Tektronix

User Manual

MCIQ
Multi-Carrier I/Q
Generation Package

070-A883-50

The MCIQ, Multi-Carrier I/Q Generation Package
is a free software. It is provided on an As-Is basis
without any warranty.

Version 1.0: June 2002

Table of Contents

1. Introduction

MCIQ is a software package devoted to the synthesis of complex digitally modulated signals to be effectively generated through arbitrary waveform generators (AWG). Among other capabilities, it is possible to:

1) Define multiple RF/IF carriers in a single waveform. Each carrier can be independently defined with parameters such as carrier frequency, symbol rate, modulation type, base band filtering, data source, etc.
2) Define base band I and Q signals.
3) Create user defined symbol maps with powerful edition tools.
4) Use a variety of modulation schemes such as BPSK, QPSK, OQPSK, DQPSK, QAM16, QAM32, QAM64, QAM128, QAM256, 8PSK, O-8PSK, 8-VSB, 16-VSB, GMSK, FSK, AM, FM, and PM.
5) Create DVB-C channel coded signals for component testing and head-end emulation.
6) Synthesize CDMA (IS95) and W-CDMA (IMT2000, UMTS) downlink signals including any number of pilot, user, and synchronization channels. Data, spreading factor, channel number and other parameters are adjustable individually for each channel.
7) Use a variety of user-created information such as data, symbol sequences, modulating signals, base band filters and symbol maps.
8) Impairments can be applied to any signal. Impairments supported include quadrature error, quadrature imbalance, and carrier feed-through.
9) Analyze frequency, time, statistical, and modulation domain characteristics of the created signals.
10) Target the complete range of arbitrary waveform generators from Tektronix including the AFG300, AWG400, AWG500, AWG500, AWG600, AWG700, and AWG2000 series through file, GPIB and Ethernet/Internet (TCP/IP) transfers.

In addition to that, the software package takes care of all the details to completely eliminate all the wrap-around effects found in arbitrary waveform generators providing seamless signals that can be played-back continuously without any discontinuity or glitch in the time, frequency, modulation, and channel coding domains.

1.1 System Requirements

- PC compatible computer running Windows 95/98, Windows NT, Windows 2000 and at least 32 Mbytes of RAM.
- 10 Mbytes of free hard disk. (More if signals are stored in local files).
- Ethernet and/or GPIB required if a direct connection to the target instrument is planned. The GPIB card must be fully compatible with National Instruments 488.2 function calls.

1.2 Installation

Just run **setup.exe** and follow the on-screen instructions.

2. Using the MCIQ application
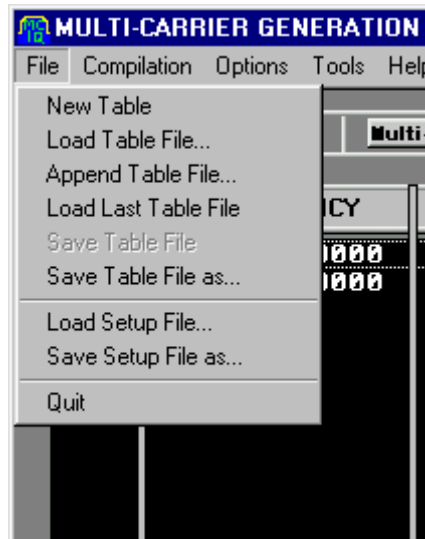
2.1 The main window
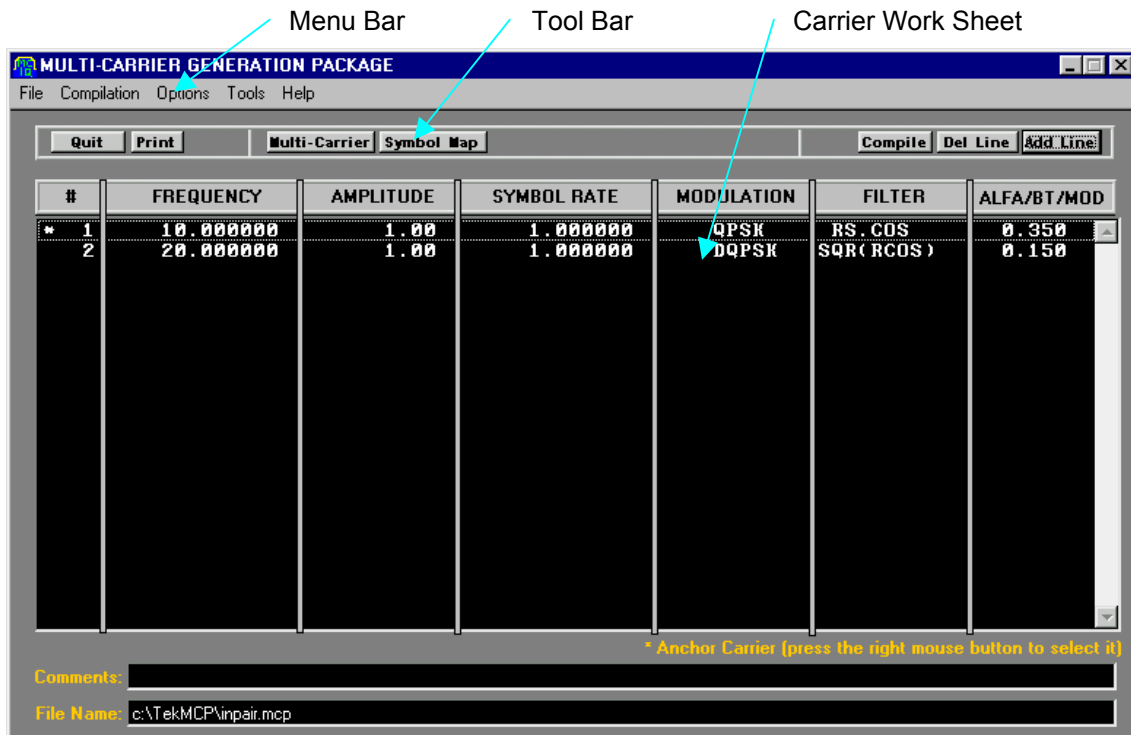
Waveforms are defined by adding all the required carriers to the project. The main window provides access to all the edition and configuration functions. It is composed by:

- Menu Bar
- Tool Bar
- Carrier Work Sheet
- Comments edition field
- File Name Information Field

2.2 The Menu Bar

2.2.1 File Menu

The file menu provides access to all the application file operations.

New Table: It clears the complete work sheet to start creating a new table.

Load Table File…: It opens a file selection window to select any existing carrier table file. It also deletes any existing information.

Append Table File…: It opens a file selection window to select any existing carrier table file. It appends the information contained in the selected file to any existing information in the work sheet.

Load Last Table File: It opens the last file open or saved by the user.

**Save Table File**: It saves the present table information preserving its previous name.

Save Table File as…: It saves the present table information after giving it a name.

Load Setup File…: It opens a file selection window to select any existing setup file. It overrides any existing setup information. The software automatically saves the active setup when closing the application and loads it when the application is started again.

Save Setup File as…: It saves the present setup information after giving it a name.

Quit: It closes the application. The present configuration (setup) is saved automatically when closing the application.

2.2.2 Compile Menu
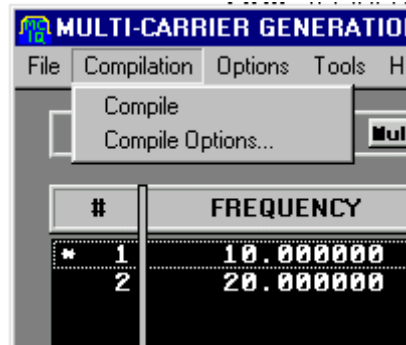
This menu provides access to all the compilation operations. The compilation process consists in a series of steps. The progress for each step is shown at an information window. The steps are:

-   FSK preprocessing: FSK kind of signals (including GMSK) requires a previous process to avoid phase-related wrap-around artifacts. Calculations in this step only involve the FSK-like carriers.
-   Compilation: The complete output waveform is calculated and normalization values are obtained. After this step the Visualization Window is updated. Calculations are performed for all the carriers in the list.
-   Transfer steps: Depending on the value of the check boxes in the Compilation Options Window, there are from none to three transfer steps. Each one involving one of the possible components: Combined Waveform (RF/IF), Base Band I, and Base Band Q. Files are effectively created in the local drive or the target instrument during these steps.
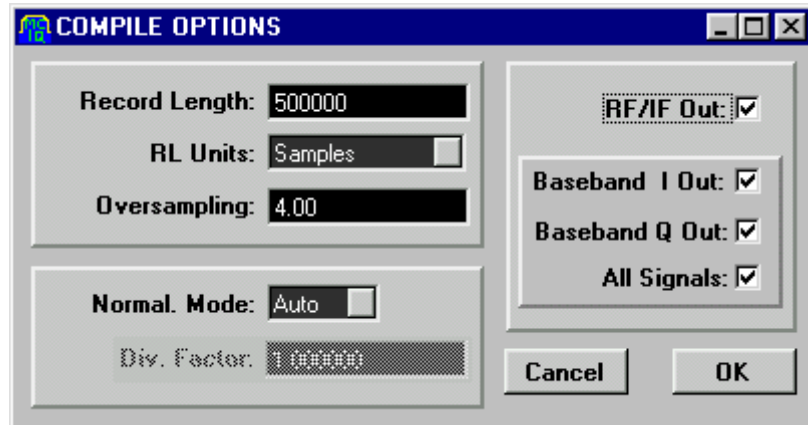
These are the possible choices in this menu:

Compile: It starts the waveform compilation. It is only active when there is something to compile.

Compile Options: It opens the Compile Options window

2.2.2.1 Compile Options Window

The user can define a set of compilation parameters to meet the requirements of the application.

These are the parameters to be defined:

Record Length: This is the time domain length of the resulting waveform. It can be expressed in convenient units. The actual length will be adjusted depending on the target instrument requirements such as maximum record length and others (see the Instrument Options section of this manual).

RL Units (Record Length Units): Record length can be defined in samples or symbols for a specific carrier of the signal called the Anchor Carrier (see the Carrier Table Edition section of this manual).

Oversampling: The MCIQ package will calculate the output clock frequency by using this number. This is roughly the number of samples per period for the maximum frequency carrier in the table.

Normal. Mode (Normalization Mode): In the Auto mode, the compilation process looks for the maximum values of each of the resulting signals and use them to normalize all the samples to completely fill the available dynamic range in the target instrument. In the manual mode the user defined Div. Factor will be used instead. Manual mode is useful when the user plans to create sequences of consistent signals where peak values can be different.

Div. Factor (Division Factor): See Normal. Mode.

RF/IF: This check box selects the RF/IF waveform to be effectively created in the target instrument or file.

Baseband I Out: This check box selects the I (In-phase) base band waveform to be effectively created in the target instrument or file. If there is more than one carrier in the carrier table, the anchor carrier I baseband signal will be created.

