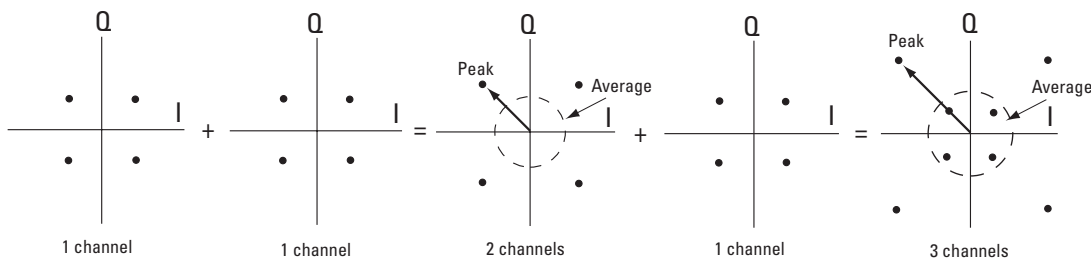


Figure 8. Effect of multiple forward CDMA channels on peak-to-average power

Typical base-station and mobile component tests

Common component tests include adjacent channel power ratio (ACPR) or spurious emissions, code-domain power, and waveform quality (ρ). Most of these tests involve standard setups of the Agilent ESG signal generator. An explanation of each of these tests follows.

Code-domain power

Code-domain power is a base-station component measurement of relative correlated power in each of the Walsh code channels. This measurement assesses a component's ability to process a multi-channel signal without distorting its code-domain response. For code-domain power and other in-channel measurements, use the standard IS-95 filter for optimal modulation quality.

Setup:

- **Preset, Mode, Arbitrary Waveform Generator, CDMA, CDMA Select, 9 Ch Fwd (or 32 or 64), CDMA Define, Filter, Select, IS-95, IS-95 w/EQ, Return, Return, CDMA On**

Waveform quality (ρ)

Waveform quality is the measured cross correlation of the actual RF waveform to an ideal waveform. The standard IS-95 filter for optimal EVM (with equalization for the base-station test) is recommended for this in-channel test. Only the pilot channel is required for base-station test, and the reverse channel is required for mobile stations.

Setup:

- Base-station components: **Preset, Mode, Arbitrary Waveform Generator, CDMA, CDMA Select, Pilot, CDMA Define, Filter, Select, IS-95, IS-95 w/EQ, Return, Return, CDMA On**
- Mobile components: **Preset, Mode, Arbitrary Waveform Generator, CDMA, CDMA Select, Reverse, CDMA Define, Filter, Select, IS-95, IS-95, Return, Return, CDMA On**

Spurious emissions

The superior ACP performance of the Agilent ESG-D with Option UN5 (typically -75 dBc for multichannel signals at 900 MHz) makes it ideal for spurious emissions measurements. With the convenience of a preset 9-channel configuration that meets IS-97 requirements, these measurements are also easy.

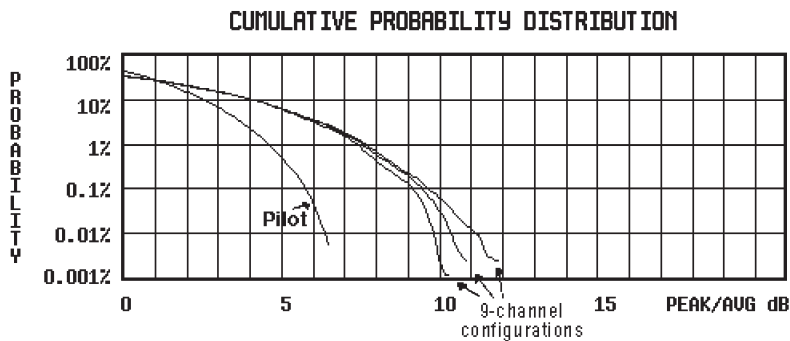


Figure 9. CCDF curves for pilot channel and three separate 9-channel configurations

Setup:

- Base-station components: **Preset, Mode, Arbitrary Waveform Generator, CDMA, CDMA Select, 9 Ch Fwd** (or 32 or 64), **CDMA On**
- Mobile components: **Preset, Mode, Arbitrary Waveform Generator, CDMA, CDMA Select, Reverse, CDMA On**

Base-station component manufacturers with special requirements can modify channel configurations to achieve a specialized CCDF, or use the multicarrier capability to test multicarrier components.

