Customizing Digital Modulation with the Agilent ESG-D Series Real-time I/Q Baseband Generator, Option UN8

Product Note

Keep pace with the demanding changes in digital communications standards with the versatile Agilent Technologies ESG-D series of RF signal generators. The ESG-D series of RF signal generators offers two flexible baseband architectures with complementary features for generating complex digitally modulated signals. These flexible architectures provide the freedom to define or create digi-

tally modulated signals, modify existing digital protocols, and simulate transmissions as specified by existing communications standards. Intentionally impair these standards or customized modulations to characterize components and test performance at design margins.

The two baseband architectures offered in the ESG-D series are

Option UN8, real-time I/Q baseband generator and Option UND, internal dual arbitrary waveform generator. This product note addresses Option UN8.

For more information on the internal dual arbitrary waveform generator, consult Agilent product note 5966-4097E, "Generating Digital Modulation with the Agilent ESG-D Series Dual Arbitrary Waveform Generator, Option UND."

Agilent Technologies
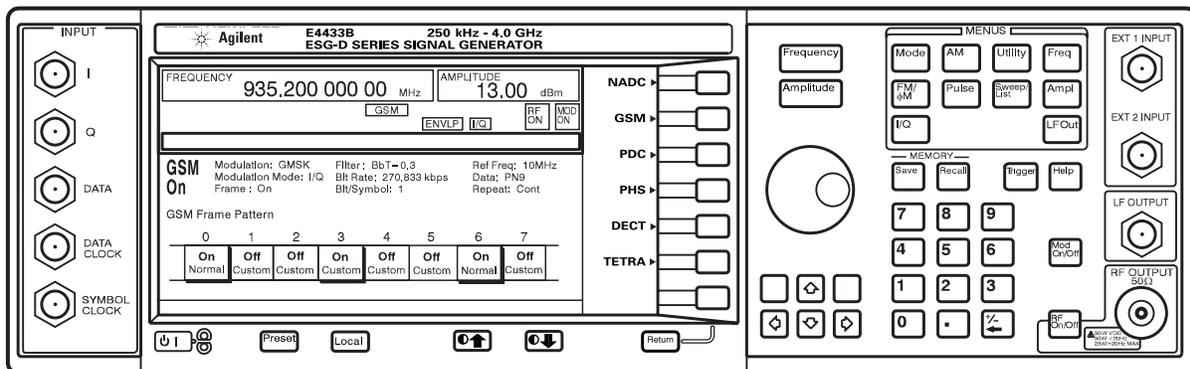
Introduction

Signal generators have three basic functions in the RF chain of a typical communication system.

A signal generator
• Provides a known good signal
• Simulates the output of a circuit that does not exist
• Simulates known impairments

This functionality assists in developing circuits, characterizing component or system performance, and developing standards. The Agilent ESG-D series of RF signal generators with Option UN8, real-time I/Q baseband generator, supports these needs in a digital system.

The real-time I/Q baseband generator operates on three levels. You can select a standard modulation, modify a standard modulation, or build a modulation from the ground up. With Option UN8 you have access to the basic building blocks of a digitally modulated signal. These building blocks are modulation, filter, symbol rate, and data.

This product note explores the flexibility of these building blocks and offers ideas for providing a known good signal, substituting for the output of a circuit, and generating impairments.

Background material

This note assumes a basic knowledge of digital modulation concepts. This is covered in detail in the Agilent application note "Digital Modulation in Communications Systems—An Introduction." The literature number is 5965-7160E.

Configuration

The examples in this product note require a minimum instrument configuration of:

• **Agilent ESG-D series RF signal generator**—digital signal generator in 1, 2, 3, or 4 GHz models (E4430B, E4431B, E4432B, or E4433B)

• **Real-time I/Q baseband generator with TDMA standards**—internal data generator and symbol builder with 1M RAM (Option UN8) *Note: Add 7M RAM additional memory with Option UN9.*
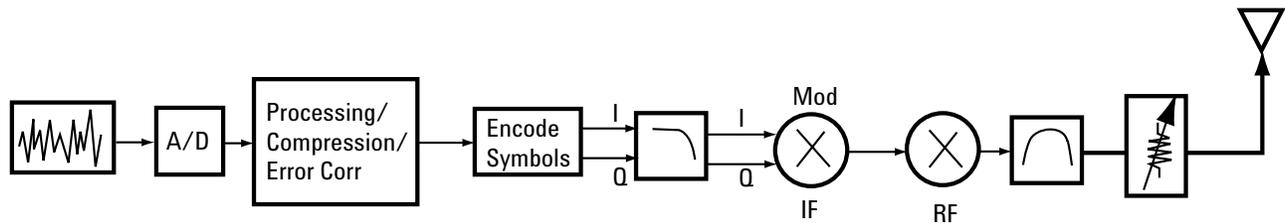
Figure 1. Engineering the signal path using a signal generator

Theory of operation

The real-time I/Q baseband generator interprets data bits and produces analog voltages representing the desired modulation. When these voltages are input to the modulator they produce a digitally modulated RF signal. The diagram and text below describe the signal as it passes through each of the blocks.

- *Data Generator*–Serial data is generated internally (PN9, PN11, PN15, PN20, PN23 or a 4- to 64-bit repeating stream), downloaded as a user file, or externally input through the front panel serial port. The input data represents the symbols to be generated. The data generator can also produce fully framed and properly formatted data for several TDMA standards.

- *Symbol Generator*–Serial data is grouped into symbols and then mapped to the I/Q plane. For example, 16 QAM has 4 bits per symbol so each group of 4 bits represents one of 16 possible symbol locations ($2^4 = 16$). The output of this block is a series of impulses, one for each symbol. This RAM based implementation supports up to 8 bits/symbol and includes a user definable differential encoder.
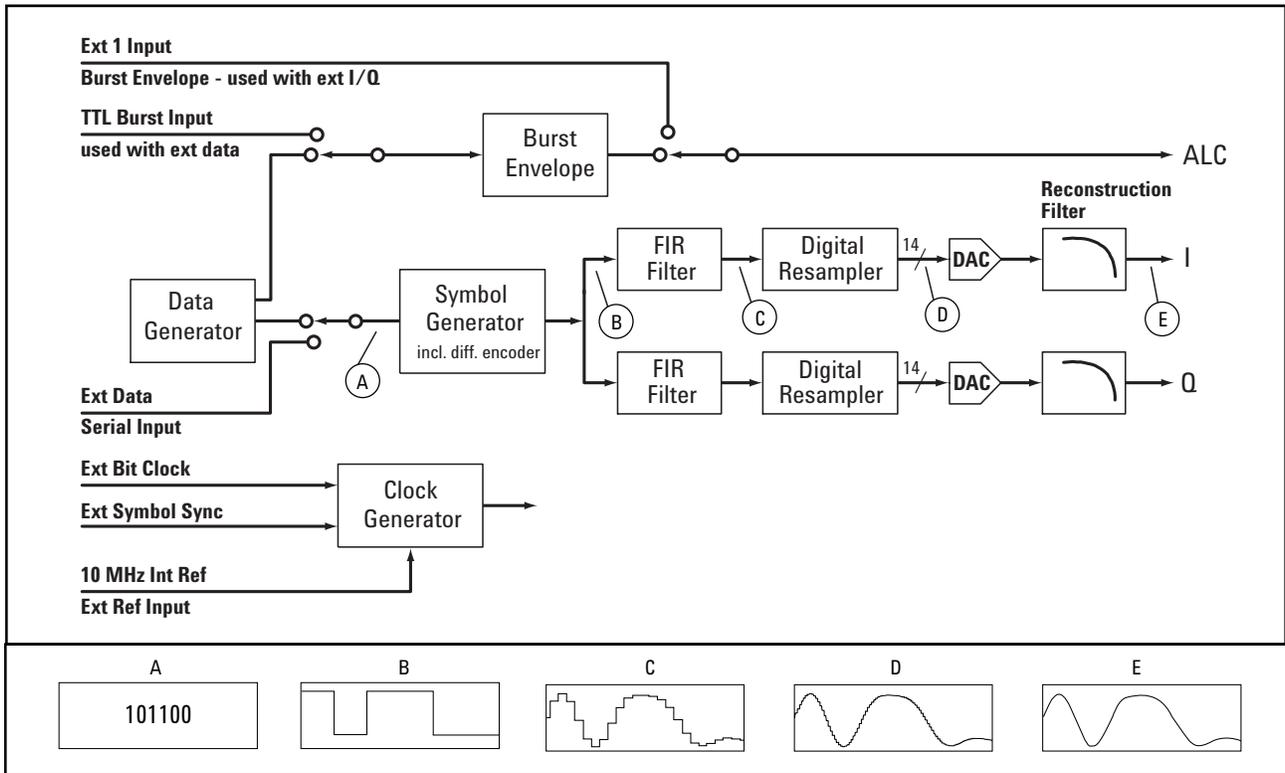
Figure 2. Real-time I/Q baseband generator block diagram