Baseband Q Out: This check box selects the Q (Quadrature) base band waveform to be effectively created in the target instrument or file. If there is more than one carrier in the carrier table, the anchor carrier Q base band signal will be created.

All Signals: This check box enables the creation of a combined base band signal made of the combination of all base band signals in the carrier list. This is especially useful for CDMA/W-CDMA signals, where multiple channels share the same carrier. All the information shown in the Visualization Display will reflect this combined waveform.

All the parameters contained in the Compilation Window belong to the MCIQ setup information, so they will be affected by the Load Setup and Save Setup actions.

When no check boxes are checked the compilation will take place without creating any waveform file in then target. It can be useful for visualization or analysis purposes.
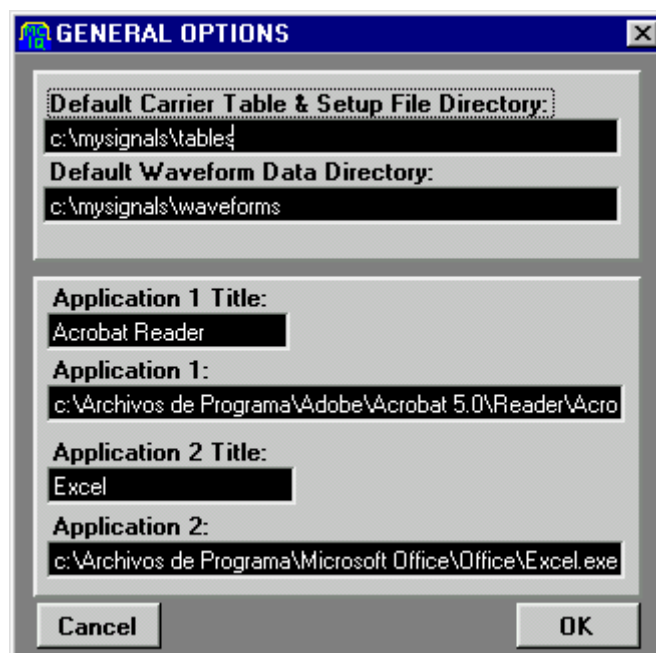
2.2.3 Options Menu
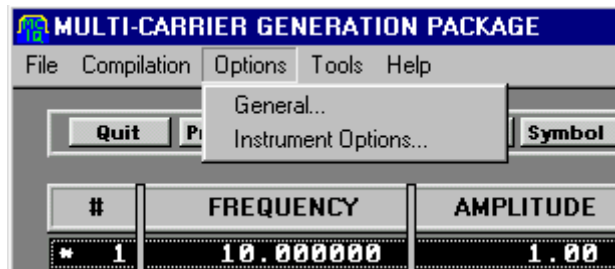
General…: It opens the General Options window.

Instrument Options…: It opens the Instrument Options Window

2.2.3.1 General Options Window

- **Default Carrier Table & Setup File Directory**: User defined default directory for the Table and Setup files.
- **Default Waveform data Directory**: User defined default directory for Waveform files when the target is an OS-accessible file (such a file in the local computer).
- **Application 1 Title/ Application 2 Title**: The user can define up to two applications that can be directly accessed from the Tools Menu. It can be useful when using external programs to define/process/visualize information related with MCIQ application. The title field contains the name shown at the menu for each application.

- **Application1/Application2**: These fields contain the complete path to the target applications.

All the information contained in the General Options menu belongs to the MCIQ setup information, so they will be affected by the Load Setup and Save Setup actions.

2.2.3.2 Instrument Options Window
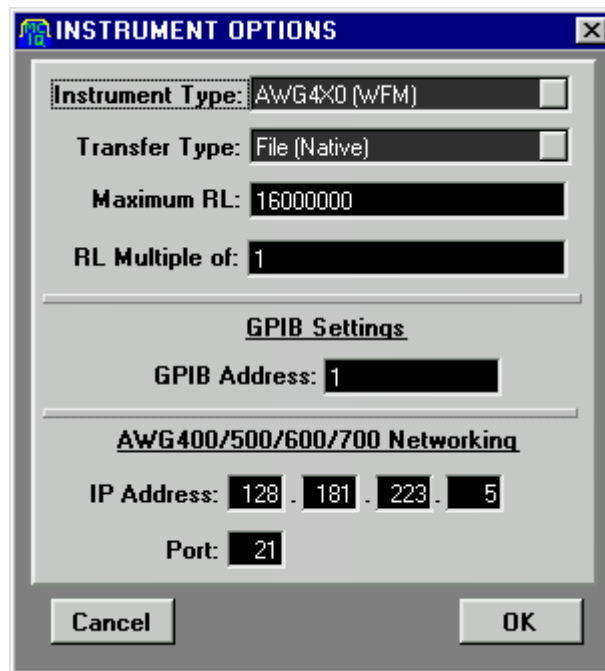
- **Instrument Type**: This selection list allows the selection of the target for the compiled waveforms. The user can choose among a variety of arbitrary waveform generators and generic files. Generic files can be used to export results to other tools as spreadsheets or mathematical analysis packages
- **Transfer Type**: This selection list allows the selection of the target' interface. It can be:
  - **GPIB**: Any local compatible GPIB interface.
  - **File (GPIB)**: A local file containing an image of all the commands necessary to create the waveform in the target instrument. Any GPIB interactive communication tool will allow the user to effectively transfer the information to the target instrument.

- **File (Native)**: A local file in the target instrument native format will be created. Native format refers to the format used by the target instrument to store data in its local hard drive/ floppy disk / non-volatile memory. A floppy disk, a NFS drive or an FTP session could be used to transfer the file to the target instrument.
- **Network**: A native format file will be directly created in the target instrument by opening an FTP session in the target instrument through a network connection.

- **Maximum RL** (Maximum Record Length): This is the maximum record length available in the target instrument. There is not a default value defined automatically when the user chooses a given instrument, so it can be changed to any desired value. This practice accommodates future changes/additions.
- **RL Multiple of** (Record Length Multiple of): It defines the multiplicity required by the target instrument. Some arbitrary waveform generators require record length to be a multiple of a given number. There is not a default value defined automatically when the user chooses a given instrument, so it can be changed to any desired value. This practice accommodates future changes/additions. Actual record lengths are rounded to the nearest multiple.
- **GPIB address**: The primary address for the target instrument.
- **IP Address**: IP address of the target instrument used in Network-TCP/IP connections.
- **Port**: TCP/IP port address. Most instruments require port address to be 21, but the user can modify it.

All the information contained in the Instrument Options menu belongs to the MCIQ setup information.

2.2.4 Tools Menu
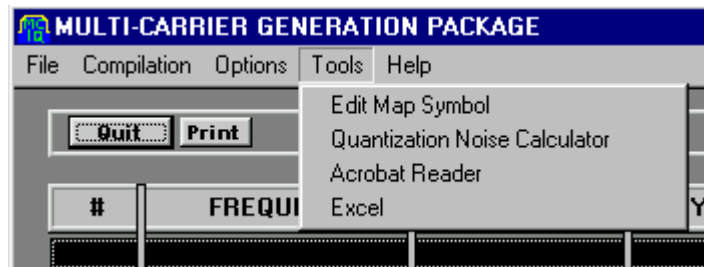
The Tools Menu provides access to a variety of standard and user defined tools.

- **Edit Map Symbol**: It opens the Map Symbol Edition tool (see the Symbol Map Edition Tool of this manual).
- **Quantization Noise Calculation**: It opens the Quantization Noise Calculation tool.
- **User Defined Tool 1 & 2**: External tools defined by the user (see the General Options Menu section of this manual).

3. Creating a Carrier Table

To create a carrier table, just add lines to the carrier list window. To do so, use the **Add Line** button or alternatively the **Multi Carrier Assistant** button. Add Line will create a single line while the Multi-Carrier Assistant will create a collection of similar carriers at once.

3.1 Symbol Edition Window

The symbol edition window opens after hitting the Add Line button (a new line will be created) or after double clicking one of the existing lines in the Carrier List Window (this line will be open for edition).

The Symbol Edition Window shows all the information related to a given carrier. All the parameters are grouped logically in different areas:

Carrier:

- **Amplitude**: The amplitude for the carrier. Amplitude is a dimensionless linear number used to adjust the relative amplitude of the carriers. Actual amplitude for each carrier depends on the Div. Factor, the output amplitude in the target instrument and its frequency response. The amplitude usually refers to the level of the projection of the highest symbol in one of the axis.
- **Frequency**: The carrier's frequency in MHz. It can be defined with one hertz resolution. The compilation process will define the actual frequency in order to avoid any wrap-around artifact. See the Anchor Carrier discussion in this section for details.
- **Phase**: Initial phase of the carrier expressed in degrees.
- **Data Source**: This selection list let the user select between internally generated pseudo random binary sequences (PRBS) and externally defined data files. Data source is no active when external files (FILE1 and FILE2) are selected as the Modulation Mode.
- **PRBS**: This button opens the PRBS Edition Window. It is activated only when Data Source is active and PRBS is selected. See the PRBS Edition Window Section below.

Modulation:

- **Symbol Rate**: Symbol Rate for this carrier expressed in MBauds (MSymbols/S). For analog modulations (AM, FM, and PM) it contains the frequency of the modulating signal. For external envelope files (FILE1) it expresses the sampling frequency for the input data. It can be defined with one hertz resolution. The compilation will define the actual frequency process to avoid any wrap-around artifact. See the Anchor Carrier discussion in this section for details.

- **Modulation Mode**: This is selection list to choose among all the internally defined modulation schemes or from externally defined files. External files can be defined for three different situations: samples (FILE1), symbols (FILE2), and symbol maps (FILE3). Samples consist in the time-domain, base band envelope for the carrier. The MCIQ package interpolates the required time samples based in the input sampling rate (defined in the symbol rate field) and using an ideal interpolator (sinc, sin x / x). Symbol consists in a file containing a symbol amplitude list. The actual time domain base band signal will be created by the MCIQ package based in the Symbol Rate and the Base Band Filter selected for this carrier. Symbol Map uses a user-defined file, which contains any symbol map required for the application. Using this information along with the Data, Filter Type, and Symbol Rate Parameters will generate the actual waveform data. Selecting any file-based mode activates the corresponding file selection area in the Symbol Edition Window.
- **Filter Type**: This is a selection list to choose among the internally define base band filters or from externally defined filters. This field is deactivated when analog or FILE1 (samples) modulation modes are selected. It is automatically programmed to Gaussian when GMSK is selected. Filter types available are NONE (no filtering), RAISED COSINE, SQUARE ROOT OF RAISED COSINE, GAUSSIAN1 (Input for the filter is a square pulse), GAUSSIAN2 (Input for the filter is a Dirac's Delta), TRIANGULAR, EDGE, and FILE. Selecting FILE activates the corresponding file selection area in the Symbol Edition Window.
- **FSK Peak Deviation**: This field is activated when any FSK modulation scheme is selected in the Mod. Mode field. It is expressed in KHz.
- **Alfa/BT/Mod. Index**: This field contains different parameters depending on the modulation mode and the filter type values. For Raised Cosine and Square Root of Raised Cosine filters it contains the alfa parameter of the filter. For gaussian filters it contains the BT (Bandwidth*Symbol Period) products for the filter. For analog modulations it contains the modulation index (% for AM, Peak Deviation for FM in KHz, and Peak Deviation for PM in degrees).