Adjacent channel power optimization

For out-of-channel tests such as spurious emissions, the adjacent channel power (ACP) performance of the signal source needs to be sufficiently below the ACP specification of the device under test. The typical performance of a standard Agilent ESG-D for multichannel CDMA on a 900-MHz carrier is -73 dBc. However, performance as good as -79 dBc can be achieved with ACP-enhancing hardware options and adjustments.

The Agilent ESG-D offers three RF output sections that provide different ACP performance:

- Standard electronic attenuator (same performance with Option UNA, electronic attenuator for alternate timeslot power)
- Option UNB, mechanical attenuator
- Option H99, output board modification and mechanical attenuator for improved ACP.

The mechanical attenuator, Option UNB, offers improved ACP over the standard electronic attenuator, as well as increased output power. Option H99 offers the best ACP, but reduces the maximum

power level from that of the standard electronic attenuator. For the best possible ACP, the suggested configuration for CDMA component test includes the ESG-D with Options UND, UN5, and H99.

For any hardware configuration there is variability in the Agilent ESG ACP performance at different power levels and settings. The complex interaction of noise levels, amplifier limitations, and attenuator steps at varying power settings leads to variability in ACP performance. Optimal settings for ACP performance can be quickly determined experimentally. The settings that can affect ACP are described below.

For high power applications above 0 dBm, the ESG ACP will degrade significantly. For optimal ACP with signal power above 0 dBm, the user should apply a higher power amplifier at the ESG RF output and use an RF power setting below 0 dBm on the ESG.

Attenuator hold causes the step attenuator to maintain the current attenuator level while power levels are adjusted. With this technique, the user has nominally 10 dB control over the operating point of the output amplifier, which may allow for improved ACP performance at a given power level.

In order to optimize ACP performance, the multichannel CDMA personality automatically activates *high-crest mode*. This lowers the operating level of the output amplifier by setting the attenuator activation point to a lower power level. In this mode all output power levels are achieved at a lower point in the amplifier's operating range, further from the compression point.

The user can experiment with these settings in addition to power level and frequency in order to get the best possible ACP for her or his application.

Baseband outputs

The Agilent ESG-D with the multichannel CDMA personality automatically modifies the internally generated baseband CDMA signal for optimal ACP. One modification is a reduction in drive level for the baseband signal. This reduces the contribution to distortion in the signal generator's I/Q modulator and output amplifiers from the baseband signal, improving performance. However, for users who use the baseband outputs ("I Out" and "Q Out"), this also reduces their drive level from nominal >1Vp-p. Users who need higher voltage levels from the baseband signals will need to provide external amplification.

Multicarrier CDMA

(available with firmware version B.02.20 and greater)

Many users are interested in multicarrier CDMA testing to evaluate broadband power amplifiers that transmit multiple RF carriers within a band to measure spectral regrowth between the carriers. The multicarrier CDMA capability in the Agilent ESG-D allows customers who manufacture components for multicarrier base stations to fully test them with just one ESG-D. It allows a user to place up to 12 carriers in a 15 MHz bandwidth, each with a custom configuration of channels. A multicarrier table setup with its corresponding signal is shown in Figure 10a.

Whether selecting predefined multicarrier CDMA configurations or explicitly defining the characteristics of each channel on a carrier, the user can determine the level of customization required for an application. This allows the user to tailor a test to specific requirements like CCDF, and use carrier placements that reflect the frequency allocation for specific systems.