3

- *FIR (Finite Impulse Response) Filter*—The I and Q values are then run through a pair of FIR digital premodulation filters. These filters reduce the bandwidth of the trans-mitted signal using the filter shape specified for the desired system. For example, 0.35 alpha Root Nyquist for NADC and 0.3 Gaussian for GSM. The FIR filter has up to 256 taps definable by the user.

- *Digital Resampler*—The resampler interpolates between the values output by the FIR filters to give a smooth, spur free I/Q output. It adjusts the sample rate to a known level to eliminate the need for mul-tiple reconstruction filters. The digital resampler allows the DACs to be updated at the clock rate independent of the symbol rate.

- *DAC*—The DAC converts the digital signal to an analog signal with high resolution (14 bits) and low broadband noise. These are not true analog signals since the DAC can only change value in discrete steps.

- *Reconstruction Filter*—This filter smooths out the digital steps and eliminates the sampling spurs introduced by the DAC. Since the DAC runs at the clock rate (25 to 50 MHz), only one low pass filter is required. These filters can run at symbol rates up to 12.5 MHz.

Digital communication standards

The real-time I/Q baseband generator includes six TDMA standards—DECT, GSM, NADC, PDC, PHS, and TETRA. This means you can invoke each of these standards by pressing a few buttons. Option UN8 also supports the data protocol for each of these standards. The screen captures in Figure 3 illustrate the data framing and format for the standards.

Figure 3. Supported TDMA standards with protocols

Example 1
Generating an NADC signal at a frequency of 825.03 MHz and a power of –10.00 dBm

1. Preset[1] the Agilent ESG-D signal generator.
2. Select the Mode of operation to be the **Real-Time I/Q Baseband** generator.
3. Select the modulation format to be **TDMA**.
4. Select the desired standard, for example **NADC**.
5. To set channel, select **More (1 of 2), Freq Channels>, Channel Band>, Mobile, Channel Number,** 10 **Enter, Freq Channels on.**
6. **Return, More (2 of 2), NADC on.** Frequency changes when NADC is turned on.
7. Set the Amplitude to the desired RF power level, for example –10 **dBm**.
8. Turn RF on.

The resulting ESG screen and measured signal are shown in Figure 4.

From here you may configure time-slots and data formats.

Modifying digital communication standards
You can attain other standards by modifying the six TDMA standards offered by the real-time I/Q baseband generator. Some of these modified standards are shown in Table 1.
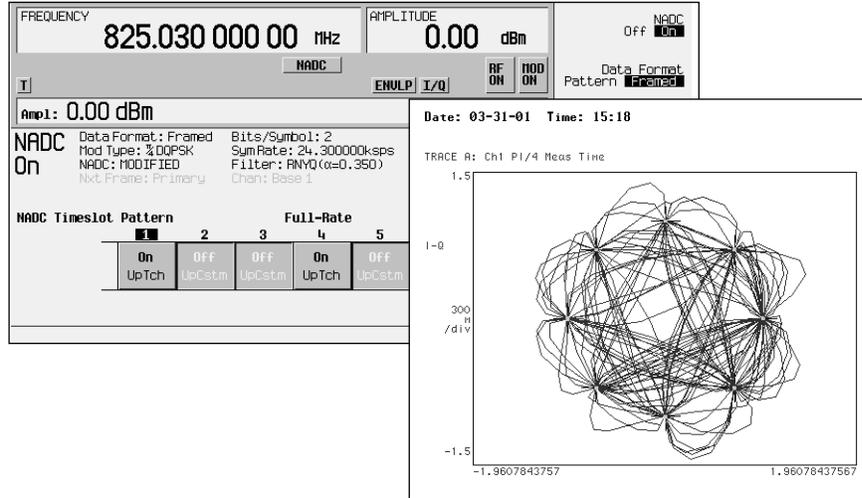
Figure 4. NADC setup and resulting signal

Table 1. Modified communication standards

Standard	Based On	Substitute...	With...
CDPD	NADC	π/4 DQPSK modulation and 24.3 ksps symbol rate	0.5 GMSK modulation and 19.2 ksps symbol rate
PWT	DECT	GFSK modulation 0.5 Gaussian filter	π/4 DQPSK modulation 0.5 root raised cosine filter
	GSM	270.83 ksps symbol rate	Any symbol rate

---

1. Underlined words represent a hardkey function and bold words represent a softkey function.

Example 2
Generating a CDPD signal by modifying an NADC signal

1. See Example 1 (page 5) to select an NADC signal.
2. Turn RF off.
3. Turn NADC **off.**
4. Select **More (1 of 2), Modify Standard>.**
5. Substitute MSK for $\pi/4$ DQPSK by selecting **Modulation Type>, Select>, MSK>.**
6. Return to the modulation menu. Return, Return, Return.
7. Select **Symbol rate** by selecting 19.2 **ksps.**
8. Return to the modulation menu. Return.
9. Change the **Filter** type. **Select> Gaussian**. 0.5 is the default bandwidth factor.
10. Return to the modulation menu. Return, Return, **More (2 of 2)**.
11. Turn **NADC on**.
12. Turn RF on.

Figure 5 depicts the resulting ESG-D display and easily generated modified signal.

Here are some hints for modifying digital communication standards:

• Be aware of modifying modulation types with modulations requiring a different number of bits/symbol.

The real-time I/Q baseband generator does not modify the selected bursting and protocol when modulation with a different number of bits/symbol is selected.

• If the modified modulation's bits/symbol is greater than the standard, the burst shape timing will be off and inconsistent.
• If the modified modulation's bits/symbol is less than the standard, extra zeros will be added to the end of the stream to maintain the bursts and protocol.

Now that you have seen some of the possibilities, the next section will explore each of the building blocks in detail. You'll soon see that the possibilities are endless.
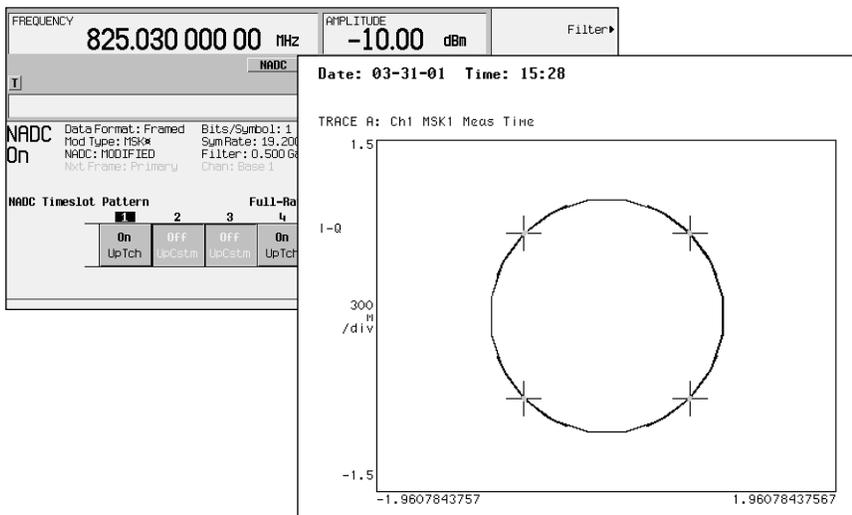
Figure 5. CDPD setup and resulting signal