- **Conv. Length (Symbols):** Convolution length expressed in symbol periods. This parameter is used to control the quality of the calculation performed to obtain the base band signals. The more consecutive symbols are used for convolution the more signal quality. This parameter also influences calculation time so usually the user must make a trade off between calculation speed and quality. This parameter must be an odd integer. If an even number is typed, the MCIQ package will assign the closest larger odd integer to this parameter.
- **Window Type**: This selection list will allow the user selecting a time domain window to apply to the filter impulse response. It is useful to limit the spectral leakage, especially when short Conv. Lengths are used. It improves the spectral behavior of the signal while it deteriorates the EVM (error vector magnitude) parameter.
- **Edit Impairment**: This button opens the Impairment Edition window. (see the impairment edition section of this manual for further information).

CDMA Area:

The CDMA area groups all the parameters needed in the definition of down-link CDMA (IS95) and W-CDMA (IMT2000, UMTS) signals. These parameters are activated or deactivated depending on the modulation scheme selected by the user. There are three different modulation schemes influencing this area: IS95 DL, DPCH DL (UMTS), and C-CCPCH/SCH DL (UMTS).

- **Chan. #**: This field codes the desired channel number for the target carrier by assigning the corresponding Walsh Code (IS95) or OVSF (UMTS) channelization code. Ranges are 0-63 for IS95 DL and 0-511 (depending on the spreading factor) for DPCH DL (UMTS).
- **SF**: Spreading Factor. It is active only for DPCH DL (UMTS). It ranges from 2 to 512.
- **Scrambling Code Group**: It contains the scrambling code group number for the target carrier. It is used only with UMTS modulation schemes. It ranges from 0 to 63.

- **Primary Scrambling Code**: It defines the specific primary scrambling code within the previously defined scrambling code group. It is used only with UMTS modulation schemes. It ranges from 0 to 7. To calculate the absolute primary scrambling code just use the following formula:

$$SC_{abs}=8xSCG+PSC.$$

- **Secondary Scrambling Code**: It defines the specific secondary scrambling code associated to the previously defined primary scrambling code. It is used only with UMTS modulation schemes. It ranges from 0 to 15. To calculate the absolute scrambling code just use the following formula:

$$SC_{abs}=(8xSCG+PSC)x16+SSC.$$

- **P-SCH Gain (dB)**: This option is active only when the C-CCPCH/SCH DL (UMTS) is selected as the modulation scheme. This parameter controls the amplitude of the Primary Synchronization Code relative to the C-CCPCH portion of the time slot. It is expressed in dB.
- **P-SCH Gain (dB)**: This option is active only when the C-CCPCH/SCH DL (UMTS) is selected as the modulation scheme. This parameter controls the amplitude of the Secondary Synchronization Code relative to the C-CCPCH portion of the time slot. It is expressed in dB.

File Definition Area:

- **Filter File Definition**: This area becomes active when FILE is selected in the Filter Type field. The user can choose between a variety of ASCII and binary format in the file format selection list. The Browse button opens a standard file selection window to choose any existing file.
- **IQ File Definition**: This area becomes active when FILE1 or FILE2 are selected in the Modulation Mode field. The user can choose between a variety of ASCII and binary format in the file format selection list. It is also possible to define the way data is organized inside the file by selecting the appropriate format in the Data Organization selection list. If separate files have been defined for the I and Q components, the user must define two carriers in the list with the same basic parameters and selecting the

corresponding component in the Data Organization field. The Browse button opens a standard file selection window to choose any existing file.

- **Data File**: This area becomes active when USER FILE is selected in the Data Source field. Delimited ASCII is the only format supported and "0" and "1" are the only allowed characters. The Browse button opens a standard file selection window to choose any existing file.

- **Symbol Map**: This area becomes active when FILE3 is selected in the Modulation Mode field. The Browse button give access to the Symbol Map Edition Tool (see section 4 of this manual for details) where a new map can be created or an existing one can be loaded.

3.2 Multi-Carrier Assistant Window
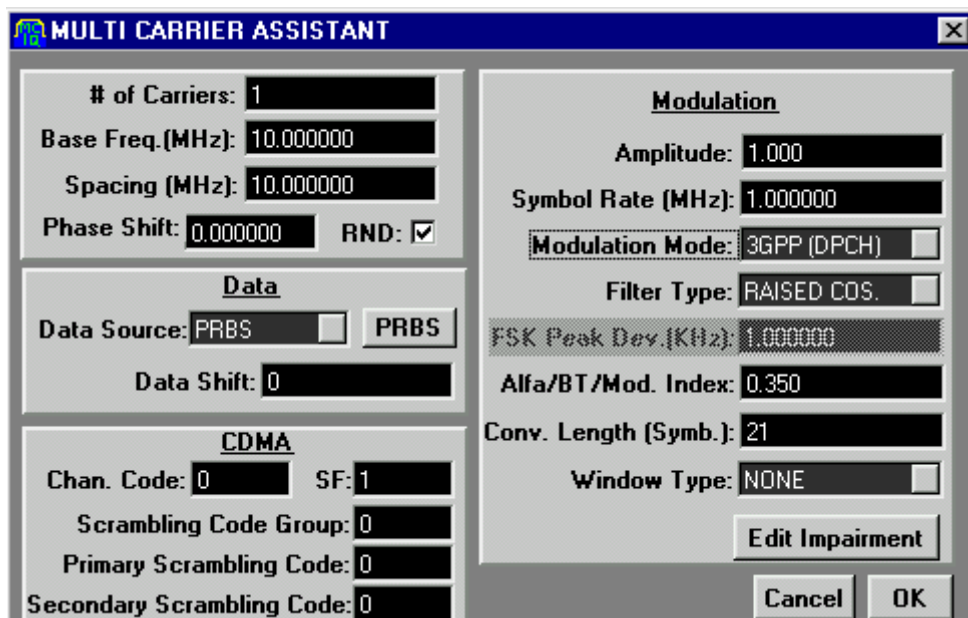
Sometimes the user application requires a collection of similar carriers. A good example is in CATV head-end or return-path emulation, where equally spaced, similar carriers (same modulation scheme, base band filtering and symbol rate) are transmitted together to the network. A possible way to create this set up is by adding all the carriers to the list in a one by one basis using the Add Line button and the Carrier Edition Window. The Multi-Carrier Assistant tool provides for a simpler and faster method to create such arrangements. The Assistant Window looks very similar to the regular Carrier Edition Window with some extensions to define a complete set of carriers instead of only one.

Most of these parameters can be found in the Multi-Carrier area of the window:

- **# of Carriers**: It contains the total amount of carriers to create.
- **Base Freq. (MHz):** This is the carrier frequency for the first carrier in the list.
- **Spacing (MHz):** Frequency distance between consecutive carriers.
- **Phase Shift:** Incremental phase shift applied to each carrier.
- **RND:** This check box activates the assignment of a random phase to each carrier. This assignment helps to reach lower peak to average power ratios, thus improving the linearity and dynamic range of the resulting signal.

Another extension can be found in the Data Area of the assistant:

- **Data Shift:** Incremental shift applied to the PRBS generator for each carrier. This feature allows the creation of uncorrelated carriers even if they share the same PRBS polynomial. Uncorrelated data sequences provide a better PAPR (Peak to average power ratio) and a more realistic behavior of the resulting signal.

Once the **OK** button is hit the MCIQ package will automatically create all the required lines in the Carrier List Window. After that, each carrier in the list is a regular carrier and it can be independently edited or deleted by using the standard methods described in this manual.

3.3 PRBS Edition Window
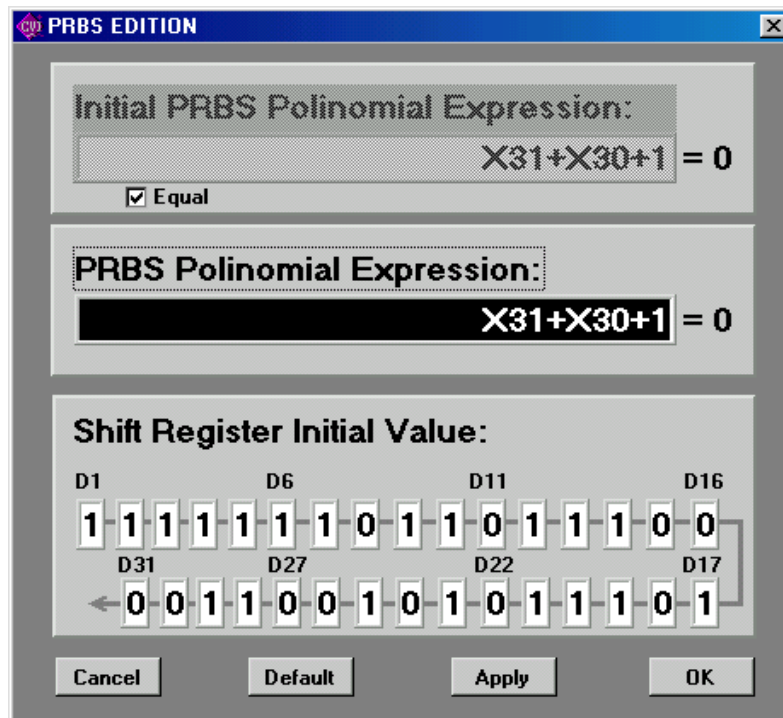
Digitally modulated, real world signals usually appear as random on purpose. By doing so, a better performance transmission system can be obtained, even when underlying data is not statistically random at all. Pseudo random binary sequences provide a good simulation of real-world signal and make easier bit error rate testing. MCIQ allows the user the complete definition of the desired PRBS for each carrier. This is the purpose of the PRBS Edition Window.

In this window the PRBS polynomial and the initial value of the shift register ("seed") can be defined:

- **Polynomial definition**: The notation to write the desired polynomial consists in typing the terms in the format **X**Y, where **X** (character 'X' or 'x') represents the variable and Y the power applied to this value, separated with the '+' character. The final term +1 is optional and the MCIQ package will add it at the end if not typed. The order the terms are entered is not important. If there are repeated terms only one will take effect. Some examples follow:

$$X31+X30+1=0 \qquad\qquad X^{31}+X^{30}+1=0$$

$$X15+X14=0 \qquad\qquad\qquad X^{15}+X^{14}+1=0$$

$$X14+x15+1=0 \qquad X^{15}+X^{14}+1=0$$

$$X15+X14+X15+1=0 \qquad X^{15}+X^{14}+1=0$$

- **Seed definition**: Bits values for the initial contents of the PRBS generator can be define individually by typing the desired values. Depending on polynomial order the unused bits will be hidden to avoid confusion. Keep in mind that an "all zeros" seed value will create an "all zeros" sequence.