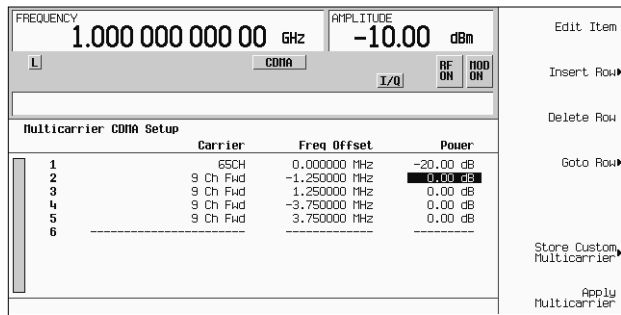


Figure 10a. Multicarrier CDMA custom configuration

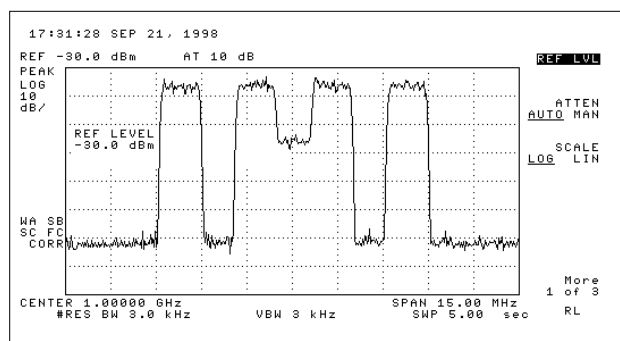


Figure 10b. Spectral plot of multicarrier CDMA signal

Note: Those who want to perform multicarrier CDMA component tests can access updated firmware at www.agilent.com/find/esg/ or contact a local Agilent sales representative. To verify the firmware version in an existing ESG, press **Utility**, **Instrument Info**, **Diagnostic Info** and read the line entitled Firmware Revision.

Two effects may be evident when a multicarrier signal is generated, depending on carrier placement: LO feedthrough and carrier images. Both effects can distort in- and out-of-channel measurements. LO feedthrough and single sideband mixing images are results of an I/Q imbalance in the baseband generator and are evident in any multicarrier signal generated at baseband.

Figure 11 depicts a multicarrier CDMA signal with baseband images. Multicarrier signals are generated at baseband by creating individual multichannel carriers and applying a complex sinusoid to achieve single sideband mixing. I/Q imbalances add an undesired mixing component as a mirror

image of the desired signal around the rf carrier setting (dc at baseband). The intended carriers are centered at the frequency setting (1 GHz) as well as -2.5 MHz and $+1.25$ MHz relative to the frequency setting. The resulting images are centered at $+2.5$ MHz and -1.25 MHz. These images can affect out-of-channel measurements such as spurious emissions. For these measurements, it is recommended that carriers be arranged such that these images do not appear where the measurement is to be made.

Image carriers can also affect in-channel measurements. Figure 12 depicts a two-carrier signal with symmetrical carriers. A code-domain power measurement on one of the nine-channel carriers shows an increased noise level as a result of the image co-located with the carrier. For in-channel measurements such as code-domain power and waveform quality, best results are achieved when carriers are not co-located with baseband images (i.e., asymmetrical waveform placement).

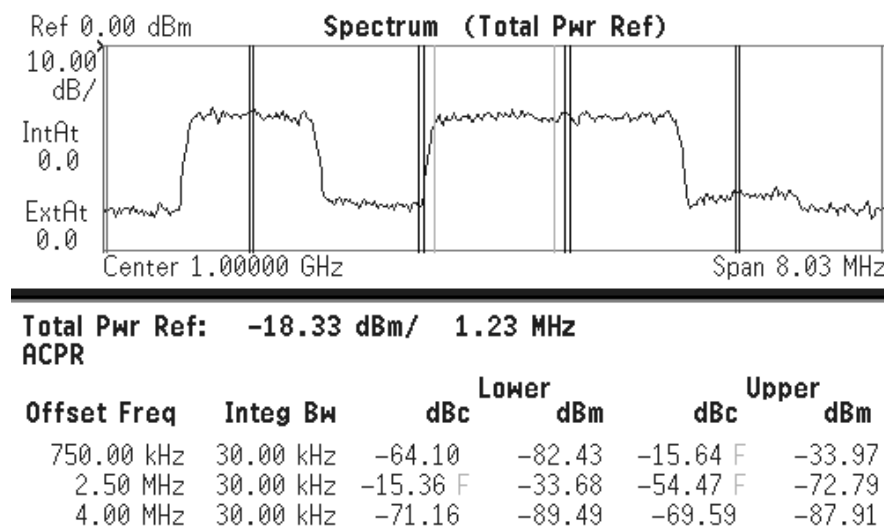


Figure 11. Multicarrier CDMA signal with baseband images

LO feedthrough is a result of dc offset in a waveform or the I/Q path in the ESG. Figure 13 depicts a multicarrier signal with LO feedthrough. LO feedthrough that is co-located with a carrier or present at the location of an out-of-channel measurement will have effects similar to those experienced with baseband carrier images, described above. LO feedthrough can be minimized by adjusting I and Q offset, and I/Q quadrature skew under the I/Q adjustments menu.