ESG building blocks

There are four general digital modulation building blocks within the real-time I/Q baseband generator:

- Modulation
- Filter
- Symbol rate
- Data

Each of these can be manipulated to create a digitally modulated signal. This note will discuss each of these building blocks in three sections: 1) selection, 2) definition, and 3) impairment ideas.
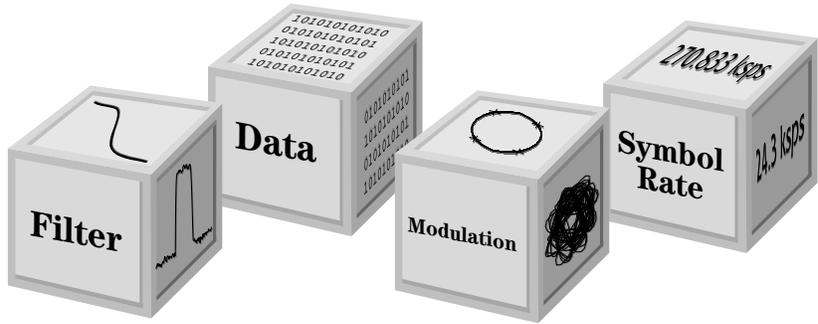
Figure 6. Building blocks of a digitally modulated signal

Modulation building block

The number of digital applications is exploding. Table 2 lists just some of the modulation types required to address the growing set of digital applications.

Table 2. Common modulation formats and applications

Modulation format	Application where used
MSK, GMSK	GSM, CDPD
BPSK	Deep space telemetry, cable modems
QPSK	Satellite, CDMA, NADC, TETRA, PHS, PDC, LMDS, DVB-S, cable (return path), cable modems, TFTS
OQPSK	CDMA, satellite
FSK	DECT, paging, RAM mobile data, AMPS, CT2, ERMES, land mobile radio, public safety
8, 16 VSB	North American digital TV (ATV), broadcast, cable
8PSK	Satellite, aircraft
16 QAM	Microwave digital radio, modems, DVB-C, DVB-T
32 QAM	Terrestrial microwave, DVB-T
64 QAM	DVB-C, modems, broadband set top boxes, MMDS
256 QAM	Modems, DVB-C (Europe), Digital Video (US)

The flexibility offered by the real-time I/Q baseband generator means that you no longer need to wait for a test equipment manufacturer to support your standard. Instead, you can define your own custom signal. The menu map depicts the many modulation choices available. Note that you can either select or define a custom modulation type.

Selecting a modulation

Any of these modulations are available by following the menu map shown in Figure 7.

- **PSK**—BPSK, QPSK, O-QPSK, π4-DQPSK, 8PSK, 16PSK, and D8PSK.
- **MSK**—Add impairments by varying the deviation up to 100 degrees in 0.01-degree increments.
- **QAM**—4, 16, 32, 64, 256.
- **Symmetric FSK**—2, 4, 8, and 16 level FSK; then choose the deviation required. Maximum deviation is 40 MHz.

Defining a modulation

You can build a unique modulation by utilizing two tools, the FSK table editor or the I/Q table editor. These tables map data onto specific absolute modulation states. To map transitions between states, a differential table editor is provided.
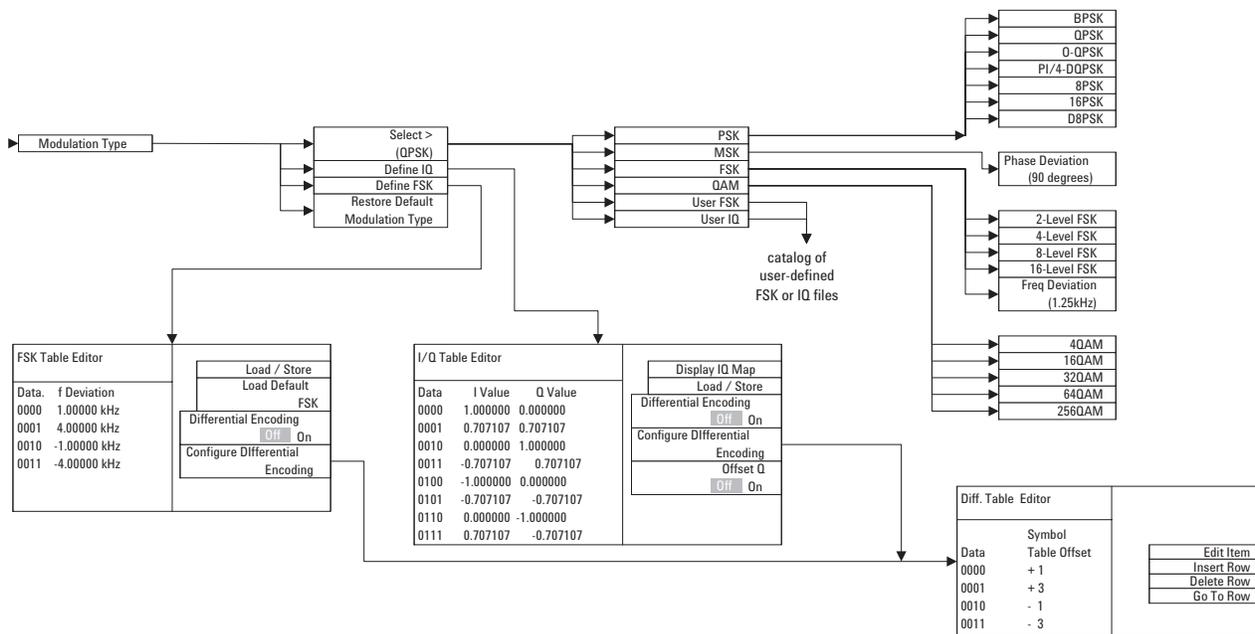
Figure 7. Modulation menu map

Building an asymmetric FSK modulation with the FSK table editor

You can use the FSK table editor to create customized asymmetric FSK modulation of up to 16 levels. Then either apply the custom FSK modulation to one of the TDMA standards or use it to modulate an unframed data transmission. An example of this capability is to create an interfering signal for adjacent channel selectivity testing of FLEX™ pagers. To do this, build a 4-level FSK modulation at 4.8 kHz and 1.6 kHz in the FSK table editor (see Figure 8). Then use this signal to modulate a PN15 data transmission.

In the FLEX™ protocol, each of the levels in 4-level FSK represents a 2-bit sequence, as shown in the dia-gram in Figure 9. Enter these fre-quency deviations into the FSK table editor to create a continuous 4-level FSK signal.

Example 3

Creating a 4-level FSK signal for adja-cent channel testing of FLEX™ pagers

1. Preset the signal generator.
2. Select the Mode of operation to be the **Real-Time I/Q Baseband** generator.
3. Access the FSK table editor. **Custom>, Modulation Type>, Define User FSK>.**
4. Input the values contained in the table below for the frequency deviations.

5. Store the file as 4FSK. **More (1 of 2), Load/Store, Store to File.** Press **Editing Keys, Clear Text.** Press **4FSK, Enter.**
6. Load the file. **Load from Selected file**, highlight 4FSK, **Confirm Load from File**, Return, Return.
7. Turn on Custom Modulation. **Custom On**.
8. Set the Frequency to the desired carrier frequency for the adjacent channel.
9. Set the desired Amplitude.
10. Press RF On. The amplitude of the interferer can then be adjusted to measure the performance of the device under test.

Figure 8. FSK table editor
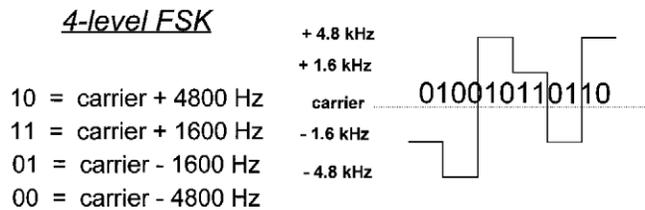
Figure 9. 4-level FSK FLEX™ signaling

Mapping I/Q values with the I/Q table editor

In most digital radio systems, the frequency of the carrier is fixed so only phase and magnitude need to be considered. The phase and magnitude of symbols can be represented as a discrete point in the I/Q plane. *I* represents "in phase" and *Q* represents "quadrature."

