User's Guide

Engineer's Waveform Work Bench
(eWWoB)

for

IEEE Std. 802.11a/b/g
(2.4 GHz & 5 GHz High-Speed WLAN)

Professional Edition

V.3.0

CommAccess Technologies, Inc.
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Notice

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1   Introduction

<u>Engineer's Waveform Work Bench</u> (eWWoB) is a high-level system tool for use in developing standard-based communication products. It provides system and test engineers with an effective and systematic approach to design, test, and verify their engineering work. Project or technical managers will benefit from it as well because it is furnished with plenty of relevant standard information and communication knowledge throughout its Help/Info windows. eWWoB is developed on a very powerful computing environment - MATLAB. It can run inside MATLAB or on stand-alone. However, eWWoB is a third-party product of MATLAB. The latter is a flagship product of The MathWorks, Inc.

eWWoB is a trademark of CommAccess Technologies, Inc. Its product roadmap covers various standards and editions. There are two editions planned for a selected standard coverage: premier and professional edition. The premier edition will address key waveform design and test and measurement (T&M) aspects prior to the receiver input, including the data import and export functions. The export function is associated with the Test Vector feature soon to be seen in this document and the import function is associated with Signal Analyzer. The professional edition will expand to cover key receiver design issues at the system level. Each product, addressing a different standard as well as edition, will be marketed and sold separately.

The hardware platform that can host eWWoB may include a standard desktop PC, laptop PC, or test equipment that supports Window-based computing power.

This document addresses the high-speed WLAN IEEE 802.11a/b/g standards. In practice, the date rate modes of 802.11g standard are the combined built of 802.11a and 802.11b. Some of them are mandatory and the others are optional. All the rate modes in 802.11g are available in 2.4 GHz ISM band. In this product and document, we interchange 802.11a/b/g and 802.11_combo because of the similarity of the waveform.

2   Product Features

eWWoB is a multi-functional software that can assist system and test engineers with waveform design, test, measurement, and verification for a standard-based product development. They are briefly described as follows:

2.1   Test and Measurement

eWWoB can take the imported data generated from an independent transmitter (hardware or software) to test and analyze the waveforms at zero-IF plus up to 50 ppm frequency uncertainty, as long as they are standard-compliant. The analysis report will not only check the compliance issue but also address performance issues. Due to the built-in receiver suite, there is essentially no constraint to the input waveform in this function. Given an imported data set, eWWoB will start with a signal detection procedure to detect the presence of the signal. Then, it will recover the frequency reference, phase reference, burst timing, and the gain level before being able to conduct the waveform analysis. This capability will make test engineer's job easy and effective.

2.2   Verification

eWWoB can generate standard-compliant test vectors (i.e., waveform samples) and export them to any independent platform to work with design engineers to verify their receiver and algorithm (e.g., ASIC or DSP) development. The waveform samples are taken into account of not only the modulation/coding process but also the interleaving and frame formatting, etc.

2.3   System Design

With the built-in waveform generation and receive signal processing suite, eWWoB can be used to conduct system (Tx & Rx) design tradeoffs and iterations. Most key hardware imperfections have been built in eWWoB for design considerations. (See Table 1 for the parameter list.)

Another important feature in eWWoB is automatic documentation. That is, it will produce comprehensive graphical plots in addition to the text reports. The user can always go back to review and save the graphs at the end of each run. The waveform analysis report for each run is printed in the MATLAB or DOS window and saved to a separate text file. Each test vector file (sample data) produced by eWWoB is accompanied by a text file recording its system information, which includes the data sequence information embedded in the waveform samples. The file name of this informational file is the name of test vector appended with "_info." For example, if the file name of the test vector is abc.dat, the name of the file carrying its information is abc_info.txt. This provides a convenient way for the user to keep track of the work using eWWoB.

3 Installation

The eWWoB installation software is an easy-to-use self-extractable application program, i.e., an ".exe" file in the Windows environment. It may come from a download or a CD. The user simply double-clicks the application program, and it will automatically unzip all the files and transfer them to the default directory **C:\Program Files\eWWoB_11abg**, unless otherwise re-directed by the installer. The program path will be set differently depending on if it is running from MATLAB or if it is on stand-alone. If the default directory has been adopted, there is no need to modify the program path. Please refer to the README files (e.g., readMe_before_install.txt and readMe_after_install.txt) for further specifics before and after installation.

4 Operations

eWWoB is a very user-friendly program. It is designed to be self-explanatory provided that the user is familiar with the Standard and its terminologies.

If your eWWoB Software is comprised of a bunch of DLL files, you have to launch eWWoB within MATLAB, by entering the following command in the MATLAB command line:
    >> eWWoB_11abg

If it is the stand-alone version, you may launch eWWoB by double-clicking the batch file **eWWoB_11combo.bat** in the Windows environment. This batch file is located in the installation folder (e.g., C:\Program Files\eWWoB_11abg, if not altered during installation). If you happen to launch eWWoB_11abg.exe residing in the same folder, error messages regarding using run-time libraries will come up. Basically, eWWoB_11combo.bat sets up the directory path for the run-time libraries before calling eWWoB_11abg.exe.

The cover screen of eWWoB is shown in figure 1. You will be able to learn about the product and 802.11abg system by clicking Product Info and System Info, respectively. If it is the first time use, the user will be prompted with the screens to read and accept all terms and conditions of the License Agreement. Afterwards, eWWoB will perform flawlessly unless the license key expires and/or is invalid.

Figure 1.