Intermediate-frequency measurements

Some users may wish to use the Agilent ESG-D with Option UN5, multichannel CDMA personality to simulate intermediate frequency (IF) portions of their system. For these users, it is important to be aware of a phenomenon that occurs in I/Q modulation for carriers below 250 MHz.

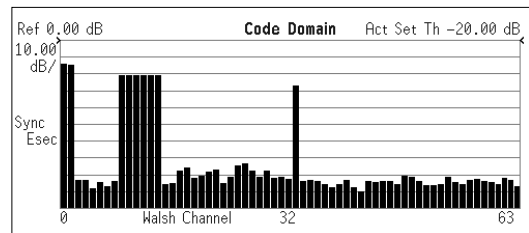
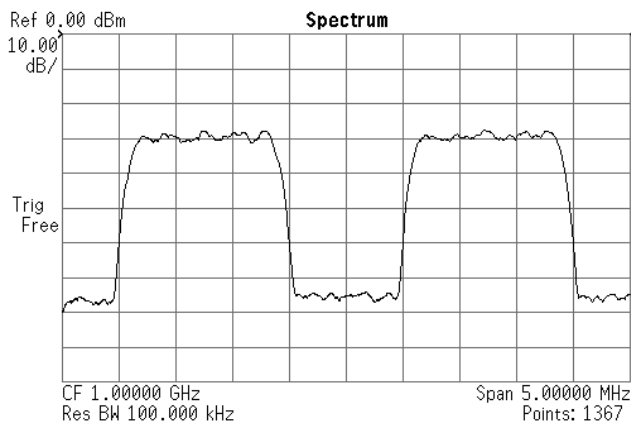


Figure 12. Two-carrier CDMA signal with code domain noise from baseband image

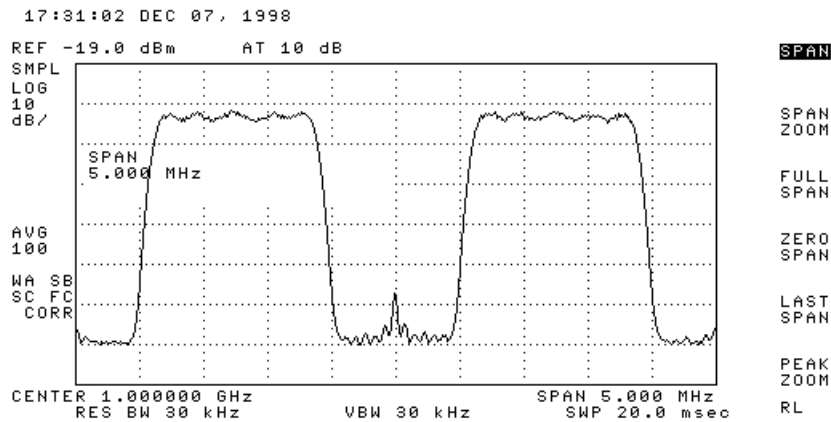


Figure 13. LO feedthrough in multicarrier CDMA

Carriers between 250 kHz and 250 MHz are in the ESG's "heterodyne band." Carriers in this band are created by mixing down from higher synthesized frequencies (Figure 14). In the case of the ESG, this is done after any I/Q modulation is applied to the synthesized carrier. To maximize spectral purity in the heterodyne band, the ESG uses synthesized carriers between 750 and 999.750 MHz with a 1 GHz LO. Since the synthesized carrier is at a lower frequency than the LO, the final RF carrier output from the mixer is the "mirror image" of the original spectrum. In terms of negative frequency, this is the image of the original modulated carrier that existed between -999.750 and -750.0 MHz. The final effect is a modulated carrier that is reversed in the frequency domain.

For spectrally symmetrical signals like IS-95 CDMA, this effect is not normally noticeable for spectrum measurements. However, it is significant, and will cause failures in code-domain power measurements. In a time-domain sense, the effect of reversal in the frequency domain of a complex signal is the same as reversing the I and Q channels. To compensate for this effect, the user can reverse the I and Q channels. The steps for doing this follow:

1. Connect the I and Q out connectors on the rear panel of the Agilent ESG to the Q and I in connectors on the front panel, respectively. *Note:* The I and Q channels have been *intentionally* switched.

2. Select external I and Q inputs as the modulation source for the ESG: **I/Q, I/Q Source, Ext I/Q, I/Q ON.**

Alternatively, the user can connect the I and Q outputs to the I and Q inputs without switching them and use **I/Q, More (1 of 2), Ext I/Q Phase Polarity Invert** to achieve the same effect.