By modulating the carrier to one of several predetermined positions in the I/Q plane, you can then transmit encoded information. Each position or state represents a certain bit pattern that can be decoded at the receiver. The mapping of the states at each symbol decision point on the I/Q plane is referred to as a *constellation diagram.*

You can create a unique signal by mapping your constellation diagram into the I/Q table editor (Figure 11) provided with the real-time I/Q baseband generator. The table editor also has a display feature, which provides a quick visual check of the expected I/Q constellation. Example 4 illustrates the utility of this feature in checking data input. The display is shown in Figure 13.

Error Vector Concept

Q

Error Vector

Measured Signal

Ideal (Reference) Signal

ϕ

Phase Error (I/Q error phase)

I

Figure 10. The I/Q diagram

Figure 11. I/Q table editor

Utilizing this I/Q mapping flexibility, you can create unique modulation schemes. For example, a circular constellation arrangement called a STAR QAM is easily implemented and saved for later recall with the real-time I/Q baseband generator. The diagram below shows that the STAR QAM has 16 states or symbols. Four data bits define each symbol. Thus, the diagram and the table are equivalents.

Example 4
Generating the STAR QAM shown below using the I/Q table editor

1. Preset the instrument.
2. Select the Mode of operation to be the **Real-Time I/Q Baseband** generator.
3. Access the I/Q table editor. **Custom>, Modulation type>, Define User IQ>.**
4. Input the values contained in the above table for I and Q using numeric keypad and arrow keys.

5. Check your entry by displaying the I/Q map. **Display I/Q Map.** At this point you can go back and adjust any entry errors.
6. Return to the Store/load menu. Return, **More (1 of 2), Load/Store.**
7. **Store to File, Editing Keys, Clear Text.**
8. Name the file **S T A R. Enter.**
9. Highlight STAR, **Load from Selected File, Confirm Load from File.**
10. Return to the Main menu. Return, Return.
11. Set appropriate Frequency and Amplitude.
12. Turn **Custom on**.
13. Turn the RF on.
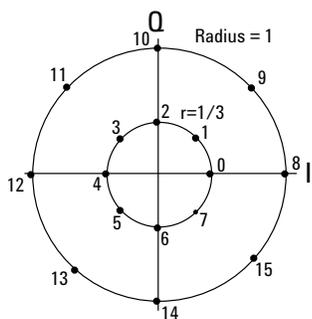
Symbol	Data bits	I Value	Q Value
0	0000	0.333333	0.000000
1	0001	0.235702	0.235702
2	0010	0.000000	0.333333
3	0011	-0.235702	0.235702
4	0100	-0.333333	0.000000
5	0101	-0.235702	-0.235702
6	0110	0.000000	-0.333333
7	0111	0.235702	-0.235702
8	1000	1.000000	0.000000
9	1001	0.707107	0.707107
10	1010	0.000000	1.000000
11	1011	-0.707107	0.707107
12	1100	-1.000000	0.000000
13	1101	-0.707107	-0.707107
14	1110	0.000000	-1.000000
15	1111	0.707107	-0.70710

Figure 12. STAR QAM diagram and table

Figure 13 shows the ESG-D setup and the I/Q display.

Here are some hints in constructing modulations:

- The map is limited to 16 total signal levels for I and Q combined. The readout on the right-hand side of the table tracks the number of I and Q levels utilized. Levels are I or Q values. Figures 14 and 15 show an 8PSK signal built in two different ways. The 8PSK signal in Figure 14 utilizes five of the available sixteen I/Q values. The 8PSK signal in Figure 15 utilizes four of the available sixteen I/Q values.

Following this example, the real-time I/Q baseband generator supports a symmetric 256QAM constellation but not an asymmetric 256QAM constellation, since the asymmetry requires more than sixteen I/Q values.

- The levels do not have to be equally spaced or symmetric in the I/Q plane. For example, the 16QAM modulations shown in Figures 16 and 17 are both possible.
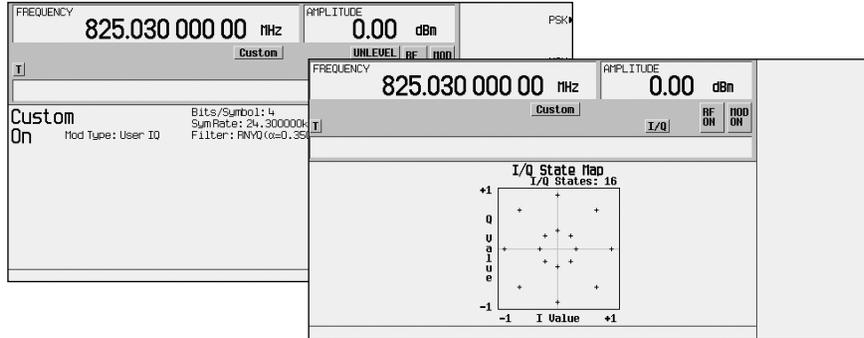
Figure 13. Custom modulation and I/Q display
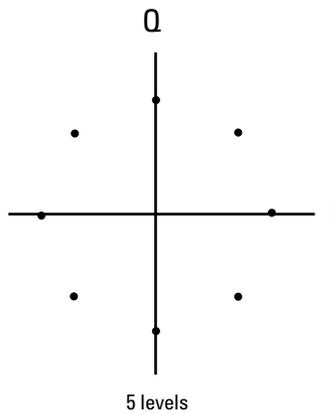
5 levels

4 levels

Figure 14. 8PSK I/Q map with five levels
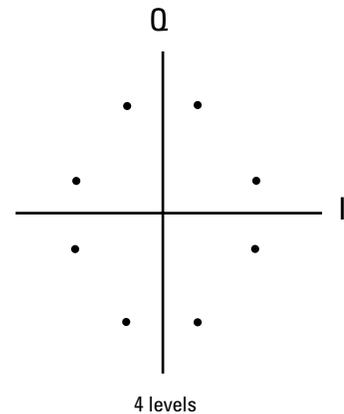
Figure 15. 8PSK I/Q map with four levels

Differential table editor

Normally there is no absolute phase reference at the receiver. There are two ways to compensate for this design trade-off. The first is to send a training sequence to let the receiver know the phase of the carrier. The second compensation is to modulate between relative I/Q states rather than absolute states. In differential modulation, the input bits do not determine the symbol location, but rather the transition between symbols. In some cases there are also restrictions on allowable transitions. This occurs in $\pi/4$ DQPSK where the carrier trajectory does not go through the origin, thus eliminating the need for carrier recovery circuitry within the receiver. With differential modulation, the input data is not represented by absolute symbol locations in the I/Q plane but by changes in symbol locations.

Continuing the STAR QAM example, you can control the state changes such that the receiver does not require an absolute phase reference.

If the absolute symbol location is 0010 (see Figure 12) and the input data is 0001 (see Figure 18), then the resulting symbol will be +1 forward in the I/Q table, or 0011.

Normal & 32-tap modes
(equal I & Q levels)
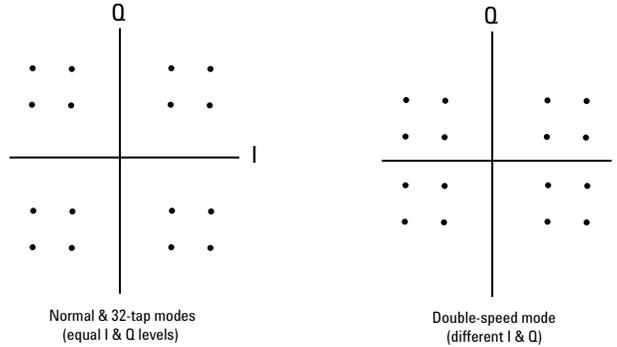
Figure 16. 16QAM I/Q map with even levels

Double-speed mode
(different I & Q)

Figure 17. 16QAM I/Q map with uneven levels

Data	Symbol Table Offset
0000	+0
0001	+1
0010	+2
0011	+3
0100	+4
0101	+5
0110	+6
0111	+7
1000	-8
1001	-7
1010	-6
1011	-5
1100	-4
1101	-3
1110	-2
1111	-1

Figure 18. Symbol offsets for differential STAR QAM signal

13

To implement this transition table in the real-time I/Q baseband generator, simply input the symbol table offset into the differential table editor (Figure 19) after mapping your I/Q constellation.