After the user becomes acquainted with the product and the system, he/she can click the box 2.4 GHz or 5 GHz to enter the main screen of eWWoB, as shown in Figure 2 below (2.4GHz selected).
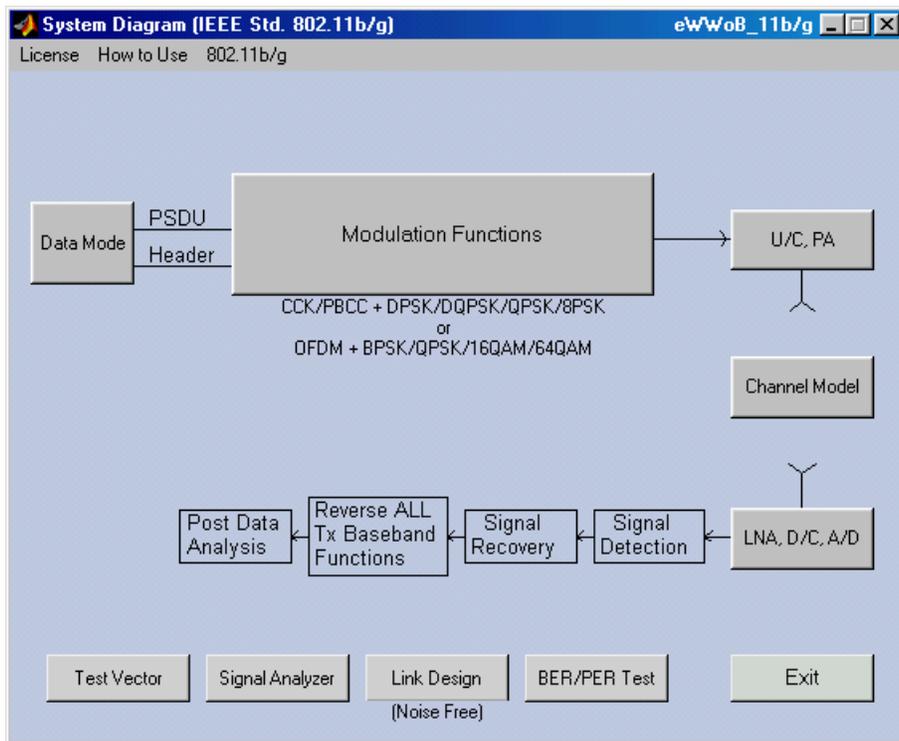
Figure 2.

In this screen, all the gray boxes are accessible. For those transparent boxes such as Signal Detection, Signal Recovery, etc., eWWoB will process them seamlessly. The user does not need to involve with sophisticated signal processing and receiver functions. When eWWoB is in use, the user can specify all the parameters and selections, to be addressed in sections 4.1 through 4.5 below, in any order. It is always the latest values to be used in the execution. In general, the selected and specified inputs will be displayed before the feature selection starts execution. There is a report printed in the Command window at the end of each execution. In the following, the gray boxes will be briefly explained.

4.1 Data Modes

The user will select the operating mode and specify the length of the PSDU (i.e., the Service Data Unit of PLCP) as shown in Figure 3. The modes available are defined in the Standard. Once the mode is selected, the details of the modulation, FEC code rate, and the data rate, etc. are defined in accordance with the Standard. The maximum PSDU length is 4096 bytes. Either the long or the short preamble can be specified as well in this screen.
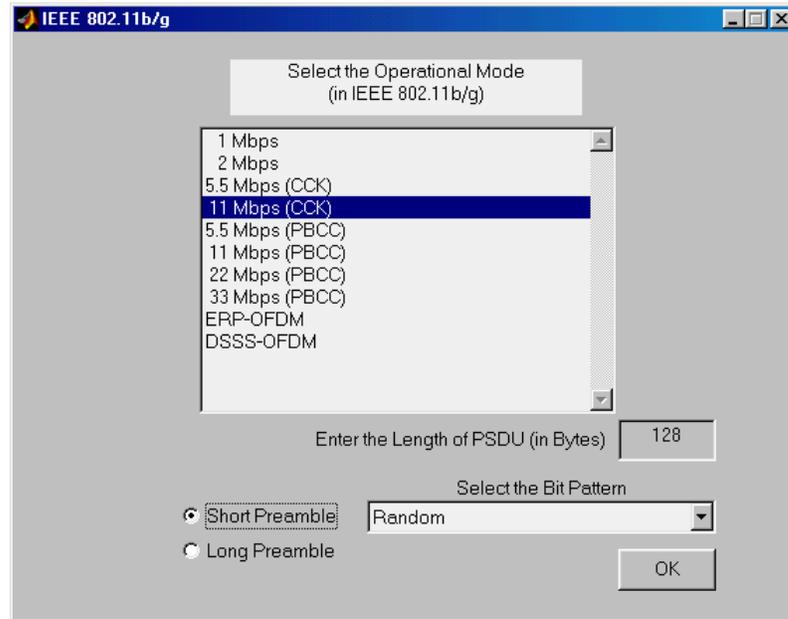
Figure 3. IEEE 802.11b/g Data Mode