If you want to adjust the basic parameters of the multichannel CDMA signal at any frequency, the following section explains some ESG capabilities and technical details that help use the full potential of Option UN5.

Adjusting CDMA parameters

The Agilent ESG-D with the multichannel CDMA personality is easy to configure for most component test. However, some advanced features allow the user to maximize testing capabilities and improve performance, while expanding potential applications areas.

Evaluation of emerging standards

Some wireless-local-loop (WLL) standards use IS-95 coding at higher chip rates. The ESG-D with multichannel CDMA personality lets a user test mobile-station and base-station components for WLL systems by simply adjusting the chip rate of the CDMA signal.

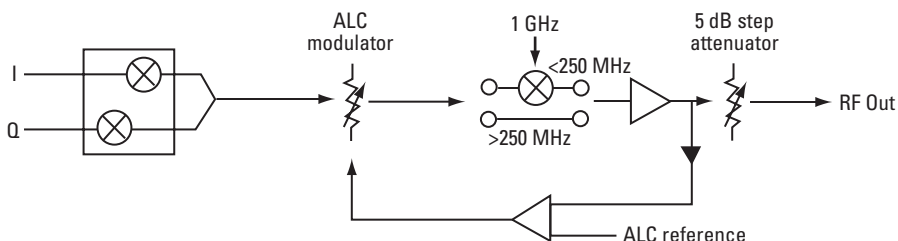


Figure 14. I/Q modulation and frequency synthesis in the ESG "heterodyne band"

For example, to test a WLL based on IS-95 coding with a chip rate of 5 MHz perform the following steps:

1. **Mode, Arb Waveform Generator, CDMA, CDMA Select, 9 Ch Fwd, CDMA Define, Chip Rate, 5, MHz** to set the chip rate to 5 MHz.
2. **Reconstruction Filter, 8.000 MHz** to select the wider reconstruction filter needed to transmit the wider spectrum.
3. **Return, CDMA On** to generate the waveform and activate it.

The ESG-D now will be generating a multichannel IS-95-based CDMA signal with a chip rate of 5 MHz. Please consult the “Constraints” section in this product note for more information on the necessary adjustments of the reconstruction filter or oversampling ratio to achieve usable signals.

The above example described changing the sample rate of a CDMA signal to emulate a WLL system based on IS-95 coding. Adjustments to the basic parameters of a CDMA signal require some calculations. These are outlined below.

Basic CDMA parameters

The multichannel CDMA personality offers the capability to modify FIR filters (choose predefined filters or enter coefficients for custom filters), chip rate, reconstruction filter, waveform length, and oversample ratio.

Fir filters

The multichannel CDMA personality provides four IS-95 based filters, and the ability to define FIR filter coefficients.

- **IS-95 w/Eq** (with equalization) is based on the standard IS-95 filter for base-station component test. This filter will provide zero PN timing offset (typically) as analyzed on an Agilent 8935A base station test set or Agilent 8921A call site test set.
- **IS-95 Mod w/Eq** (modified with equalization) improves the ACP for base-station component test. Because this filter modifies group delay in-channel to improve ACP out-of-channel, a PN offset of typically 2 microseconds will appear on an 8935 or 8921A.
- **IS-95** is a version of the standard filter from the IS-95A specification.
- **IS-95 Mod** (modified) improves the IS-95 filter for better ACP. This is normally selected for reverse-link component test such as mobile power amplifiers.

FIR filters with up to 1024 FIR coefficients with 16-bit resolution and up to 32-times oversample ratio can be saved in the instrument. FIR filter coefficients can be modified from existing filters, computed externally and downloaded into the ESG-D, or entered on the front panel.

From the front panel, press **Mode, Arb Waveform Generator, CDMA, CDMA Define, Filter, Define User FIR**.

The FIR table editor will be displayed (Figure 15). Enter coefficients for the first half of the filter. For symmetrical coefficients, press the **Mirror Table** softkey to generate the second half of the coefficients in reverse order. Otherwise, enter the remaining coefficients manually. Set the **Oversample Ratio** (number of filter taps per symbol).

To verify the data, use the **Display Impulse Response** and **Display FFT** soft keys, and compare it against the expected outcome (Figure 16).