Some arbitrary waveform generators allow the creation of virtually infinite length signals by using a feature called sequencing. Sequencing consists in creating waveform segments that will be output in a pre-programmed sequence defined in the target instrument. Defining different content for each segment and designing an appropriate sequence can obtain very long repetition time, far beyond the memory capability of the generator. The resulting signals will behave more realistically and will have a denser (noise-like) spectrum. Sequencing digitally modulated data requires special care to preserve time domain consistence and spectral quality. In order to have consistent segments which can be seamlessly sequenced it is necessary to preserve the convolution continuity. To do so segments have to use the same initial symbols, what translates to using the same initial bits. This can be accomplished by using the same PRBS at the beginning of each segment while using a different one for the rest of the segment. This is the purpose of the **Initial PRBS** field in this window. This field is activated when the check box **Equal** is not checked. It is advisable that the initial polynomial be of lower or equal order to avoid any chance of having an "all zeros" seed value for the rest of the sequence. Keep also in mind that in order to keep the amplitude consistence all segments must use the same Division Factor. Compiling all the segments, obtaining the worst-case division factor, and then recompiling all the segments using this worst-case factor in "Force" mode can do this.

3.4 Impairment Edition Window

MCIQ calculates near-perfect waveforms. As some tests require impaired signals, an impairment addition tool is available to the user. A processing block model has been used for the impairment parameter set-up process.
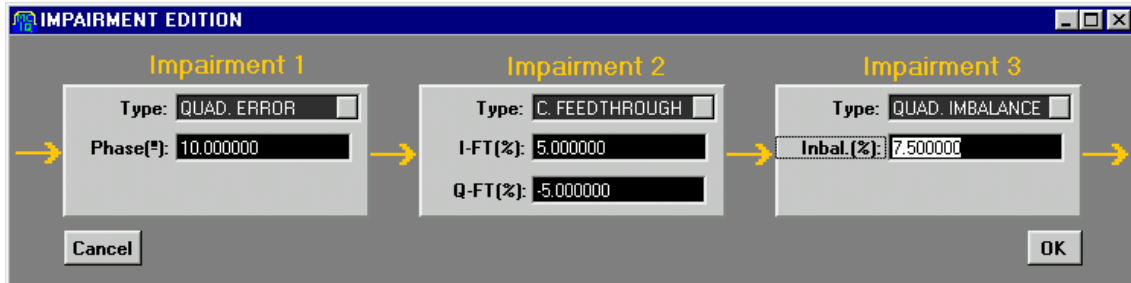

Three blocks are accessible to the user. Each block can add an impairment process to the calculation chain. The following impairment types and parameters can be used in each block:

- **NO IMPAIRMENT**: No further processing.
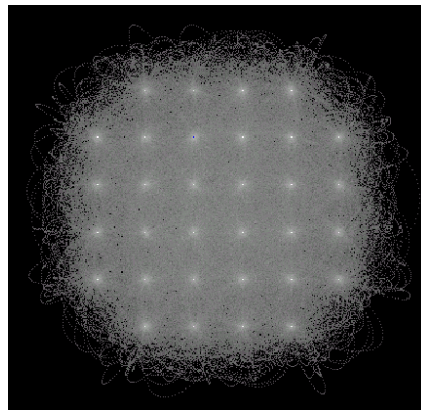
- **QUAD. ERROR**: Quadrature error refers to the phase deviation between the I and Q axis relative to the ideal phase (90°). The associated parameter (**Phase (º)**) is expressed in degrees. Calculation consists in adding half the deviation to each axis but in opposite direction.
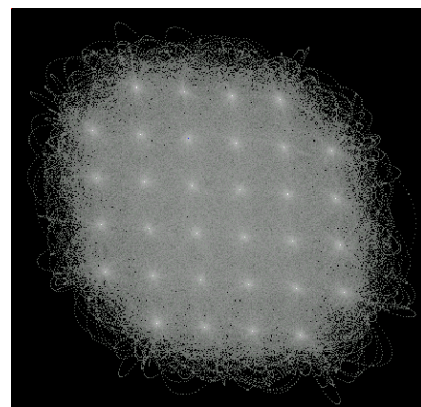
- **QUAD. IMBALANCE**: Quadrature imbalance refers to the amplitude deviation between the I and Q components of the signal relative to the ideal one (same amplitude). The associated parameter (**Inbal (%)**) reflects the desired difference between both axis. Calculation consists in incrementing and decrementing the I and Q components in such a way that the resulting waveform shows the required imbalance.
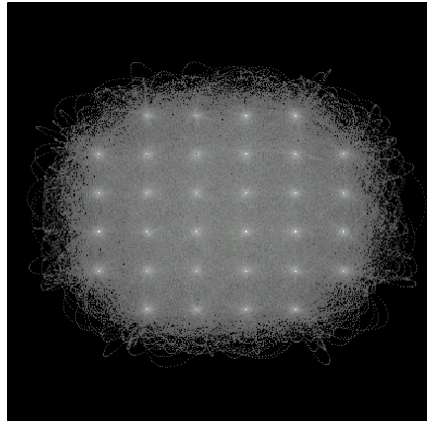
- **C. FEEDTRHOUGH**: Carrier feed through consists in adding a DC component to the base band signals. The associated parameters (**I-FT(%)** and **Q-FT(%)**) allows controlling both the amplitude and phase of the remaining carrier. They are expressed as **%** of the signal basic amplitude, which is related with the maximum value for a symbol in on of the axis.
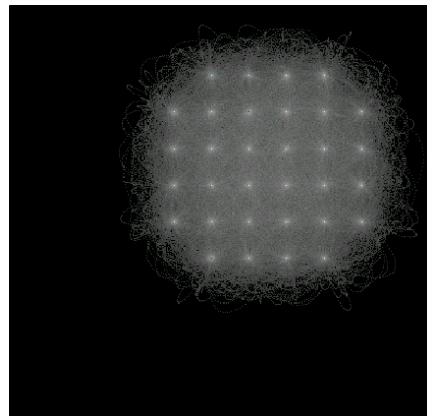
3.5 Carrier List Window

The carrier list window shows the current contents of the carrier table. It can be used to visualize the progression of the project, to edit any existing line, and to define the Anchor Carrier.

Double clicking any existing line will open the Carrier Edition Window with the current parameters for the line. This allows the user to visualize all the details about a given carrier and to edit them if necessary.

Left clicking the mouse on any existing line selects it. After being selected a line can be deleted (by hitting the Delete Line button in the tool bar) or can be marked as the "Anchor Carrier" (by right clicking the mouse on that line).

Scrolling bars become active when the amount of carriers overflows the available visible area in the Carrier List Window.

3.6 The Anchor Carrier

Arbitrary waveform generators require repeating the same basic signal again and again to obtain a continuous output. In order to avoid discontinuities at the transition between the end and the beginning of any pair of segments, special care must be taken to avoid all the "wrap-around" artifacts. For a modulated carrier a set of conditions must be met by the signal. The following are some of these conditions:

1) There must be an integer number of carrier cycles in the segment for any given carrier.
2) There must be an integer number of symbols in the segment for any given carrier.

In general, it is impossible to meet these criteria for any given set of carriers if the record length in the target instrument is a finite and integer number. This means that some rounding must be performed. The user can select one of the carriers to act as a reference. The output clock will be calculated in order to preserve some of the frequency characteristics of the anchor carrier. If record length is expressed in samples then the carrier frequency will be preserved. If record length is expressed in symbols then the symbol rate will be the preserved parameter. The actual clock output will be also influenced by the maximum carrier frequency in the list and the oversampling factor.

The actual values for carrier frequencies and symbol rates will be shown in the carrier list window after compilation. The previous values will be overwritten, so the carrier table must be stored before compiling if these values must be reused in the future.

4. SYMBOL MAP EDITION TOOL
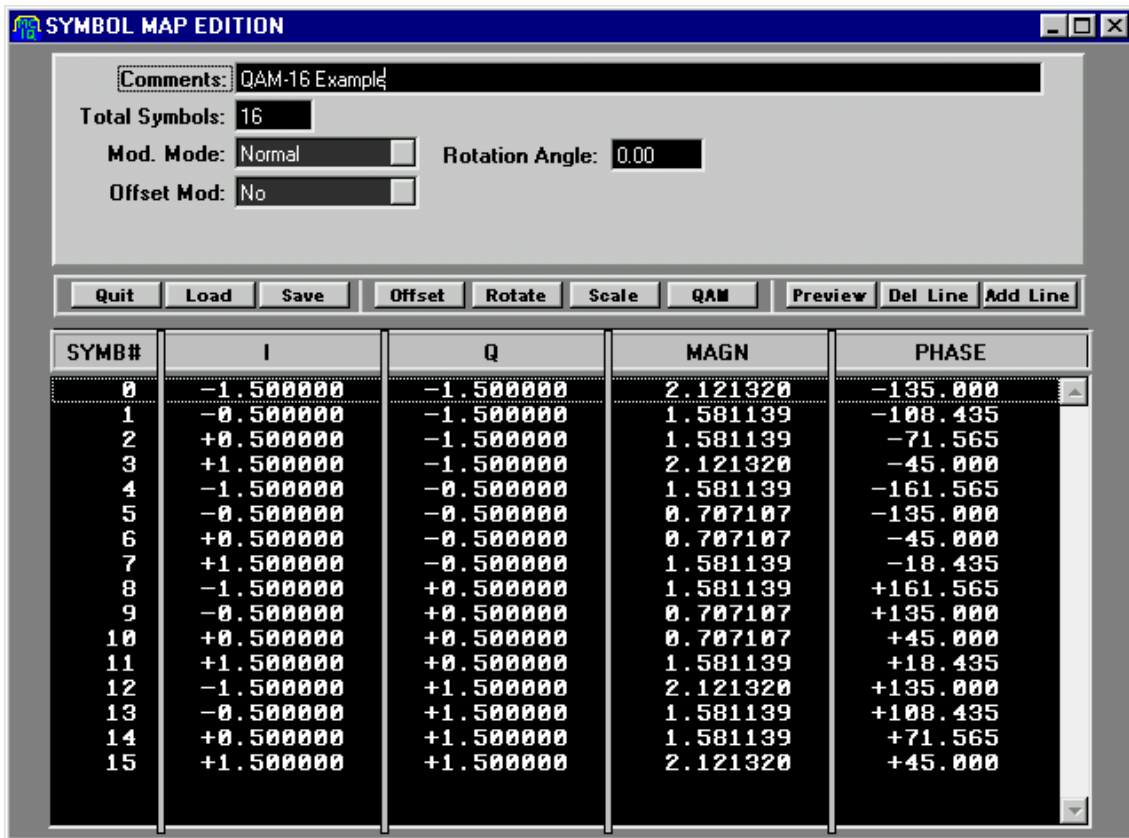
Although the most popular modulation schemes are native in the MCIQ application, a tool to create user-defined modulation schemes is provided. This feature can be useful when the required modulation scheme is not available or when some impairments need to be simulated within the resulting waveform.