4.2 Transmit Functions

As soon as the user clicks this box, a block diagram illustrating all the transmit functions implemented in the software pops for informational purpose, as shown in Figure 4. Since this is a standard-specific product, there is no need for the user to make any changes in this screen, except that the pulse shaping can be specified. The user may specify any shaping function defined by himself/herself or choose to use the most popular squared root raised cosine functions. In the latter case, the roll-off factor can be specified. For generating test vectors, it will used with the transmit shaping function. For use in Signal Analyzer, it will be used for the matched filter. In Link Design and BER Tester, it will be used for both the transmit shaping and the receive matched filters.
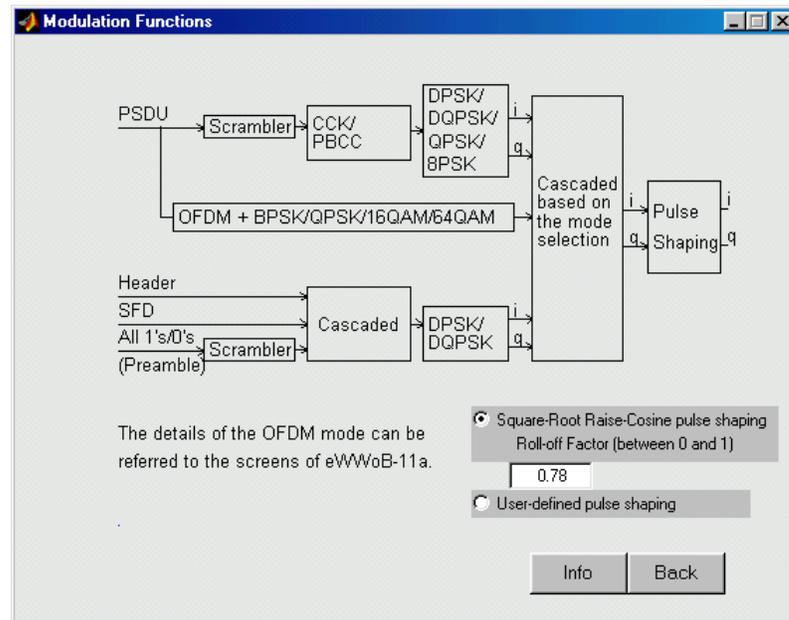
Figure 4. Transmit Functions

4.3 U/C and PA

This box represents the up-converter (U/C) and the power amplifier (PA) employed in a real-life communications system. Figure 5 is the screen shot when this box is selected. There are two PA models available for selection: the standard model and the user-defined model. In the standard model, the user enters AM/AM and AM/PM parameters (illustrated in the PA screen) that characterize the power transfer function. In addition, an operating point is required to model the nonlinear effect. For the user-defined model, the user enters the power transfer characteristics point by point up to 10 points. The operating point is also required for evaluating nonlinear effect. This feature allows the user to select and evaluate the PA device from multiple vendors. The effects of U/C (for example, like spurious signals and phase noise, etc.) can be lumped into the down converter (D/C), as far as the modeling is concerned. Thus, there is no specific U/C parameter treated in this screen.
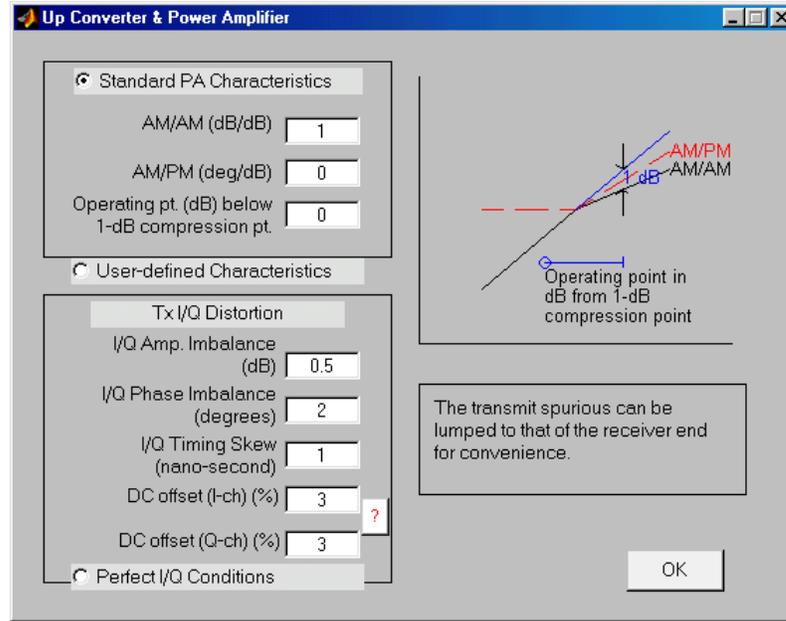
Figure 5. Up-Converter and PA

4.4 Channel Model

Two major factors in the channel model are the multipath characteristics and the Eb/No level, as shown in Figure 6 below. There are two multipath models for selection: the IEEE model and the user-defined model. For the IEEE model, there is only one parameter to specify and that is the rms delay spread. For the user-defined model, up to 3 rays can be specified. In each multipath ray, the delay time and the power level are specified. When the multipath is selected, it applies to generating test vectors only. The Eb/No can be specified when the user wants to conduct BER/PER tests. It is always set to a very high level (beyond 60 dB) for other cases, including the link design.
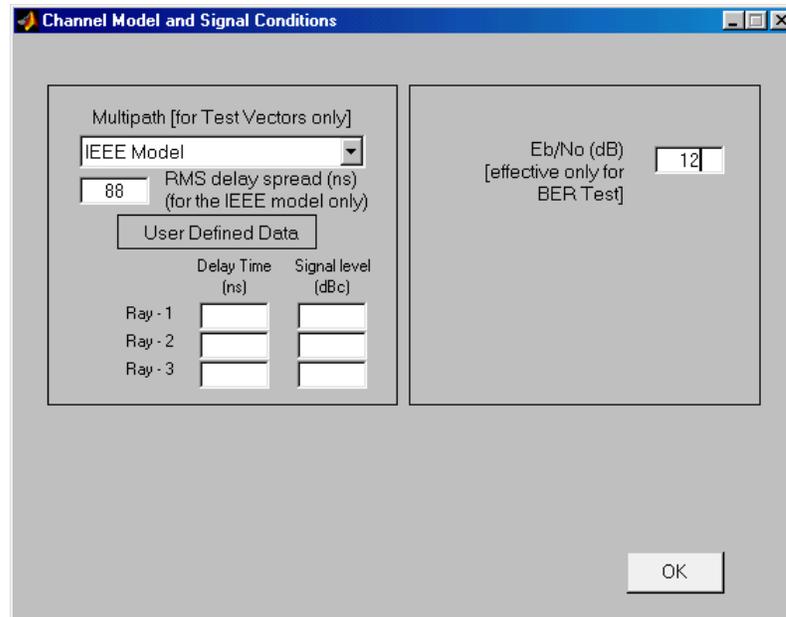
Figure 6. Channel Model