Chip rate

Chip rate is adjustable from 10 Hz to 20 MHz, depending on the setting for oversample ratio. To simulate wider bandwidth systems such as WLL based on IS-95 coding structures, increase the chip rate (for example, to 5 MHz).

FIR Values (UNSTORED)		Oversample Ratio: 4
Coef.	Value	
10	-0.157348	
11	-0.088484	
12	0.123414	
13	0.442748	
14	0.767329	
15	0.972149	
16	0.852245	
17	0.767329	
18	0.442748	
19	0.123414	

Figure 15. FIR table editor

You may need to adjust the reconstruction filter or oversample ratio to accommodate various chip rates. This is discussed below under “Constraints.”

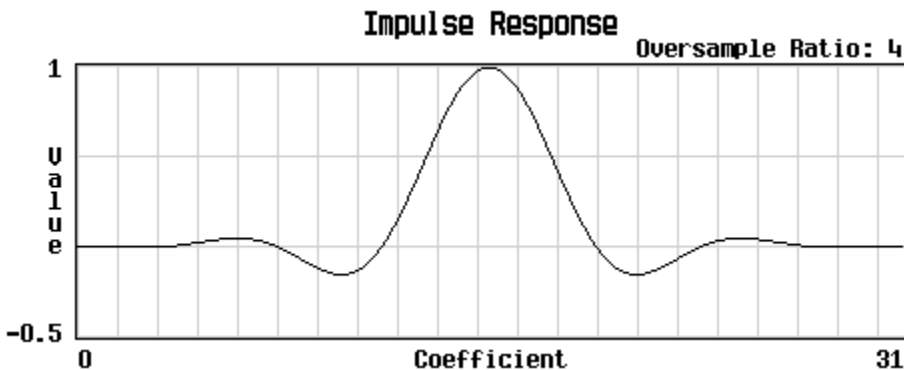


Figure 16a. Screen plot of impulse response of FIR filter data

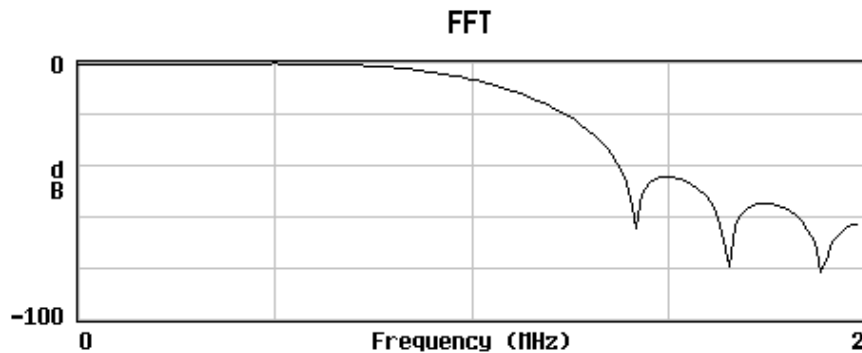


Figure 16b. Screen plot of frequency response (FFT) of FIR filter data

Reconstruction filter

Option UN5 offers three reconstruction filters: 250 kHz, 2.5 MHz and 8 MHz. IS-95 defaults to the 2.5 MHz reconstruction filter. Other reconstruction filters can be selected or externally applied.

The reconstruction filter should have a bandwidth greater than the baseband bandwidth of the signal. For CDMA, the baseband bandwidth equals one-half the chip rate. If possible, allow extra guard-band between the filter cut off and the signal's baseband bandwidth to prevent in-channel roll off.

Waveform length

Waveform length can be set from 1 to 16 short codes. This lengthens the amount of random data that feeds the Walsh code, thus lengthening the time before the data repeats.

Lengthening the waveform will also increase the amount of memory storage required, limiting both the maximum number of waveforms and the oversample ratio for each waveform.

Question: What is meant by waveform length (in short codes)?

Answer: In generating data to build the multiple channels simulated in Option UN5, random bit streams are built and multiplied by the standard IS-95-defined 32,768 chip short code. The default is to use enough data to exhaust one short code (32,768 chips/64 chips per bit = 512 bits). Thus, the same short code repeats, with the same random data, once every 26.667 ms for a 1.2288 MHz chip rate (32,768 chips/1.2288 Mchips per second). If we use six short codes, then six 512-bit random sequences are generated. This way, the entire baseband signal repeats once every $6 \times 26.667 = 160$ ms.