Impairment ideas

You can manipulate symbol locations to intentionally impair the EVM. By moving symbol locations closer to the origin, as in the case of 16QAM signal (see Figure 20), you can simulate crossover distortion.

Map the desired distorted points as in Example 4 (page 11). By manipulating the symbols, you can test receiver performance under the effects of EVM.

| FREQUENCY | AMPLITUDE |
| 825.030 000 00 MHz | 0.00 dBm |

Custom

T   I/Q   RF ON   MOD ON

Differential State Map

Data	Symbol Table Offset
00000000	+0
00000001	+1
00000010	+2
00000011	+3
00000100	+4
00000101	+5
00000110	+6
00000111	+7
00001000	−8
00001001	−7
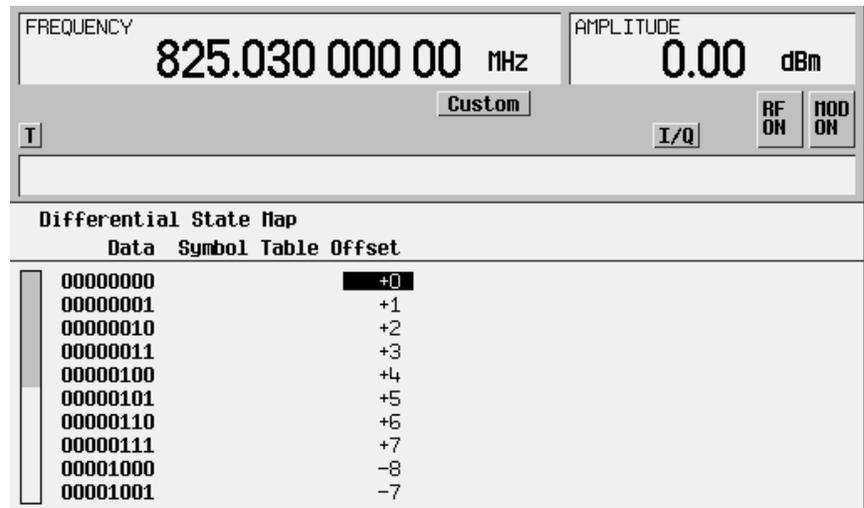
Figure 19. Differential table editor
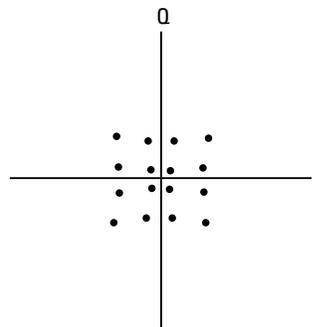
Figure 20. 16QAM distortion

14

Filter building block

FIR filters are used to limit the bandwidth of the input to the I and Q modulators. Several different types of FIR filters exist. The NADC, PDC, PHS, and TETRA standards specify a root Nyquist filter in both the transmitter and the receiver. The combined response is equivalent to a Nyquist filter. The Nyquist filter has an impulse response that rings at the data clock rate so nulls appear at all symbol decision points except the desired one at the center of the impulse response. Since each symbol causes zero response at all undesired decision points, there can be no inter-symbol interference (ISI). The alpha term (α) defined for Nyquist-type filters identifies the frequency cutoff point were the filter response is zero. The closer the alpha term is to zero, the steeper the filter roll off becomes. Alpha gives a direct measure of the occupied bandwidth of the system and is calculated as

Occupied bandwidth = symbol rate x (1 + α)

The NADC and TETRA standards specify an alpha of 0.35. PDC and PHS standards specify an alpha of 0.50. For each of these standards, the Agilent ESG-D series signal generator provides a root Nyquist filter with the designated alphas as the default premodulation filter. The graph in Figure 21 shows the Nyquist impulse response for several values of alpha.

Notice that the half-amplitude point is always at the half-symbol rate. Since all of the information is contained within the half symbol rate bandwidth, alpha is a measure of the *additional* occupied bandwidth.

Another type of FIR filter, which is specified in the GSM and DECT standards, is the Gaussian filter. Gaussian filters typically have more inter-symbol interference than Nyquist filters, but their adjacent channel power performance is better for constant-amplitude modes like MSK, where Nyquist filtering of I and Q is not possible. The bandwidth bit time (BbT) product (similar to α) is defined by the GSM standard as 0.30 and by the DECT standard as 0.50. For each of these standards, the Agilent ESG-D series signal generator provides a Gaussian filter with the designated BbT product as the default premodulation filter.

Fs : Symbol Rate
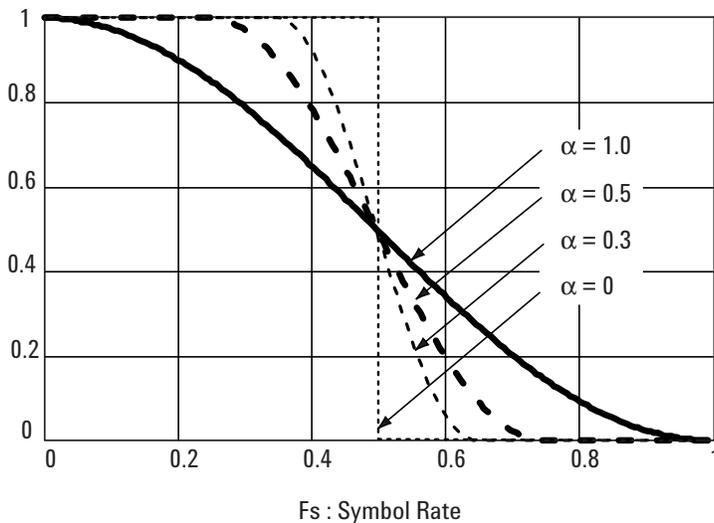
Figure 21. Nyquist filter impulse response

Selecting a filter and the alpha (α) or bandwidth bit time (BbT) product

Due to individual system design requirements, you may decide to change the filter or the filter α or BbT. With the Agilent ESG-D series, this is a very simple step. The menu map depicts your choice of filters. You can adjust the alpha from 0 to 1 and the BbT from 0.1 to 1.

Example 5

Changing the filter alpha

1. Preset the instrument.
2. Select the Mode of operation to be the **Real-Time I/Q Baseband** generator. Access the menu for the desired TDMA standard (for example, PDC). **TDMA, PDC.**
3. Access the Filter menu. **More (1 of 2), Modify Standard>, Filter>.**
4. Select **Filter Alpha.** Enter a new value by using the front panel knob, the up/down arrow keys, or use the numeric keypad and terminate your entry with the **Enter** key.
5. Returning the alpha to the value specified by the standard is as easy as pressing **Restore Default Filter** in the Filter menu.