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4.5   LNA, D/C, A/D

This box models a typical receiver chain, from the low noise amplifier (LNA), down-conversion (D/C), and the analog-to-digital (A/D) sampling devices. Almost all the major hardware imperfect factors in this chain are considered in this box. The typical signal parameters or imperfection factors include I/Q amplitude imbalance, phase imbalance, phase noise of the oscillators, spurious signals from various mixers, etc. In particular, the broadband effect of the I/Q timing skew is included. The user may enter the phase noise spectrum or enter one rms phase error, depending on the available data. When the user enters the phase noise spectrum, an equivalent phase error will be computed and used in the subsequent execution. The user can also specify the anti-aliasing filter to evaluate the performance degradation. It is particularly important when the sampling rate is set close to the Nyquist rate. When this case occurs, the group delay effect may become dominant and hence some kind of equalizer or FIR filer must be considered. Figure 7 is the screen shoot of LNA-D/C-A/D, visually illustrating the aforementioned discussion.
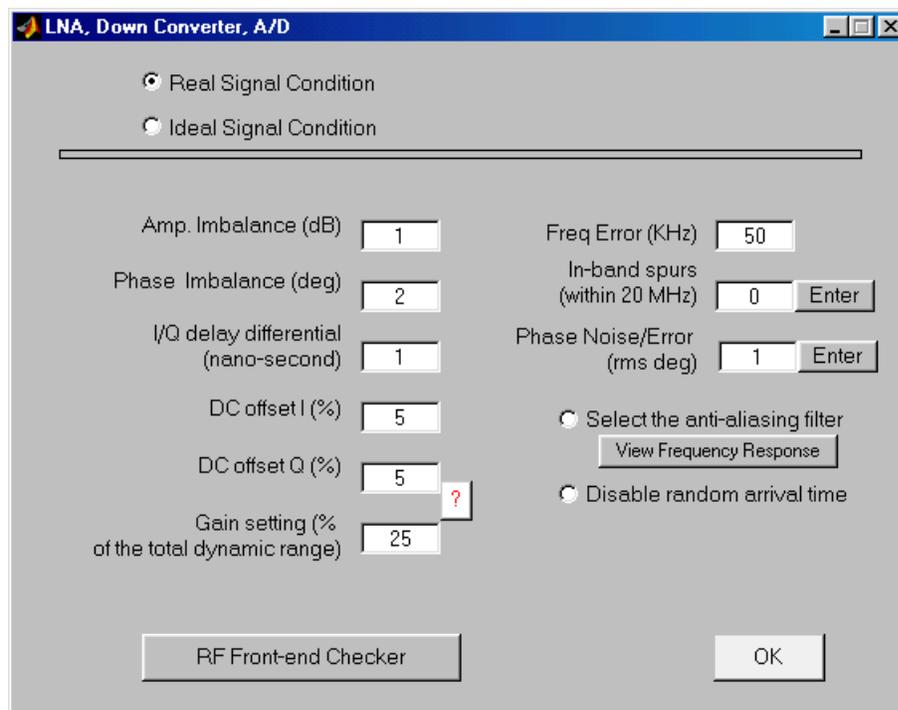
Figure 7. LNA, D/C, A/D

4.6   Test Vector

This is one of the four feature functions in eWWoB. The user will be able to generate standard-compliant test vectors for external use in this box. Before saving the samples into a data file for export, the user will be able to view and confirm the selected waveform (including the power spectrum and the constellation) along the specified system parameters. As an example, Figure 8 shows the evidence of the DC offset on the I-channel as opposed to no DC offset on the Q-channel. To understand the integrity (if distortion factors are specified) of the test vector, the user can use Signal Analyzer (to be discussed in the next section) to evaluate by saving it first into a file. The file format currently