Oversample ratio

Oversample ratio is adjustable from 2 to 8, depending on the settings for chip rate and waveform length.

Question: How does the "oversample ratio" work for UN5?

Answer: There are two "oversample ratio" soft keys in the multichannel CDMA personality. They are distinguished by their positions in the softkey menu tree.

One type of oversample ratio is used for filter definition, and exists under the **Define User FIR** softkey. For instance, if users choose to enter the IS-95 filter, they would enter 48 filter-tap values. These would correspond to the 4X-oversampled filter with 12 symbols. The user would then use **Mode, CDMA, CDMA Define, Filter, Define User FIR, Oversample Ratio** to set the ratio to 4. This informs the instrument that the filter-tap values correspond to a 4x oversampled filter. It is very important to enter the oversampling rate correctly to assure that further calculations for the filter will be consistent with the filter design.

When the CDMA signal is generated, the user can choose an oversampling ratio for playback, which can be found under the CDMA Define softkey. This will adjust the smoothness and memory usage of the CDMA signal loaded in the dual arbitrary waveform generator. If, as in the above example, users enter an IS-95 filter, they can go to the **Mode, CDMA, CDMA Define, More** (1 of 2), **Oversample Ratio** function to select, say, a 5X oversampling rate for playback. In this case, the instrument would use the definition's sampling rate (4 taps/symbol) entered above to correctly re-sample the filter to a 5X oversampling rate, which results in a similar filter consisting of 12 symbols, but 60 taps. This increases the number of data points, consuming 25% more arbitrary waveform generator memory ($5/4 = 1.25$).

Oversampling rates can also be adjusted for the predefined filters included in the multichannel CDMA personality. In this case, the instrument knows the original sampling rate, and uses that in its calculations for re-sampling, if necessary.

Constraints

Certain aspects of the dual arbitrary waveform generator, the multichannel CDMA personality, and digital-to-analog conversion limit the application of the above parameters. The constraints imposed by the hardware are:

- Memory
- Maximum sample rate
- Reconstruction filters.

Fortunately, for standard CDMA applications, many of the parameters are optimized by the Agilent ESG signal generator. However, when the user wishes to change the chip rate, these constraints must be taken into account. This discussion traces the decisions a user might make when setting up a nonstandard CDMA signal such as WLL.

1. *Set a chip rate.* The basic design parameter that drives this analysis is chip rate. Most other parameters are set to optimize the output based on the chip rate. In this example, select a 5 MHz chip rate for WLL.
2. *Select a reconstruction filter.* The reconstruction filter should have a cut off higher than the

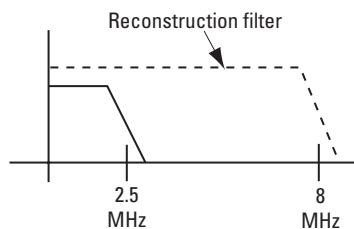


Figure 17. Selecting a reconstruction filter for CDMA with a 5 MHz chip rate

baseband bandwidth of the signal. In this case, the 2.5 MHz filter has a 3 dB roll off at the edge of the baseband spectrum ($5 \text{ MHz}/2 = 2.5 \text{ MHz}$), so use the 8-MHz filter (Figure 17). Selecting the minimum filter cut off that still sufficiently transmits the desired bandwidth allows more freedom in later stages.

3. *Select an oversample ratio (OSR).* The oversample ratio, in conjunction with the symbol rate, determines the sample rate (sample rate = OSR x symbol rate). In digital-to-analog conversion, sampling images are created at offsets equal to the sample rate. These images need to be sufficiently attenuated by the reconstruction filter to avoid distortion. With an oversample ratio of two, the sampling image will be centered at 10 MHz ($5 \text{ MHz symbol rate} \times 2$), resulting in a significant interfering signal at less than 7.5 MHz (Figure 18). This is below the reconstruction filter cut off. An OSR of four, however, moves the sampling image to 20 MHz (Figure 19). This is sufficient to reject the sampling image with the reconstruction filter. For most applications, a minimum OSR of four is recommended. However, select the lowest oversample ratio possible to conserve memory.