The symbol map edition tool can be reached from the main window menu bar, from the tool bar, and from the carrier edition window.

Three areas compose the symbol map edition window shown above:

a) A **header** area includes the basic information about the symbol map:
- **Comments**: This field can contain up to 200 characters defined by the user.
- **Total Symbols**: It shows the total number of symbols in the table. It is automatically updated and cannot be modified by the user.
- **Mod. Mode** (Modulation Mode): This option is used to create differential modulation schemes (such as DQPSK or O-8PSK) without having to take

care of all the constellations. The user must create only the basic constellation (i.e. QPSK for the D-QPSK modulation scheme, 8PSK in O-8PSK) and then define the angle rotation for each symbol transition. Modulation mode can be Normal (no rotation), Diff (Continuous) and Diff. (Alternate). The difference between Continuous and Alternate is the way the phase rotation is added for each symbol transition. Continuous adds the phase entered in the Rotation Angle field for each transition. Alternate adds and subtracts alternatively the rotation angle.

- **Rotation Angle**: It is expressed in degrees.
- **Offset Mode**: It allows the user to create modulation schemes with a half a symbol time delay between the I and the Q components as in the OQPSK modulation scheme. It can be switched between Yes and No.

b) The **tool bar** allows the user to operate the symbol map edition tool. It is divided in three areas: The file operation area, the calculation tool area, and the symbol edition area:

- **Quit**: It closes the Symbol Map Edition Window without saving any changes. The user must save these changes by clicking the Save button.
- **Load**: It opens a file selection window where the user can select an existing symbol map file to be opened for edition. If the symbol map edition tool has been opened from the carrier edition window the file name will be copied to the Symbol Map File field.
- **Save**: It opens a file selection window where the user can define a new name or select an existing symbol map file name to save the edited data. If the symbol map edition tool has been opened from the carrier edition window the file name will be copied to the Symbol Map File field.
- **Offset**: It allows the user to add a DC offset to the I and/or Q components of the current constellation. It opens a dialog window where both offset levels can be independently defined.
- **Rotate**: It allows the user to define the angle between the I and Q axis. It opens a dialog window where the user can define the desired angle. Its default value is 0 degrees (no impairment). It is useful to create signals that show quadrature errors.

- **Scale**: It allows the user to apply a scale factor to the I and/or Q components of the current constellation. It opens a dialog window where both scale factors can be independently defined. Scale factors are expressed in % and their default value is 100%.

- **QAM**: It will automatically create symbol tables for the following modulation schemes: BPSK, QPSK, QAM16, QAM32, QAM62, QAM128, and QAM256. It can save time when the user just wants to create an impaired modulation scheme based in those standards.

- **Preview**: It opens a symbol map visualization window where the symbols in the current table can be seen in a graphical way.
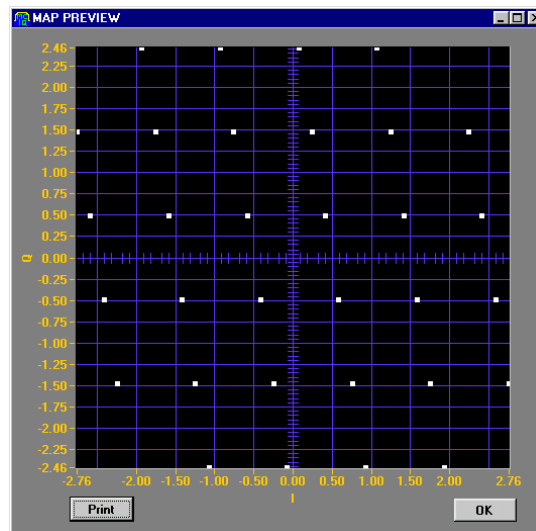
- **Delete Line**: It will delete the highlighted line in the Symbol Map Table.

- **Add line**: It will open the symbol edition window to create a new line in the symbol map table. The symbol edition table shows the symbol number and allows the user to edit the I and Q components or alternatively the Magnitude and Phase of the symbol. Every time the user hits the return key in any of the editing fields all the others are updated to be consistent. Anyway, the values contained in the I and Q component fields will be effectively stored. OK will close this window and validate the entered data while Cancel will just close the window.

c) The **symbol table** shows the current symbol values and it can be used to select any symbol for edition or deletion. There are several columns in the table:

- **Symb#** : This is the position of the symbol in the list. It also shows the data value corresponding to the symbol.
- **I**: The linear magnitude of the I component.
- **Q**: The linear magnitude of the Q component.
- **Magn**: The magnitude of the vector from the origin (0,0) to the symbol.
- **Phase**: The phase of the vector from the origin (0,0) to the symbol.

To navigate through the symbol map table just use the mouse or arrow keys and the scrolling bar (in case all the symbols don't fit the viewing area) to highlight any specific symbol. Double-clicking the highlighted symbol will open the symbol edition window (see the Add Line section above).
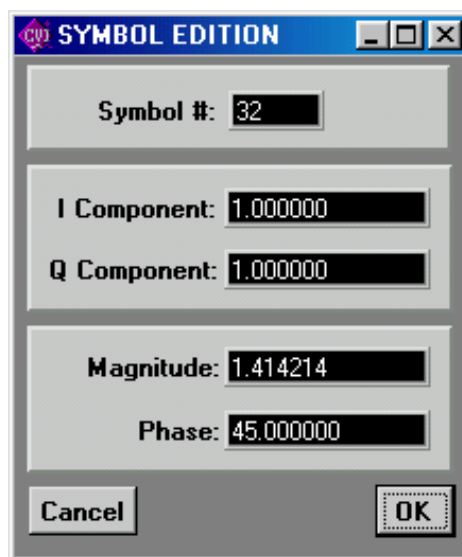
5. VISUALIZATION WINDOW
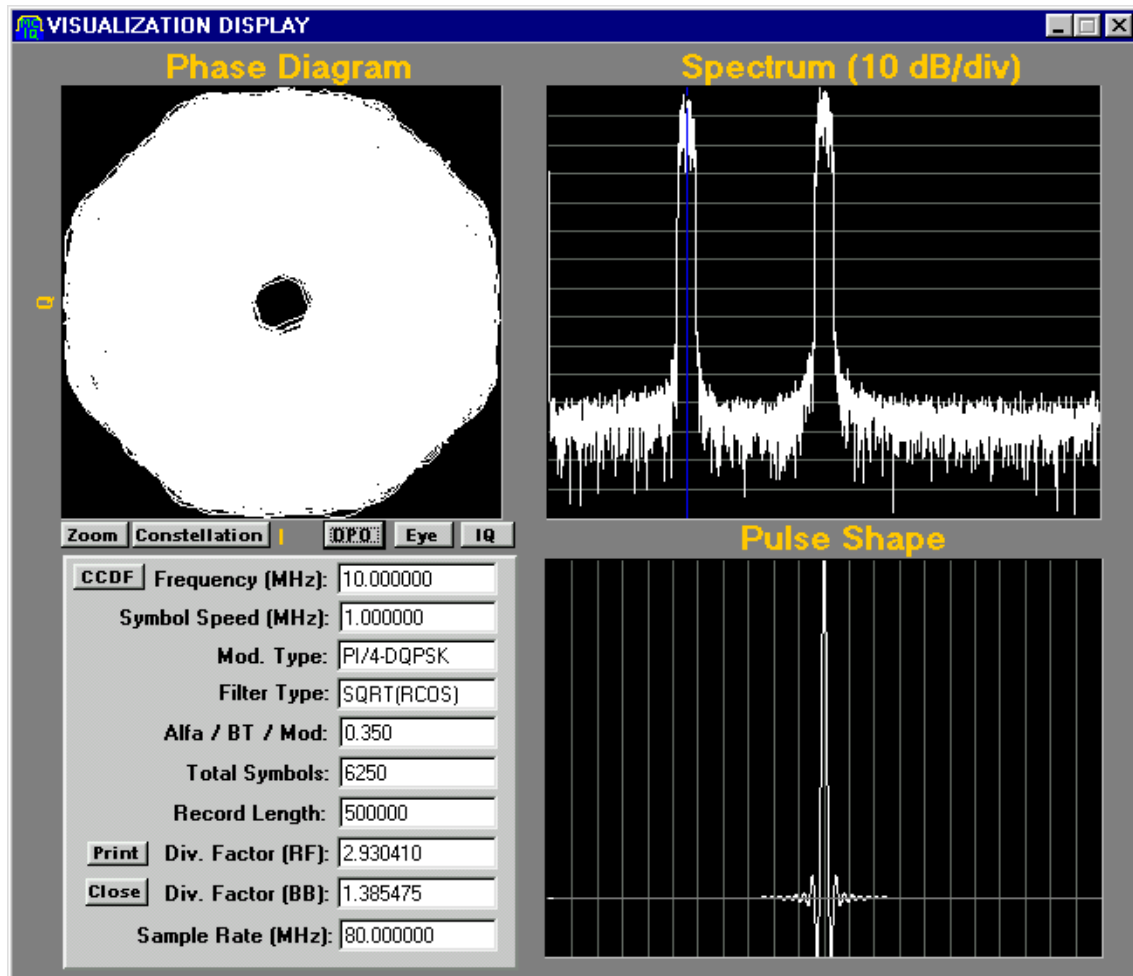
The compilation process also creates a visualization window to help monitor and document the results. This window shows several pieces of information to help the user to validate the resulting waveform:

- **Phase Diagram**: It shows the phase diagram for the Anchor Carrier. Any interfering signal or filter at the intended receiver does not affect this phase diagram.

- **Spectrum**: This is an FFT corresponding to the first 8192 samples of the combined output waveform. A blue vertical cursor shows the location of the anchor carrier. This spectrum display is not affected by the analog frequency response of the target instrument. Sample data has been previously quantized depending on the target instrument to give an idea of the ideal level of quantization noise. It can help to select appropriate calculation parameters to limit processing time while keeping the signal quality.

- **Pulse Shape**: It shows the base band pulse shape for the Anchor Carrier.

- **Data Window**: It includes numerical and textual information for both the Anchor Carrier and the combined output waveform.