Defining a filter

Option UN8 provides on-screen capability for creating and modifying FIR filters. The graph in Figure 23 shows the FIR filter parameters.
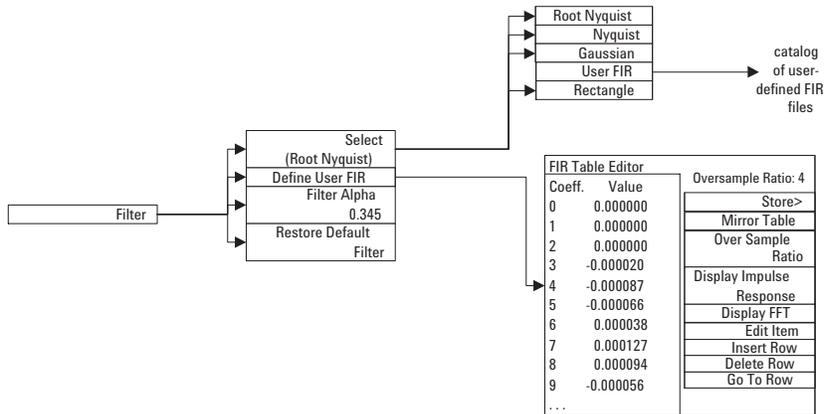
Figure 22. Filter menu map

$\Delta T = 1/fs$
fs = symbol rate x oversampling ratio
OSR = # samples per symbol
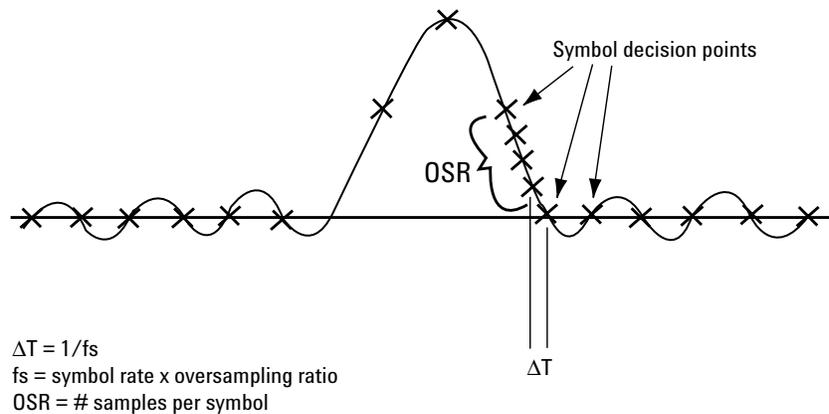
Figure 23. FIR filter parameters

The editor allows a filter length of up to 1,024 taps. The oversample ratio (OSR) is the number of filter taps per symbol. Option UN8 allows oversample ratios from 1 through 32. The maximum combinations of OSR and symbols allowed are 32 symbols with an OSR of 32. The hardware achieves the filtering through a combination of digital and analog implementation. The hardware is actually limited to 256 taps. So any number of taps you put in are digitally resampled to be either 16 times oversampling with 16 symbols or 8 times oversampling with 32 symbols.

The sampling period (Δt) is equal to the inverse of the sampling rate (Fs). The sampling rate is equal to the symbol rate times the oversample ratio. For example, the GSM symbol rate is 270.83 ksps. With an oversample ratio of 4, the sampling rate is 1083.32 kHz and ΔT (inverse of Fs) is then 923.088 ns.

You can create a unique filter by mapping your filter coefficient values into the FIR table editor provided with the real time I/Q baseband generator (Figure 24).

For Example 6, the 32 coefficients shown in Figure 25 were calculated for a sinc function filter with 8 symbols and an oversample ratio of 4.

Figure 24. FIR table editor

Coefficient	Value	Coefficient	Value
0	-0.031435	16	0.974495
1	-0.081126	17	0.784213
2	-0.087135	18	0.470528
3	-0.038980	19	0.139214
4	0.042369	20	-0.108277
5	0.112030	21	-0.213876
6	0.123823	22	-0.180972
7	0.057323	23	-0.064966
8	-0.064966	24	0.057323
9	-0.180972	25	0.123823
10	-0.213876	26	0.112030
11	-0.108277	27	0.042369
12	0.139214	28	-0.038980
13	0.470528	29	-0.087135
14	0.784213	30	-0.081126
15	0.974495	31	-0.031435

Figure 25. FIR coefficients

Example 6
Creating a FIR filter using the FIR table editor

1. Preset the instrument.
2. Select the Mode of operation to be the **Real-Time I/Q Baseband** generator.
3. Access the FIR table editor from any of the TDMA menus (for example, PHS). **TDMA, PHS, More (1 of 2), Modify Standard>, Filter>, Define User FIR>**. The FIR table editor can also be accessed from the custom modulation menu.

4. Input the first 16 filter coefficients (0–15), provided in Figure 25.
5. Press **Mirror Table** and the last 16 coefficients are automatically duplicated from the first 16 in the reverse order.
6. Store the filter in a file. **More (1 of 2), Load/Store, Store To File**.
7. Name the file **Editing Keys, Clear Text, N E W F I R. Enter**.
8. Load the filter file. Highlight NEWFIR, **Load from Selected File, Confirm Load from File**.
9. **Display the impulse response.**
10. Return.

11. **Display the FFT.**
12. Return.

Impairment ideas
One way to introduce adjacent channel impairments is to increase the out-of-channel spurs. Using the FIR table editor, you can truncate the first and last symbols of the filter. The result would typically be only minor changes to the passband with increased out-of-band spurs.
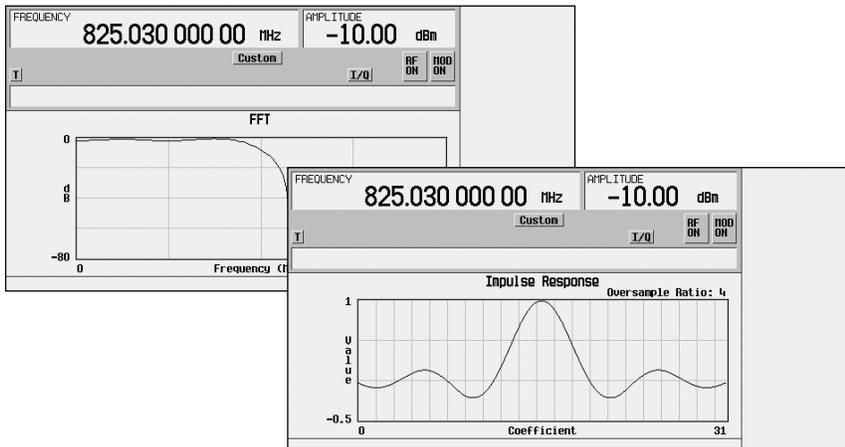
Figure 26. Filter response and FFT of custom FIR filter
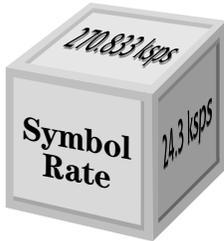
Symbol rate building block

Symbol rate is the rate at which data is modulated onto the carrier. The real-time I/Q baseband generator supports symbol rates up to 12.5 Msymbols/sec. The maximum bit rate is 50 Mbits/sec. The number of bits per symbol will determine the maximum bit rate or symbol rate, as shown in Table 3.

You can select or define the symbol rate easily over the front panel.

Selecting a symbol rate

The bit rate is automatically determined when you select a standard. For example, the symbol rate for GSM is 270.833 ksps and PDC is 21 ksps.

Defining a symbol rate

You may alter the given symbol rate to match your application requirements. Adjusting the symbol rate affects the occupied bandwidth proportionally. Doubling the symbol rate will double the filter bandwidth. The standard for a NADC FIR filter specifies a symbol rate of 24.3 ksps, and a filter alpha of 0.35. The resulting RF bandwidth is 32.8 kHz. Adjusting the symbol rate to 48.6 ksps with the same filter alpha doubles the RF bandwidth to 65.6 kHz. Figure 28 illustrates this relationship.

Table 3. Data and symbol rates

Bits/symbol	Max. symbol rate (Msymbols/sec)	Max. data rate (Mbits/sec)
1	12.5	12.5
2	12.5	25
3	8.33	25
4	12.5	50
5	10	50
6	8.33	50
7	7.14	50
8	6.25	50
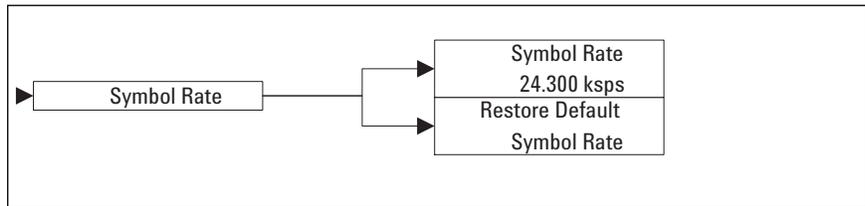
Figure 27. Symbol rate menu map
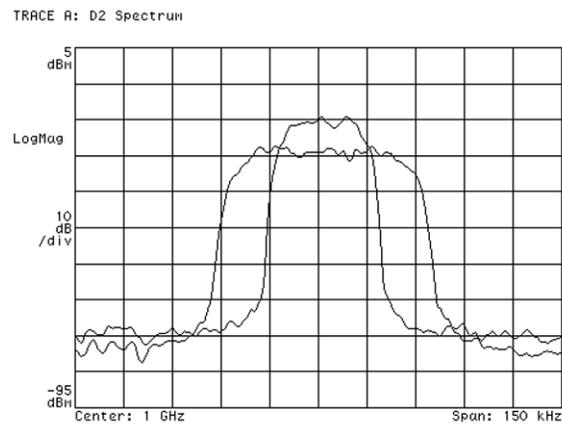
Figure 28. Determining filter bandwidth

19

Occupied bandwidth = (1 + α) x symbol rate/2
RF bandwidth = 2 x occupied bandwidth
= (1 + α) x symbol rate

Example 7
Changing the symbol rate

1. <u>Preset</u> the instrument.
2. Select the <u>Mode</u> of operation to be the **Real-Time I/Q Baseband** generator.
3. Press **TDMA, NADC, More (1 of 2), Modify Standard>**.
4. Select **Symbol rate**. Enter a new value by using the front panel knob, the up/down arrow keys, or use the numeric keypad and terminate your entry with the **ksps**.