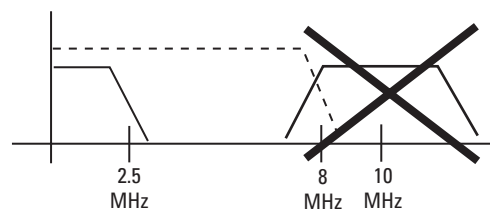


Figure 18. WLL with a 5 MHz chip rate, 8 MHz reconstruction filter, and OSR of 2

4. *Select a waveform length.* An increased waveform length decreases the repetition rate of the random data encoded on the Walsh channels of the CDMA signal. However, a longer waveform length also results in more memory usage. With an OSR of four, the maximum waveform length is:

$$\frac{1,048,576 \text{ samples}}{32,768 \text{ chips/short code} \times 4 \text{ samples/chip}} = 8 \text{ short codes}$$

There are some other constraints to keep in mind:

- The maximum sample rate can limit OSR or chip rate. For instance, with an OSR of four, the maximum chip rate is $40 \text{ MHz}/4 = 10 \text{ MHz}$.
- The presence of other waveforms in RAM will limit the available space to store and play back CDMA waveforms.

Below are the critical equations needed to calculate viable combinations of chip rate, OSR, reconstruction filter, and waveform length:

$$\text{sample rate} = \text{OSR} \times \text{chip rate} \leq 40 \text{ MHz}$$

$$\text{memory (samples)} = \text{waveform length} \times \text{OSR} \\ \times 32,768 \leq 1,048,576$$

$$\text{reconstruction filter cutoff} < \frac{\text{sample rate} - \text{chip rate}}{2}$$

$$\text{reconstruction filter cutoff} > \frac{\text{chip rate}}{2}$$

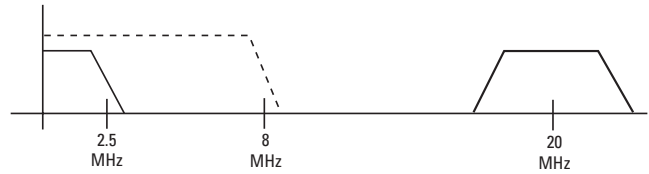


Figure 19. WLL with a 5 MHz chip rate, 8 MHz reconstruction filter, and OSR of 4

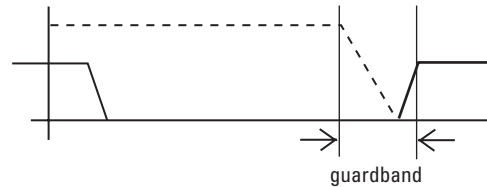


Figure 20. Guardband to allow for filter rolloff in reconstruction filter selection

1. The "guard" term allows for filter rolloff. See Figure 20.

Summary

The Agilent ESG-D with Option UN5, multichannel CDMA personality, offers a flexible high-performance signal for CDMA base-station and mobile component test. Ready-made channel and carrier configurations allow the user to quickly generate a test signal, while the channel and carrier editors provide the capability to tailor signals to very specific needs. The realistic CCDF of these signals ensures an accurate stimulation for tests like code-domain power, waveform quality, and spurious emissions. By using the performance-enhancing capabilities of the Agilent ESG signal generator the user can optimize critical specifications like ACP to test even the most advanced active components.

The ability to adjust chip rates and FIR filters allows the user to simulate new IS-95-based standards in addition to IS-95. Knowledge of the interaction of parameters like reconstruction filters and chip rates enables the user to effectively generate these signals.

With the wide range of capability illustrated above, and the path to expand and enhance these capabilities as new standards evolve, the Agilent ESG-D is an ideal solution for component test both today and in the future.

For further information

Related literature:

Agilent ESG Family of RF Signal Generators, Data Sheet, literature number 5965-3096E

IntuiLink Software, Data Sheet, literature number 5980-3115EN

Agilent ESG Family of RF Signal Generators, Configuration Guide, literature number 5965-4973E

Generating and Downloading data to the ESG-D RF Signal Generator for Digital Modulation, Product Note, literature number 5966-1010E

Customize Digital Modulation with ESG-D Series Real-Time IQ Baseband Generator, Option UND, Product Note, literature number 5966-4096E

Multi-channel CDMA Personality for Component Test, Option UN5, Product Note, literature number 5968-2981E

Generating Digital Modulation with the ESG-D Series Dual Arbitrary Waveform Generator, Option UND, Product Note, literature number 5966-4097E

Using the ESG-D Series of RF Signal Generators and the 8922 GSM Test Set for GSM Applications, Product Note, literature number 5965-7158E

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Printed in U.S.A. May 29, 2001

5968-2981E



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