There are some buttons in the visualization window to further analyze the data:
- **Zoom**: It zooms on the phase diagram.
- **Constellation**: It shows a zoomed Constellation Diagram for the anchor carrier.
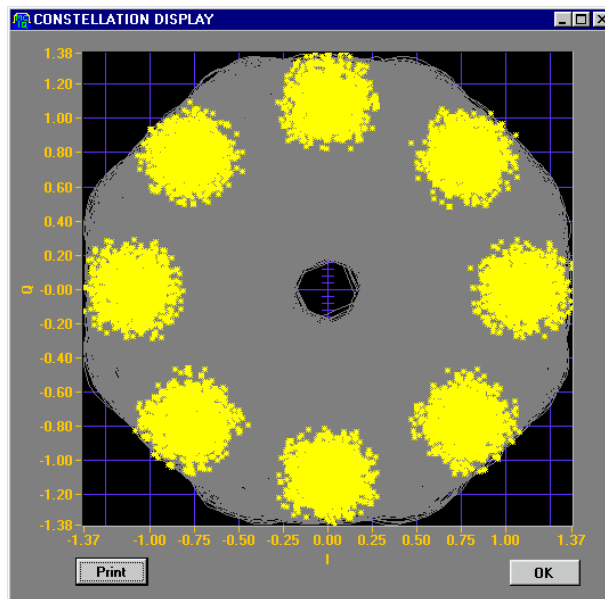
- **Eye**: It shows the I and Q Eye diagrams for the Anchor Carrier.
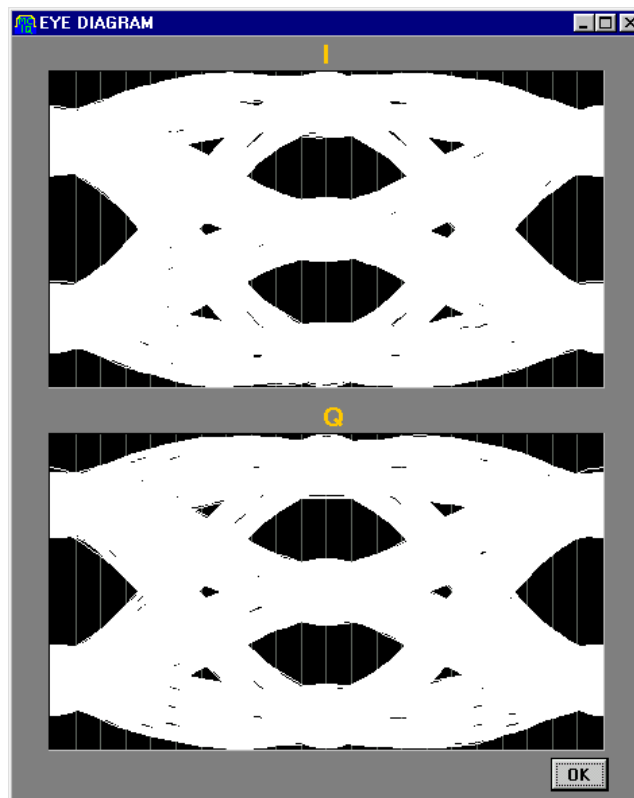
- **Show IQ**: It shows the first 8192 time domain samples of the I and Q components of the anchor carrier.
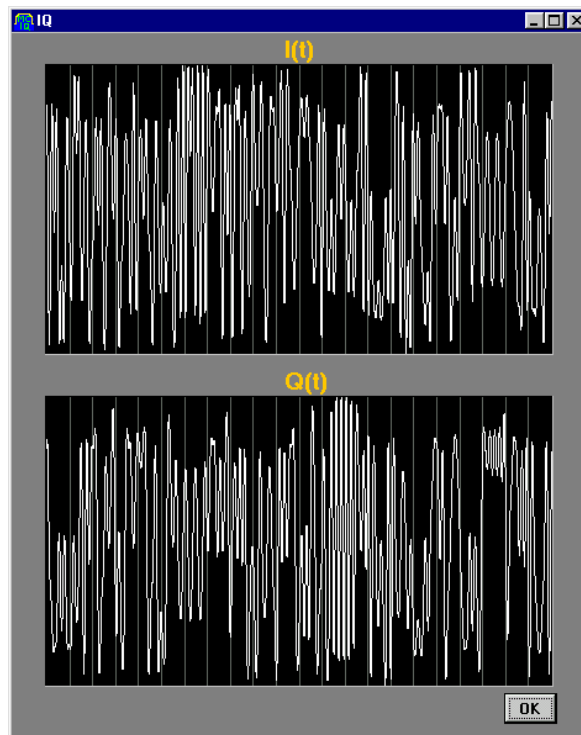
- **CCDF**: It opens the Complementary Cumulative Distribution Function window where the statistical power distribution of the anchor carrier or the combined base band signal (if the "all signals" check box is checked in the Compile Options window). Crest Factor (also know as PAPR, Peak to Average Power Ratio) is shown in addition to the CCDF graphical display. A cursor is available to accurately determine specific values of the CCDF function.
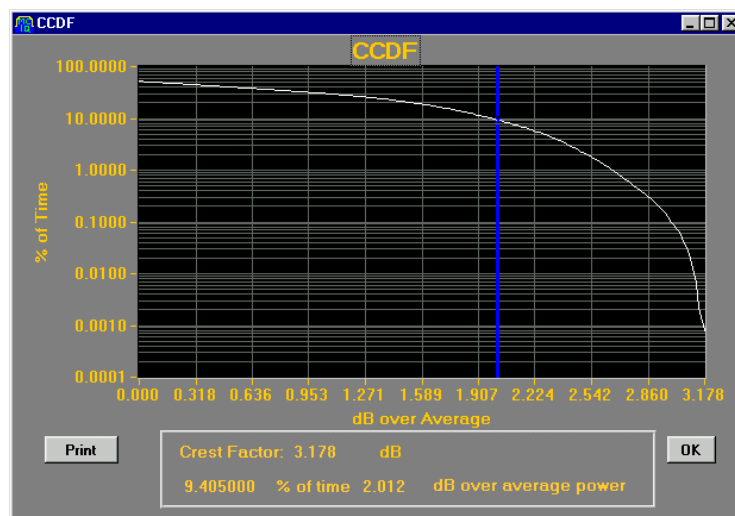
- **DPO**: It shows a DPO-like (DPO stands for Digital Phosphor Oscilloscope) graphical Window. The purpose of such a display is to give a qualitative visualization of the statistical distribution of the signal. This is especially useful in very complex signals such as multi-channel W-CDMA downlink signals. It is also possible to obtain horizontal (I axis), and vertical (Q axis) histograms by placing the two available XY cursors. The g parameter helps the user to obtain the desired gray level range for a comfortable visualization. Some information about the number of samples used in the histogram calculation is shown in a box located at the bottom right side of the window.
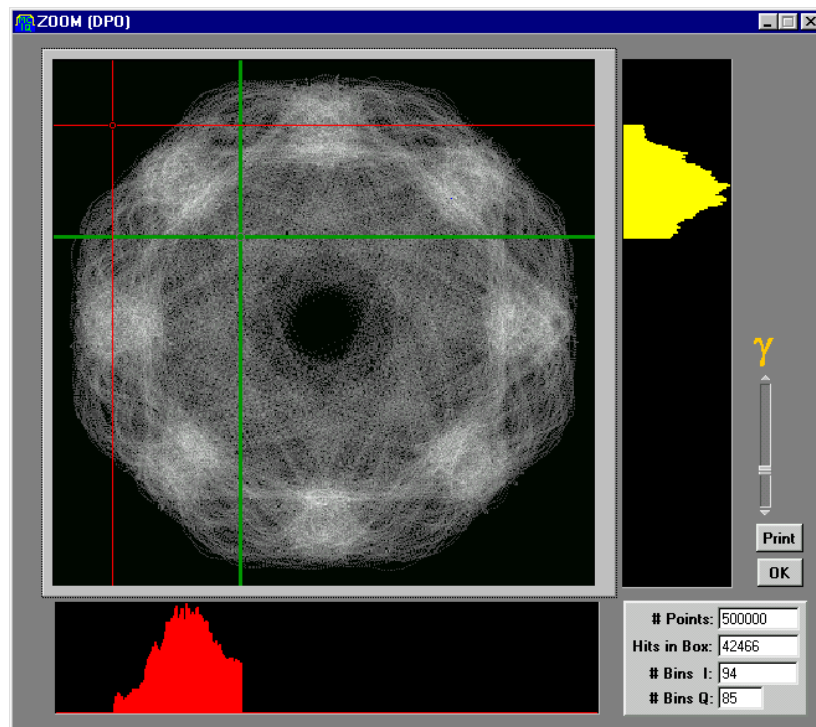
APPENDIX 1: DVB-C

Generating DVB-C compliant signals require setting up properly some parameters. First of all the modulation scheme must be chosen among the DVB-C compatible ones:

- DVBC-64 (QAM64)
- DVBC-256 (QAM256)
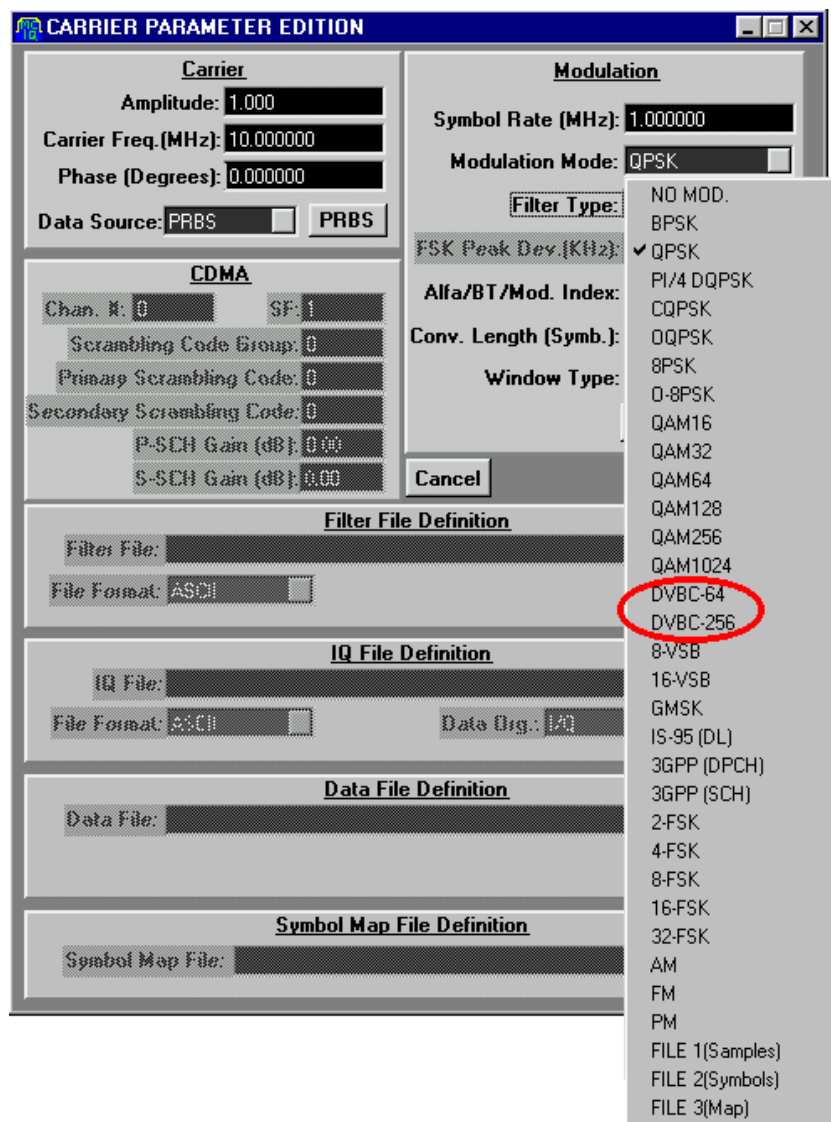
DVB-C includes QAM16, QAM32, and QAM128 as legal modulation schemes. MCIQ doesn't support these schemes yet.