supported includes both the binary format and the ASCII text format. The former is suitable for machine reading and large quantity of sample data, and the latter can be read and modified by human. Both are commonly known data formats and hence can be read by most external devices with ease. The sampling frequency can be set differently for each test vector. It is also a handy option that the user can choose to digitize waveform samples by selecting the number of A/D used and the level setting. Two additional data files will be generated for each saved (for export) test vector file. One of them contains the "mode" information in association with the test vector file, and the other data file contains some part of numerical data of PLCP in case that the user is interested in comparing numbers with their own design. The filename conventions are *filename*_info.txt and *filename*_PLCP.txt, respectively.
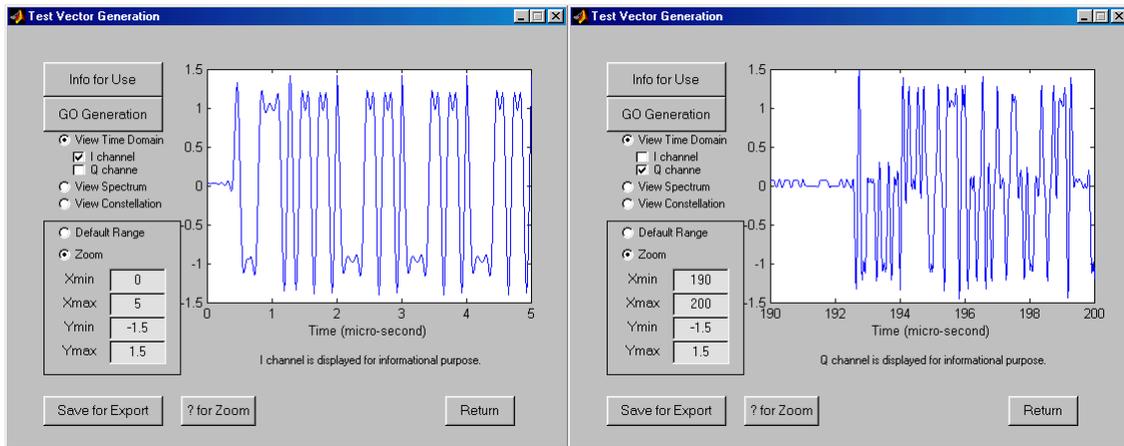
Figure 8. Viewing facility in Test Vector (e.g., DC offset on I-channel)
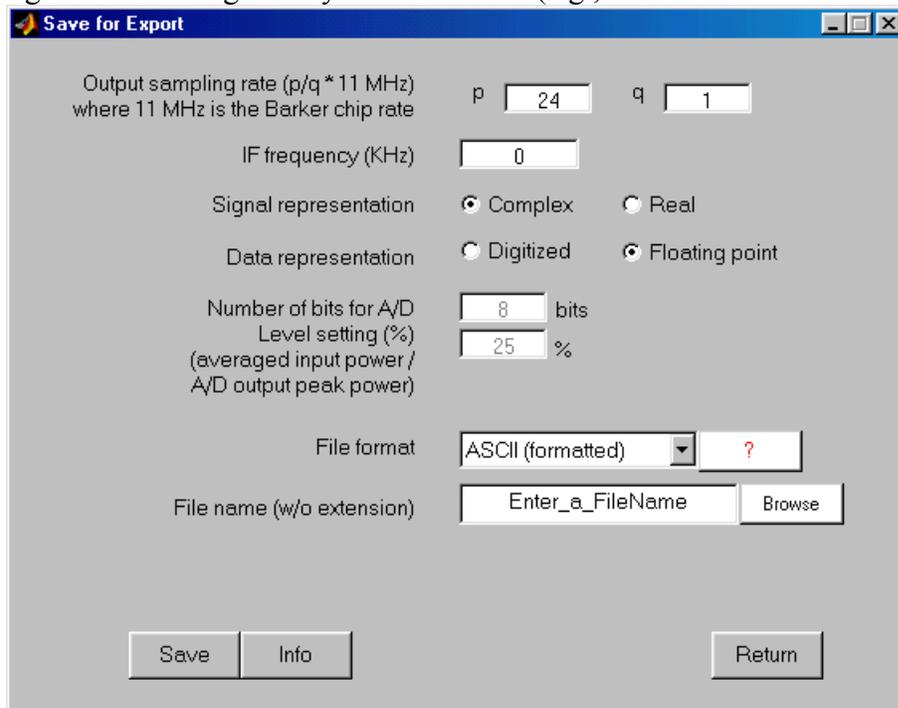
Figure 9. Input setup for saving a test vector

4.7 Signal Analyzer

In this function, the user may import a data file containing the samples taken from external devices to analyze it, provided that the samples represent valid IEEE Std. 802.11abg waveform. The external devices can be a transmit software module or a hardware prototype board developed independently outside eWWoB. The same file format addressed in Section 4.6 applies to the input file format herein and hence it is easy to interface with any external devices. A text file reporting the results of this function is generated at the end of each run. Included are error vector magnitude (EVM) statistics, SNR estimation, and the decoded data sequence, depending on the waveform under examination. The user can easily validate or associate the report with the input data files under test. There is essentially no input constraint or requirement for the imported file except for the sampling rate and the IF frequency, which are common parameters to any commercial test equipment. eWWoB is equipped with a receiver suite and hence is capable of detecting, demodulating, and decoding the 802.11abg waveform with any frequency error (up to 50 ppm at 5.8 GHz), phase non-coherency, burst and sampling timing, etc. Figure 10 is the screen shot for the use of this function. As shown, the user has a chance to "view" the signal before conducting analysis.

Figure 10. Inputs for Signal Analyzer

4.8 Link Design

This function facilitates the user with a vehicle to conduct design evaluation, verification, or trade-off iterations by specifying the selected parameters given in the program. This is an end-to-end modeling and simulation. There are about a dozen key system design parameters built into this program. The final SNR degradation estimate is obtained by an analytical approach. When the degradation is computed to account for the distortion

factors prior to the receiver end, like in the premier edition, a perfect anti-aliasing and an ideal matched filter will be assumed in computation. This is an important isolation step in waveform design. The results obtained from this function are time-efficient and good for serving as the first order performance assessment, due to the analytical modeling approach. For detailed performance, one will need the Monte-Carlo simulator in the next section.

4.9 BER/PER Test

This box provides a time-domain simulation environment, also known as Monte-Carlo simulation, for the user to validate their system design. Bit error rate (BER) and packet error rate (PER) are primary performance measures. This feature function models all the parameters specified prior to invoking the simulations. The effects of key receiver tracking loops are also modeled. The PHY layers of IEEE 802.11a/b/g employ FEC (forward error correction), with puncturing and trellis coded techniques, to achieve high throughput rate and performance. The Viterbi algorithm is known the most effective way for decoding such FEC.