Impairment ideas
Simulate a clock drift by changing the symbol rate. Simulate a 0.08% clock drift of 0.008 symbols per symbol on an NADC signal by changing the symbol rate from 24.3 ksps (as specified in the standard) to 1.008 x 24.3 = 24.32 ksps.

Example 8
Simulating a 0.008 symbol/symbol clock drift on an NADC signal

1. Go through Example 1 (page 5) to select an NADC signal.
2. Turn <u>RF off</u>.
3. Turn NADC **off**.
4. Select **More (1 of 2), Modify standard>**.
5. Change the symbol rate by selecting **Symbol Rate**.

6. Type in the number 24.32 and select **ksps**.
7. Return to the NADC menu. <u>Return</u>, <u>Return</u>, **More (1 of 2)**.
8. Turn NADC **on**.
9. Turn <u>RF on</u>.

The Agilent ESG-D series screen shows the new symbol rate. The signal analyzer shows the effect of the change on the EVM. This "v" plot is very characteristic of clock drift.
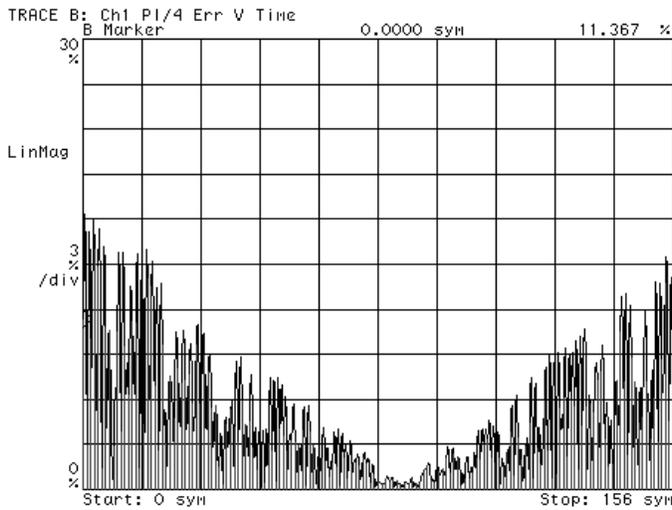
Figure 29. Effects of 0.008 symbol/symbol clock drift

Data building block

The data building block's flexibility is only limited by the data that you download. Data may be internally or externally generated. When full protocol is desired, configure frames and timeslots as different types of traffic or control channels.

Selecting data

Any of these data types are internal to the Agilent ESG-D:

- 4-128 bit repeating patterns
- PN9
- PN11
- PN15
- PN20
- PN23

When working with standard TDMA formats, PN9 and PN15 sequences are available for generated framed signals.

Defining data

Define data by either downloading data into pattern RAM or the user file. External data may also be provided "real-time" using data, data clock, and symbol sync inputs. This topic is covered in detail in the product note "Generating and Downloading Data to the Agilent ESG-D RF Signal Generator for Digital Modulation," publication number 5966-1010E.
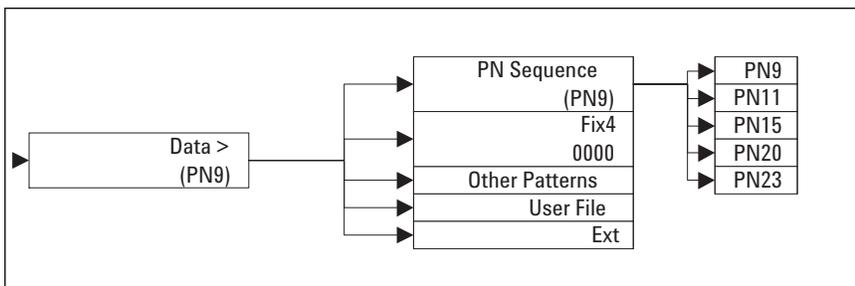
Figure 30. Data menu map

Use any of the four building blocks included with Option UN8, real-time I/Q baseband generator, to build your own modulation. With this flexibility you can develop new circuits or characterize components rapidly, without waiting for new firmware implementations. Simply select your own modulation, filter, symbol rate, and data.

For additional flexibility, Option UND adds a dual arbitrary waveform generator to the ESG-D series. Consult your Agilent representative or our web page at www.agilent.com/find/esg for more information.

Appendix 1

Consider this a road map to help you navigate through the flexibility designed into the real-time I/Q baseband generator.
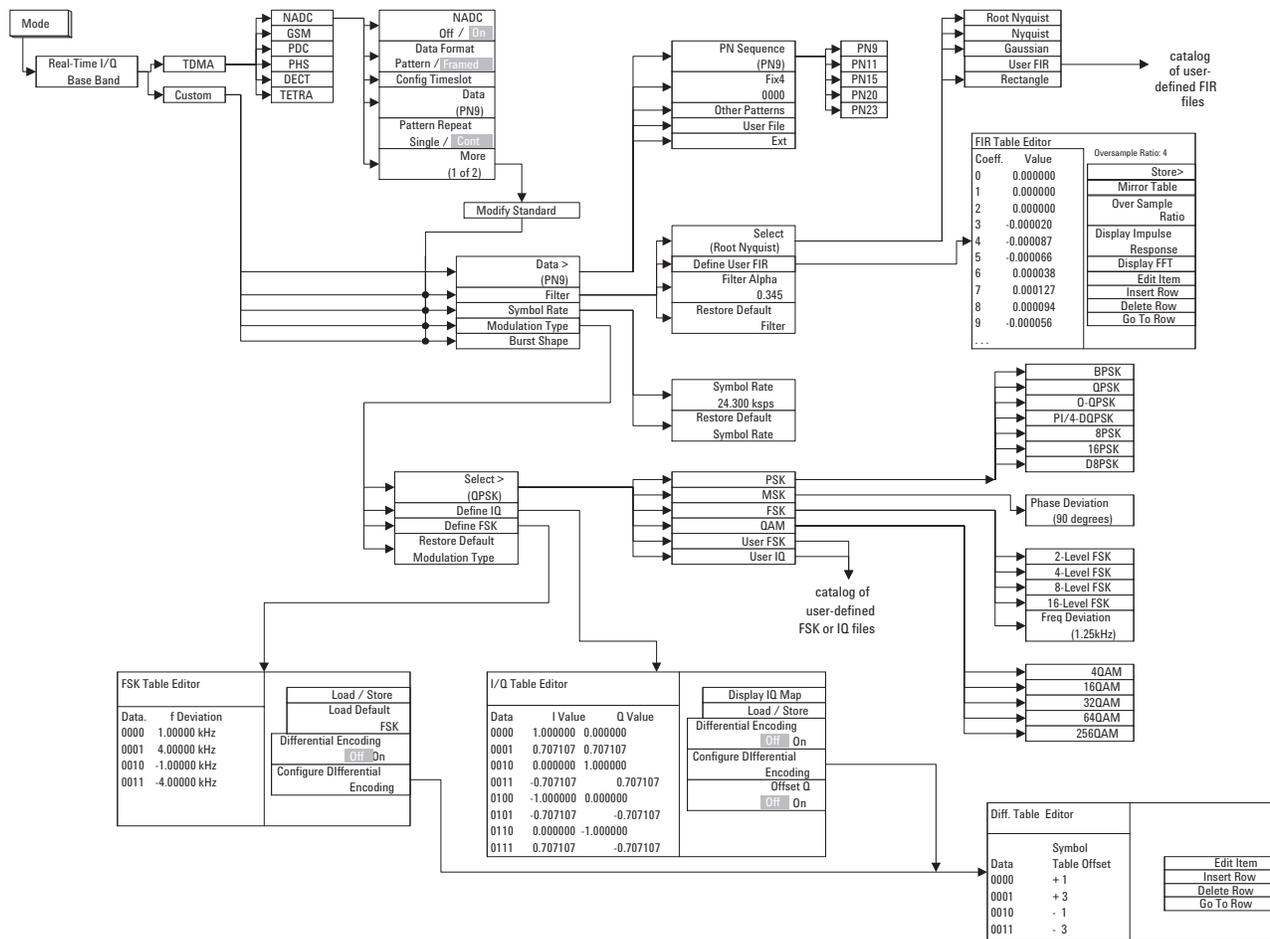
Figure 31. Complete menu map for Option UN8