In order to have a working channel coded DVB-C signal it is necessary to implement the following steps:

1) Obtain a MPEG2/DVB transport stream. The user doesn't have to provide a TS to the MCIQ tool. There is one already pre-defined (it is stored in the origin.res file) consisting in a very simple TS made of packets composed by a sync byte and then 187 "all-zeros" bytes.

2) The sync byte must be inverted every eight packets. This operation is already performed in the available file (origin.res).

3) An 8 packet long scrambling code is applied to the TS. Again this operation is already performed in the available file.

4) Packets must be extended by 16 bytes (from 188 to 204 bytes). These extra bytes are used in error protection by providing the required space to carry a block correction code (Reed-Solomon as defined in the DVB standard). Again this operation is already performed in the available file.

5) An interleaving process is added in order to disperse error bursts. This operation is performed programmatically by the MCIQ application.

6) Byte oriented information must be translated to modulation symbols. The first steps is to convert bytes to m-tuples (m=6 for QAM64 and m=8 for QAM256). This operation is performed programmatically by the MCIQ application.

7) DVB-C establishes a rotationally invariant symbol map arrangement. To do so, the two more significant bits code the required phase rotation for the present symbol (Differential Coding), what means that the previous symbol influences the current one absolute location, and the least significant bits use a mapping scheme that preserves its information regardless of the symbol's quadrant. This operation is performed programmatically by the MCIQ application.

In order to have a consistent, usable signal it is necessary to meet the wrap-around requirements at the channel coding level. This implies meeting two conditions:

1) The total number of symbols must accommodate an integer multiple of DVB-C frames (8 packets long, 8 x 204 = 1632 bytes), This means 2176 symbols for QAM64 and 1632 symbols for QAM256. The easiest way to

accommodate this number of symbols is by defining them directly in the Record Length field in the Compile Options Window.
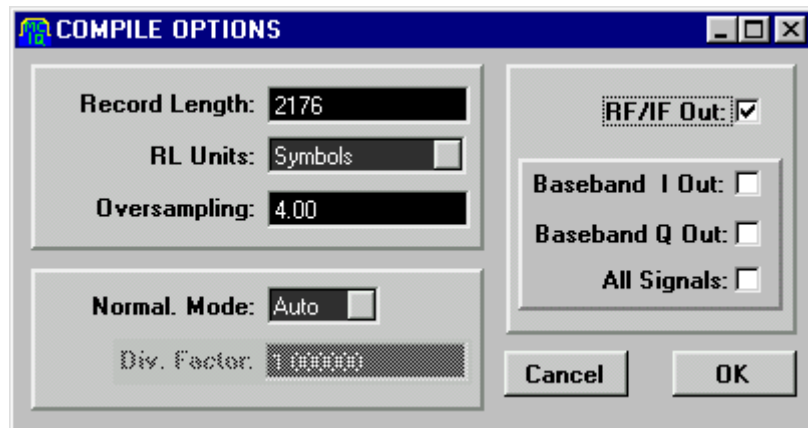
2) Differential coding requires the quadrant change between the first and the last symbols in the sequence to be consistent. This condition can be met in general by repeating the same sequence 4 times (thus requiring 4 times more sample memory). Another solution is selecting a particular TS which meets the differential coding wrap-around-free condition. MCIQ doesn't require either solution as a special algorithm is used internally to build a single frame, self-consistent signal regardless of the TS contents saving generation memory (which can be useful to reach higher carrier frequencies).

When the application requires using a user-defined TS, just replace the provided file (origin.res) with the user defined file. Keep in mind that the file must contain at least 1632 bytes (8 packets) and must implement channel coding up to the scrambling operation.

When generating multiple carriers, special care must be taken in using carriers as uncorrelated as possible. As the same basic TS is used by the MCIQ application for all the carriers, the correlation among carriers is perfect, resulting in a poor quality signal due to its very high PAPR (Peak to average power ratio) and its low effective dynamic range. There are different solutions for this problem:

- If only a limited set of carriers require error testing, then the other carriers can use regular QAMXXX with different, uncorrelated PRBS sequences.

- If different convolution lengths are defined for each carrier (defined in the carrier parameter window) the resulting individual carriers will be time shifted by the difference between the different carrier # of symbols. The scrambling process assures a very low correlation as long as signals are not aligned in time.

DVB-C defines the following parameters for base band filtering: Square Root Raised Cosine, α=0.15.

For more information on DVB-C coding and modulation, take a look to the DVB-C official standard (EBU, EN 300 429).
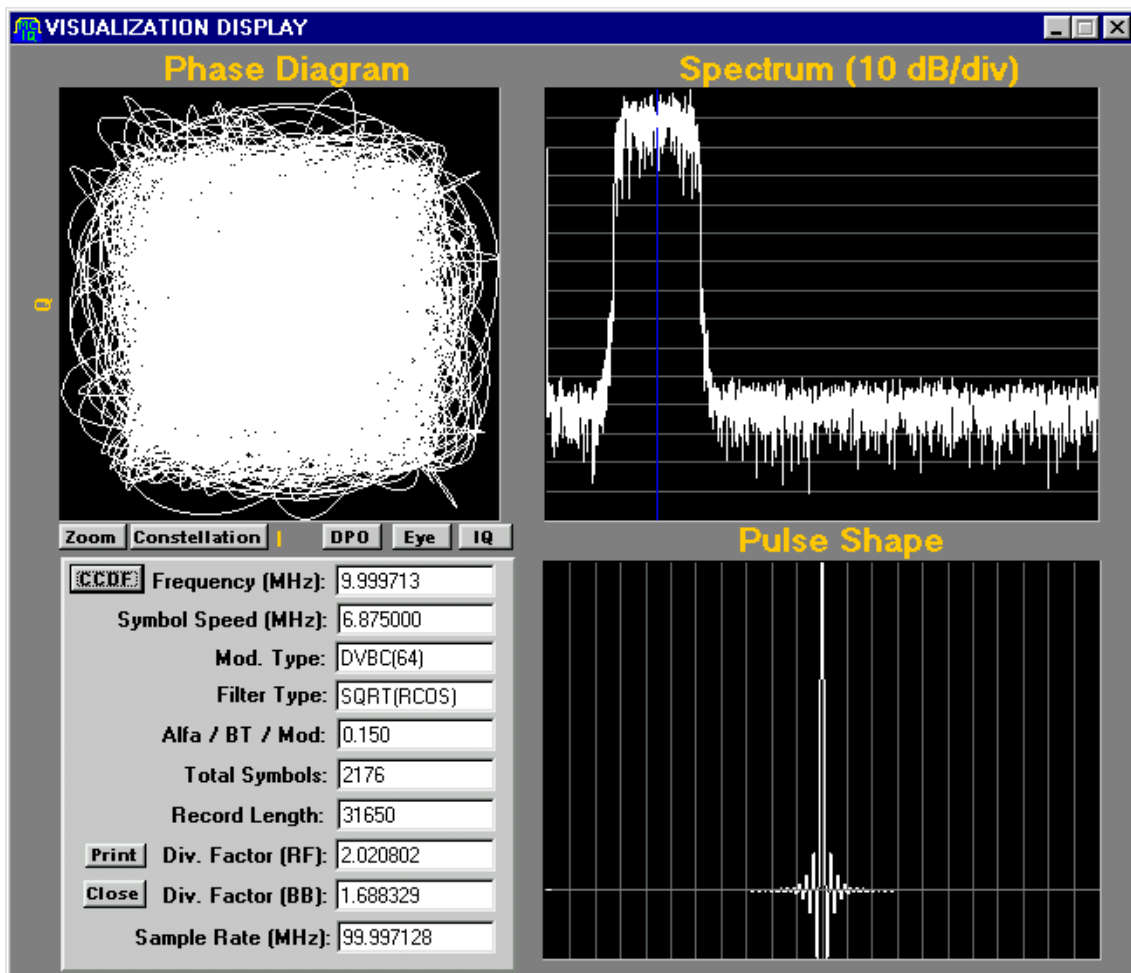
APPENDIX 2: IS95 (CDMAOne)

Generating IS95 Down Link signals require following some simple steps. To do so, a line must be added for each desired channel in the signal. Adding all the required channels to the carrier list could create multiple carriers. Of course, each channel entry must incorporate the right carrier frequency. Complete IS95 (CDMAOne) require a minimum of requirements to be viable:
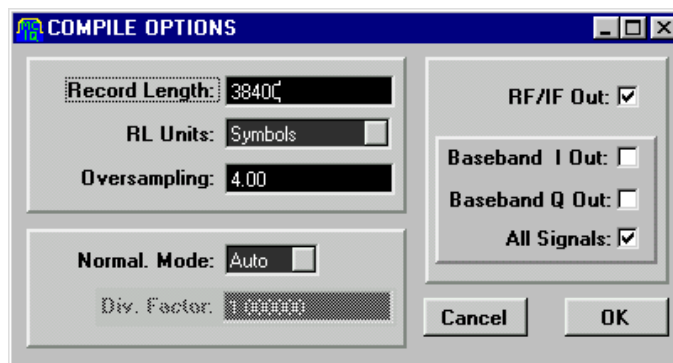
1) It must incorporate a Pilot Channel. Pilot channel implements a simple timing alignment signal consisting in a pure scrambling sequence. To get this signal just define an IS95 channel with channel #=0 and select "all zeros" as its data source.
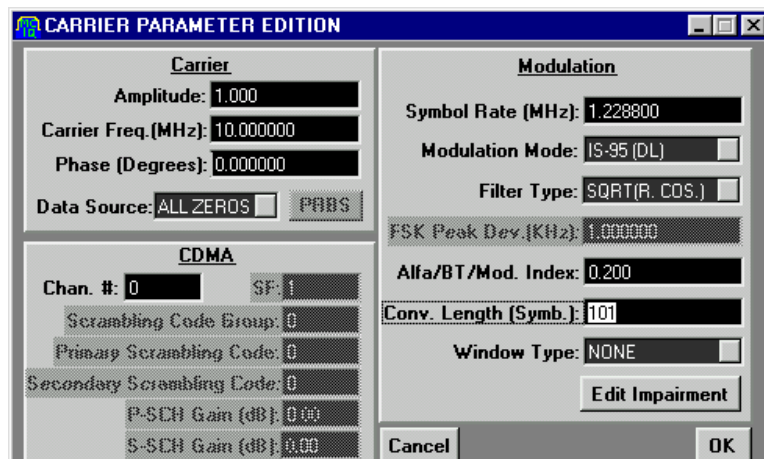
2) All the other channels, including the sync channel (channel #=32), can use simple PRBS as their data source. Of course, all the channels must share exactly the same symbol rate and carrier frequency and should use different channel numbers.

3) Scrambling sequences for IS95 are 32768 (2^{15}) chips long. This means that record length (measured in symbols) must be an integer multiple of this number. The easiest way to accommodate this number of symbols is by defining them directly in the Record Length field in the Compile Options Window.