BER/PER test-runs will consume more time compared to the Link Design. However, they offer close-to-real-life understanding and validation on the user's design selections and specifications. Therefore, it is not recommended until the user has achieved certain confident level with the Link Design. A family of BER performance in the AWGN channel is stored and available as a reference baseline, as shown in Figure 11. These curves are obtained from running eWWoB with ideal signal conditions and near-optimum Viterbi decoding (i.e., a Maximum Likelihood decoder). PER cannot be related to BER accurately in burst or packet communications under certain imperfect system conditions. It is thus necessary to execute the BER/PER tester eventually to complete the design process.
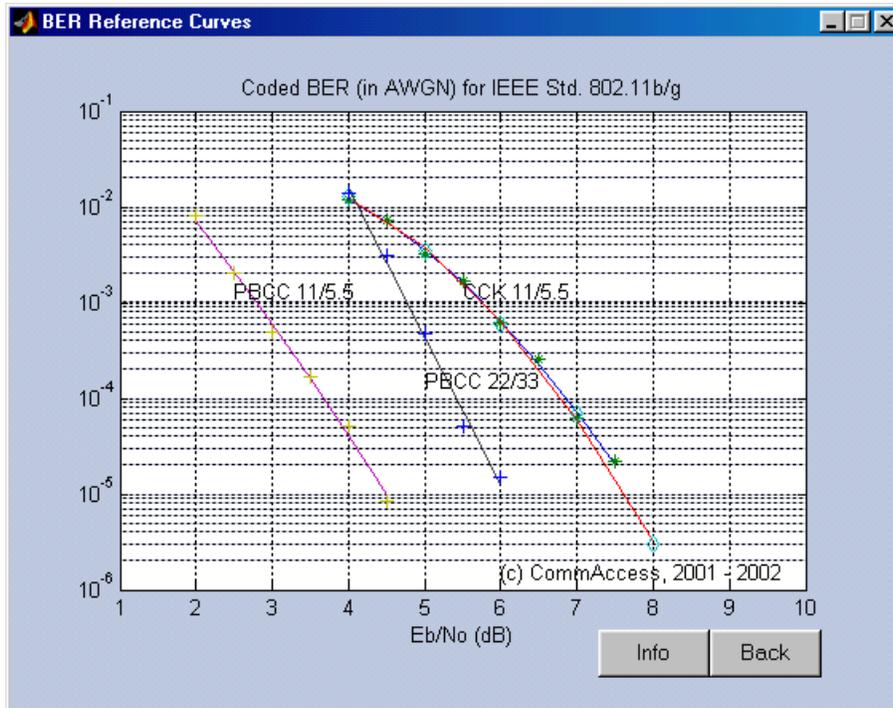
Figure 11. Coded BER Reference for IEEE Std. 802.11b/g

All the design or selectable parameters built in this software are summarized in Table 1. The unmarked items are implemented for both premier and professional editions.

Table1. Built-in Parameters

Parameter Description	Remarks
Data Mode	
U/C and PA	

Standard Model
    - AM/AM conversion (dB/dB)
    - AM/PM conversion (deg/dB)
    - Operating point in dB below 1-dB compression point
   User-defined Model
    - User may enter up to 10 transfer points
    - Operating point
	Pro. Ed.[1]

Tx I/Q amplitude imbalance (dB)	
Tx I/Q phase imbalance (deg)	
Tx DC offset (I & Q) (% of the short preamble peak)	
Tx I/Q path differential (ns)	
Channel Model	

Multipath selection
    IEEE model
     - Delay spread (in ns)
    User-defined paths
	Test Vectors only

Eb/No (dB)	BER Tester only
LNA, D/C, and A/D	
I/Q amplitude imbalance (dB)	Pro. Ed
I/Q phase imbalance (deg)	Pro. Ed
DC offset (I & Q) (% of the total range)	Pro. Ed
I/Q path differential (ns)	Pro. Ed
In-band spurious (number and dBc level)	Pro. Ed
Frequency error (KHz)	Pro. Ed
RMS phase error due to phase noise (deg)	Pro. Ed.
Low Pass Filter (type, order and bandwidth)	Pro. Ed.
Select to disable modeling random arrival time	
Viterbi decoding (BER Tester only)	[2]
Path memory length (in # of the constraint length)	Pro. Ed.
Number of bits in the Quantizer	Pro. Ed.
Quantization boundary	Pro. Ed.
Phase noise related loop design (in BER Test)	Pro. Ed.

Note:
1) Pro. Ed. = Professional Edition
2) A near-optimum decoder setup is built in the Premier Edition.

4.10 Effect of Tracking Loops

As we mentioned earlier, eWWoB simulates the BER effect due to various tracking loops in a receiver. For example, the simulation may account for the effect due to the gain accuracy variation resulting from the gain control loop. Similarly, the effects due to the output characteristics of carrier tracking loop, timing tracking loop, etc. can be selected. However, it is noteworthy that there is no dynamic loop functions (such as equalizers or tracking loops) modeled in the BER/PER tester. It is beyond the scope of the waveform designs defined in this product. In other word, the performance results obtained from this feature function will be used to guide the receiver tracking loop designs. (For any user interested in receiver design core technology, please contact CommAccess separately.) Figure 12 illustrates how this feature capability is selected and specified.
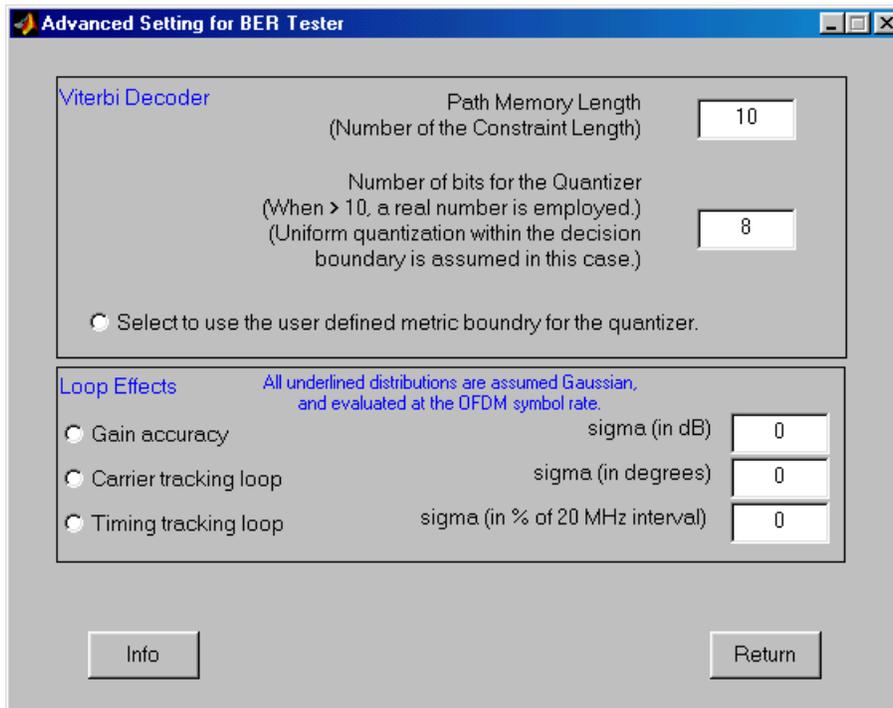
Figure 12. Advanced Settings for BER/PER Tester