Appendix 2

This table gives an overview of the most common communications systems in use today and the key specifications that define them. Many of the specifications including modulation, symbol rate, and filter can be varied or defined from scratch using the real-time I/Q baseband generator.

	GSM900	NADC	PDC	CDMA
Geography	Europe	North America	Japan	North America, Korea, Japan
Introduction	1992	1992	1993-1994	1995-1997
Frequency Range EGSM 925-960 MHz	935-960 MHz down 890-915 MHz up 880-915 MHz	869-894 MHz down 824-849 MHz up 1777-1801 MHz down	810-826 MHz down 940-956 MHz up 832-834, 843-846, 1429-1453 MHz up	824-849 MHz (US) 869-894 MHz (US) 860-870 MHz (Japan) 887-889, 898-901, 915-925 MHz (Japan)
Data Structure	TDMA	TDMA	TDMA	CDMA
Channel per Frequency	8-16	3-6	3-6	32-64 (Dyn. adapt)
Modulation	0.3 GMSK (1 bit/symbol)	$\pi/4$ DQPSK (2 bits/symbol)	$\pi/4$ DQPSK (2 bits/symbol)	Mobile: QPSK Base: OQPSK (1 bit/symbol)
Speech CODEC	RELP-LTP 13 Kbits/s	VSELP 8 Kbits/s EFR	VSELP 8 Kbits/s	8 Kbits/s var rate CELP 13 kbit/s var rate CELP
Mobile Output Power	3.7 mW to 20W	2.2mW to 6W	.3W to 3W	10nW to 1W
Modulation Data Rate	270.833 Kbits/s (1 bit/symbol)	48.6 Kbits/s (2 bits/symbol)	42 Kbits/s (2 bits/symbol)	9600/14,400 bps data; 1.2288 Mb/s spreading
Filter	0.3 Gaussian	SQRT raised cosine $\alpha = .35$	SQRT raised cosine $\alpha = .50$	Chebychev low pass (FIR)
Channel Spacing	200 kHz	30 kHz	50 kHz 25 kHz interleave	1.23 MHz
Number of Channels	124 frequency ch. w/8 timeslots per ch. (1000)	832 frequency ch. w/3 users per ch. (2496)	1600 frequency ch. w/3 users per ch. (4800)	19-20 frequencies
Est # of Subscribers by year 2000	15-20 million	35-40 million (8.9 million 9/92)	5 million	
Source	GSM Standard	IS-54	RCR Spec Std 27B	IS-95 spec
Service	Public Cellular	Public Cellular	Public Cellular	Public Cellular

Figure 32. Look-up table of communications systems

	DCS1800	PHS	DECT	TETRA
Trunked Radio			Trans European	
Geography	Europe	Japan/China	Europe/China	Europe
Introduction	1993	1993 Private office 1995 Public	1993	1995
Frequency Range 1710-1785 MHz down	1.7-1.9 GHz up/down 1805-1880 MHz up	1895-1918 MHz 1.9, 1.93 GHz (China)	1.897-1.913 GHz < 1 GHz 1.9, 1.93 GHz (China)	450 MHz
Data Structure	TDMA	TDMA/TDD	TDMA/TDD	TDMA
Channel per Frequency	8-16	4-8	12	4
Modulation	0.3 GMSK (1 bit/symbol)	π/4 DQPSK (2 bits/symbol)	0.5 GFSK ±202-403 kHz dev (1 bit/symbol)	π/4 DQPSK
Speech CODEC	RELP-LTP 13 Kbits/s	ADPCM 32 Kbits/s	ADPCM 32 Kbits/s	Includes channel & speech coding 7.2 Kbits/s
Mobile Output Power	250 mW to 2W	10 mW	250 mW	
Modulation Data Rate	270.833 Kbits/s	384 Kbits/s	1.152 Mbit/s	19.2 Kb/s
Filter	0.3 Gaussian α = .50	SQRT raised cosine	0.5 Gaussian raised cosine	α = 0.4 SQRT
Channel Spacing	200 kHz	300 kHz	1.728 MHz	25 kHz
Number of Channels	3000-6000		10 carrier frequencies w/12 users per frequency (120)	
Est # of Subscribers by year 2000	4-13 million	6.5-13 million		
Source	prI-ETS 30 176 prETS 300 175-2	RCR spec Std 28 China-First News Release 8/15/96	CI Spec., Part 1, Rev 05.2e China-First News Release 8/15/96	Mobile Europe Magazine 1/92
Service	Personal Communications	Cordless Telephone Personal Communications	Wireless PBX	Trunked system Adj. ch. sel > 60 dB

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

Agilent Technologies' Test and Measurement Support, Services, and Assistance
Agilent Technologies aims to maximize the value you receive, while minimizing your risk and problems. We strive to ensure that you get the test and measurement capabilities you paid for and obtain the support you need. Our extensive support resources and services can help you choose the right Agilent products for your applications and apply them successfully. Every instrument and system we sell has a global warranty. Support is available for at least five years beyond the production life of the product. Two concepts underlie Agilent's overall support policy: "Our Promise" and "Your Advantage."

Our Promise
"Our Promise" means your Agilent test and measurement equipment will meet its advertised performance and functionality. When you are choosing new equipment, we will help you with product information, including realistic performance specifications and practical recommendations from experienced test engineers. When

you use Agilent equipment, we can verify that it works properly, help with product operation, and provide basic measurement assistance for the use of specified capabilities, at no extra cost upon request. Many self-help tools are available.

Your Advantage
"Your Advantage" means that Agilent offers a wide range of additional expert test and measurement services, which you can purchase according to your unique technical and business needs. Solve problems efficiently and gain a competitive edge by contracting with us for calibration, extra-cost upgrades, out-of-warranty repairs, and on-site education and training, as well as design, system integration, project management, and other professional services. Experienced Agilent engineers and technicians worldwide can help you maximize your productivity, optimize the return on investment of your Agilent instruments and systems, and obtain dependable measurement accuracy for the life of those products.

By internet, phone, or fax, get assistance with all your test and measurement needs.

Online Assistance
www.agilent.com/find/assist

Phone or Fax
United States:
(tel) 1 800 452 4844

Canada:
(tel) 1 877 894 4414
(fax) (905) 206 4120

Europe:
(tel) (31 20) 547 2323
(fax) (31 20) 547 2390

Japan:
(tel) (81) 426 56 7832
(fax) (81) 426 56 7840

Latin America:
(tel) (305) 269 7500
(fax) (305) 269 7599

Australia:
(tel) 1 800 629 485
(fax) (61 3) 9272 0749

New Zealand:
(tel) 0 800 738 378
(fax) (64 4) 495 8950

Asia Pacific:
(tel) (852) 3197 7777
(fax) (852) 2506 9284

Product specifications and descriptions in this document subject to change without notice.

Agilent Technologies