4) Base band generation (I & Q components) require to check the "All Signals" box in the Compile Options Window. Checking this option does

not influence RF/IF generation but it is necessary to check it for a correct visualization in the Visualization Window.

The fastest way to define a complete signal is by using the Multi-Carrier Assistant as shown below. Assigning 0 to the Spacing parameter will create a set of carriers with the same carrier frequency. The RND phase parameter is not checked, as all the channels ideally must share the same carrier. The Data Shift is not equal to 0 in order to obtain uncorrelated data. After creating the carrier list some editing is necessary to complete the job. The Pilot channel must be edited to assign the right Channel # (0) and the right data source ("All Zeros"). All the user channels must be edited to assign the desired amplitude and Channel #.
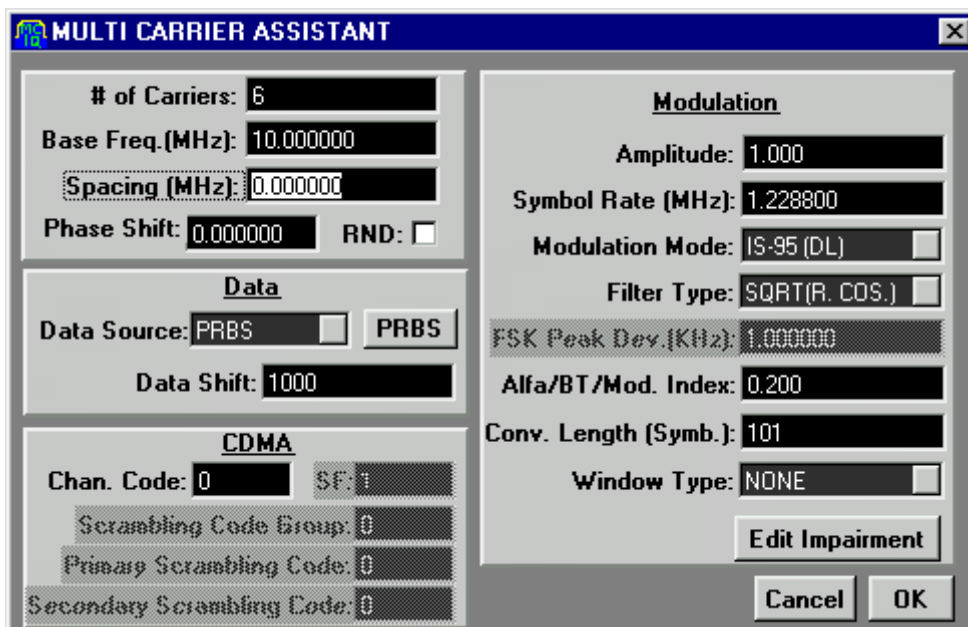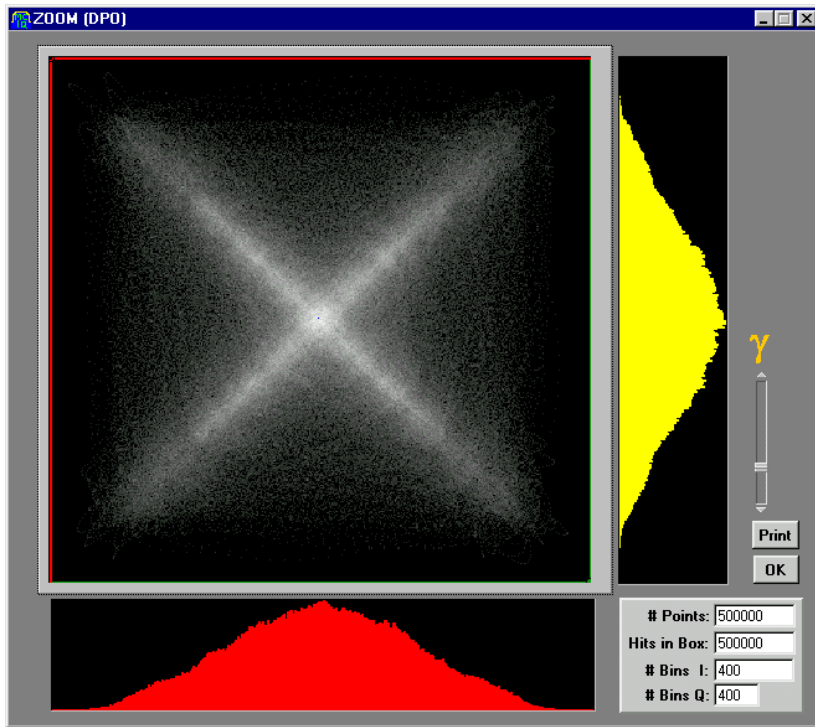
APPENDIX 3: 3GPP W-CDMA (IMT2000, UMTS)

Generating 3GPP (FDD) WCDMA (IMT2000, UMTS) Down Link signals require following some simple steps. To do so, a line must be added for each desired channel in the signal. Adding all the required channels to the carrier list could create multiple carriers. Of course, each channel entry must incorporate the right carrier frequency. Complete WCDMA (IMT2000, UMTS) require a minimum of requirements to be viable:

1) It must incorporate a Common Pilot Channel (CPICH). Common Pilot channel implements a simple timing alignment signal consisting in a pure scrambling sequence. To get this signal just define a DPCH channel with channel #=0, spreading factor (SF)=256, and select "all zeros" as its data source. Cells and sections within a cell can be separated one from the other by assigning different carrier frequencies and/or different scrambling codes. To completely define the required scrambling code the following information must be provided:

   a. **Scrambling Code Group (SCG)**: It contains the scrambling code group number for the target carrier. It ranges from 0 to 63.
   b. **Primary Scrambling Code (PSC)**: It defines the specific primary scrambling code within the previously defined scrambling code group. It ranges from 0 to 7. To calculate the absolute primary scrambling code just use the following formula:
   $$PSC_{abs}=8 \times SCG+PSC.$$
   c. **Secondary Scrambling Code (SSC)**: It defines the specific secondary scrambling code associated to the previously defined primary scrambling code. It ranges from 0 to 15. To calculate the absolute scrambling code just use the following formula:
   $$SC_{abs}=(8 \times SCG+PSC) \times 16+SSC.$$
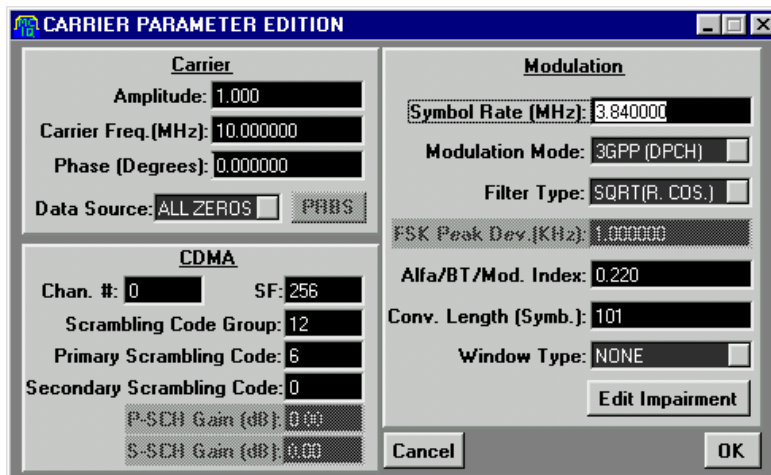
2) Another important components in the signal are the time-multiplexed P-CCPCH/SCH channels. The P-CCPCH part of the multiplex follow the DPCH scheme, so it is possible to use any legal data source to completely define its contents. Regarding the channelization (OVSF) and spreading factor parameters, they are fixed by the standard to 1 and 256 respectively. MCIQ includes a specific modulation scheme to implement the P-CCPCH/SCH channels, which is called SCH for simplicity. The complete definition of the multiplex requires the specification by the user of the scrambling code. This information is used for two purposes: to scramble the P-CCPCH section of the timeslot and also to implement the right scrambling code group identification sequence in the SCH section. The SCH channel is made of two sub-channels: P-SCH (Primary Synchronization Channel) and S-SCH (Secondary Synchronization Channel). The amplitude of these two components can be set independently of each other and from the P-CCPCH portion of the time slot.
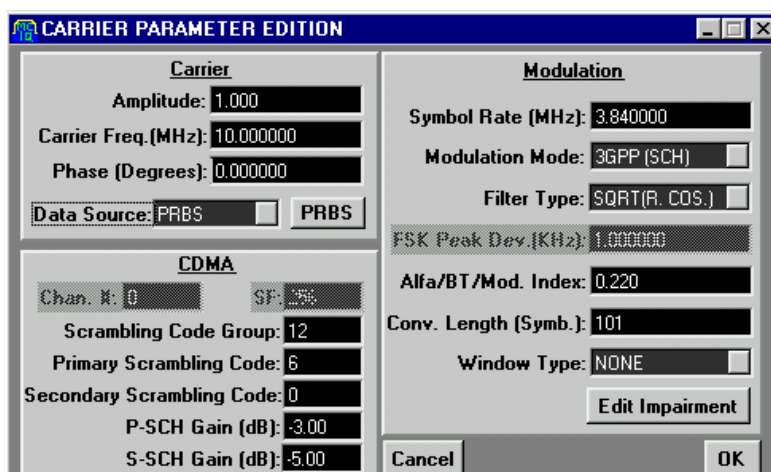
3) All the other channels can use simple PRBS as their data source. Of course, all the channels must share exactly the same symbol (chip) rate and carrier frequency and should use different channel numbers and have the required spreading factors set.

4) Scrambling sequences for IMT-2000 are 38400 (2560*15) chips long. This means that record length (measured in symbols) must be an integer multiple of this number. The easiest way to accommodate this number of symbols is by defining them directly in the Record Length field in the Compile Options Window.

5) Base band generation (I & Q components) require to check the "All Signals" box in the Compile Options Window. Checking this option does not influence RF/IF generation but it is necessary to check it for a correct visualization in the Visualization Window.

The fastest way to define a complete signal is by using the Multi-Carrier Assistant as shown below. Assigning 0 to the Spacing parameter will create a set of carriers with the same carrier frequency. The RND phase parameter is not checked, as all the channels ideally must share the same carrier. The Data Shift is not equal to 0 in order to obtain uncorrelated data. After creating the carrier list some editing is necessary to complete the job. One of the carriers in the list must be edited to become the Common Pilot Channel (CPICH). Just assign the right Channel # (0), the right spreading factor (256) and the right data source ("All Zeros"). All the user channels must be edited to assign the desired amplitude, Channel #, Spreading Factor, and so on. Finally another carrier in the list can become the P-CCPCH/SCH multiplex just by changing the modulation scheme to 3GPP (SCH) and assigning the right levels to the P-CCPCH, P-SCH, and S-SCH components.

For more information on the 3GPP air interface specification, take a look to the 3GPP Partnership official document TS 25.213 (3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Spreading and modulation (FDD)).

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