4.11 Viterbi Decoder

Also shown in Figure 12, eWWoB allows the user to specify key Viterbi parameters for BER simulation. In addition, eWWoB provides the flexibility allowing the user to specify the boundary points of the quantizer prior to the decoder. These are key design issues for the user if he/she were to design the Viterbi decoder. Figure 13 shows a quantization boundary map that reflects the boundary points specified by the user.

4.12 User-defined Filter

The filters employed prior to the A/D converter may affect the system performance. Depending on the RF architecture, there may be more than one filter, for example like the image rejection filter and anti-aliasing filter. For the practical purpose, meaning that the image rejection effect has been designed to do its job, the waveform distortion due to the

anti-aliasing filter may dominate the effect because its bandwidth is normally narrower than that of the image rejection filter. We can always consider both filter responses together if we wish due to the linear function in nature. eWWoB permits the user to import his/her filter designs to evaluate the performance effect. Both finite impulse response (FIR) and infinite impulse response (IIR) filters are accepted. The user may design the filter employing any independent design tool like the one provided in the Signal Processing Toolbox by MATLAB. Figure 14a shows the screen importing filter coefficients and Figure 14b shows the preview of the filter response.
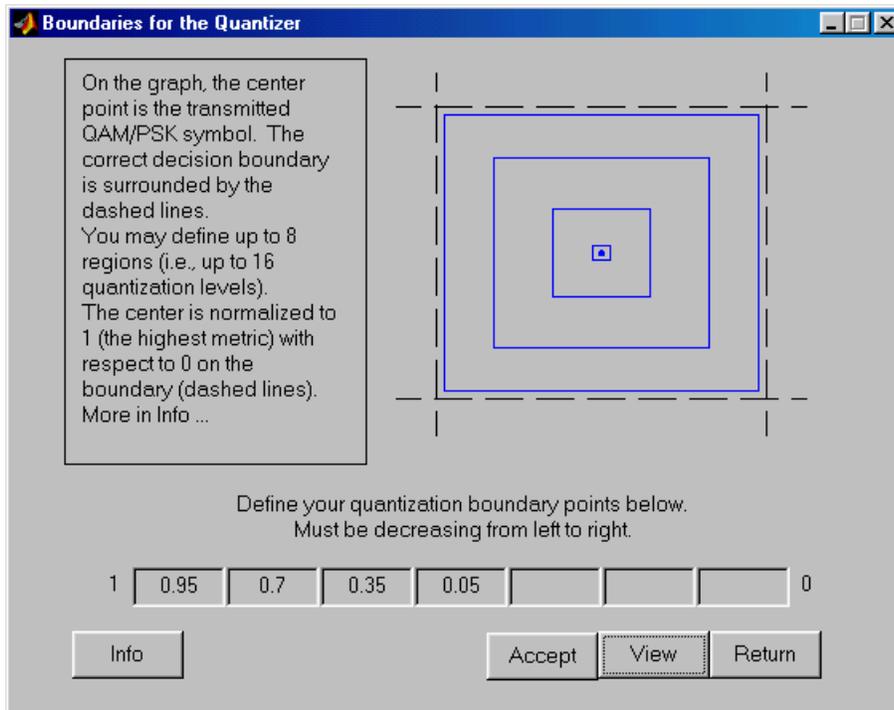
Figure 13. Boundaries for the Quantizer
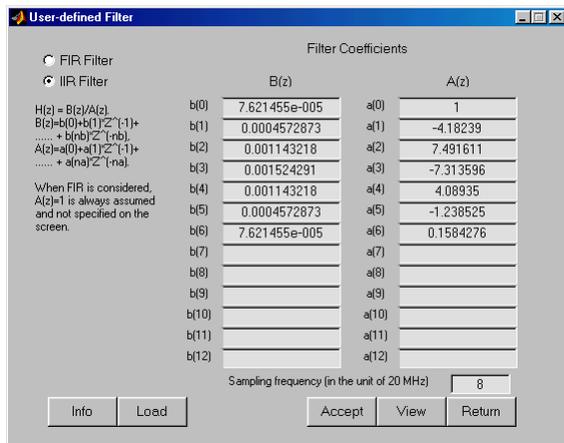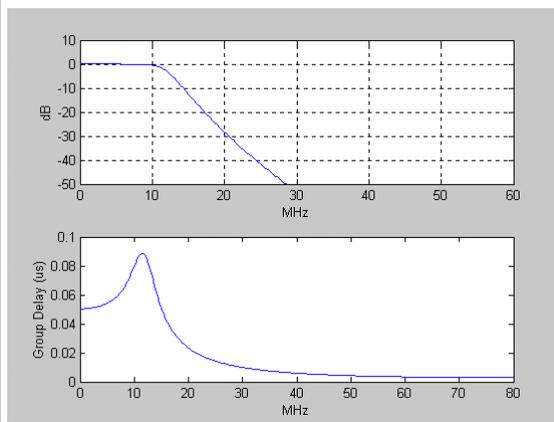
Figure 14a   Figure 14b

4.13 Examine Signal Score

Due to the different characteristics of the PSK and OFDM waveform, we create a window for the user to refine the sampling time and frequency adjustment through interactive iteration for the PSK signals. Figure 15a is the screen that first comes up. The user may click either the eye diagram or the scattering plot to view the signal effect. The user enters Update Graph to display the selected view (Figure 15b). He /she will be able to enter any adjustment until the eye completely open at the integer index. That will be used for subsequent signal score evaluation.
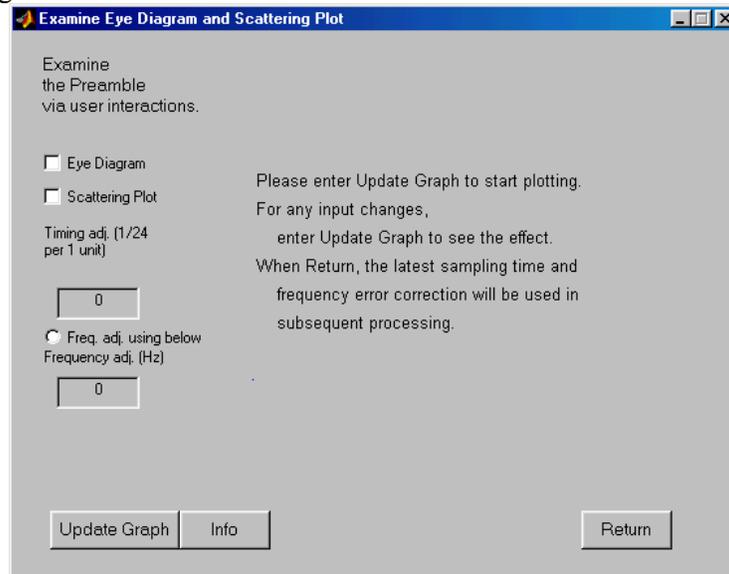
Figure 15a

Figure 15b

19
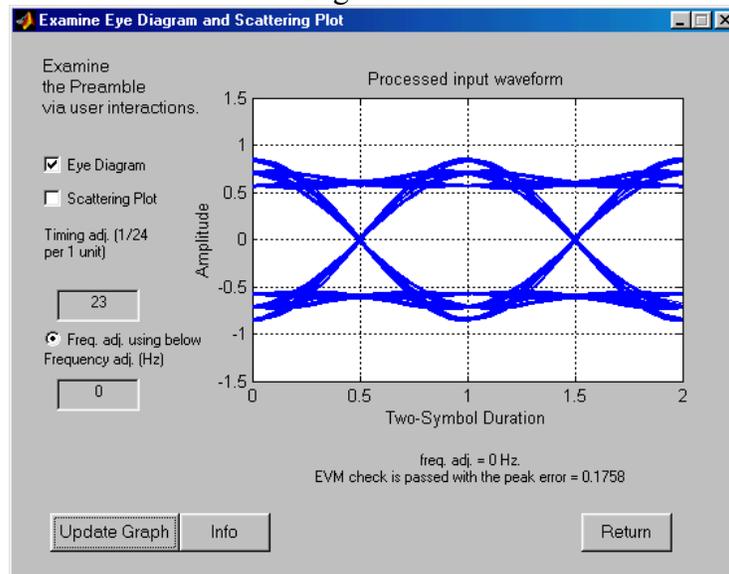
4.14 RF Front-End Checker

In Figure 7, there is a button called RF Front-end Checker. This is an advance feature recently added to eWWoB. Inside the checker, the user will be able to examine system level RF front end designs to assess its "capability." The information dealt in this subject include noise figure, input IP3 point of a non-linear device, etc. The resultant information from this checker includes receiver sensitivity, noise floor, and spurious free dynamic range, as shown in Figure 16 below. These are very important design information that may affect the receiver performance. The user has the chance to enter parameter values at the subsystem or component levels.

Figure 16

5 Sample Outputs

In this section, we present some example outputs for informational purposes. Table 2, below, is a typical text printout from a Link Design run. As shown, all the input conditions, intermediate status, and the waveform score outputs are all shown in one place.

<u>Table 2. Sample Text Report (from MATLAB Command Windows)</u>

```
...... start execution >>> Watch the displays ......
---> Burst arrival is detected!
---> The coarse frequency estimation is obtained.
---> The sampling timing is obtained.
---> Phase is adjusted.
---> Demodulated signal constellations are being shown in Figure windows.
---> Start demodulating the OFDM symbols.


************** Link Design Report **************
The burst arrival time is a random variable.
The initial signal phase is a random variable.
The input frequency offset in this run is   100.000 KHz.
The initial frequency correction is    99.959 KHz.
The final frequency correction is   100.080 KHz.
The gain estimate is   1.004.
Data Rate = 36 Mbps.
Modulation= 16-QAM, FEC Code Rat= 3/4, Length of PSDU = 240 bytes.
Eb/No = 60 dB
A linear amplifier is modeled.
A brick-wall filter is assumed in this run.
Other signal parameters:
 I/Q amplitude imbalance (dB)        :  1.00
 I/Q phase imbalance (deg)           :  0.00
 I/Q delay differential (ns)         :  3.00
 DC offset I channel (%)             :  3.00
 DC offset Q channel (%)             :  2.00
No in-band spur was specified in this run.


***** Results *****


  !!! Congratulations !!!
---    You have passed the waveform test with NO bit error out of 2016 bits
The overall EVM is  15.36%.
Figure 4: The EVM distribution as a function of frequency bin.
Figure 5: PDF of EVM as function of its magnitude in (%).
Figure 6: Predicted SNR losses as function of operating Eb/No level.


This is the end of the specified run.
Please go back to the System Diagram for the next case.
---------------------------------------------------------
```

There are typically six figures produced in each run. They (OFDM waveform) are shown below.

1st (Figure 17a):   Time domain I/Q waveform display
2nd (Figure 17b):   (Preamble) I/Q constellations at different stage of processing
3rd (Figure 17c):   (Data) I/Q scattering plot
4th (Figure 17d):   EVM function of sub-carriers
5th (Figure 17e):   EVM density functions
6th (Figure 17f):   SNR degradation estimation
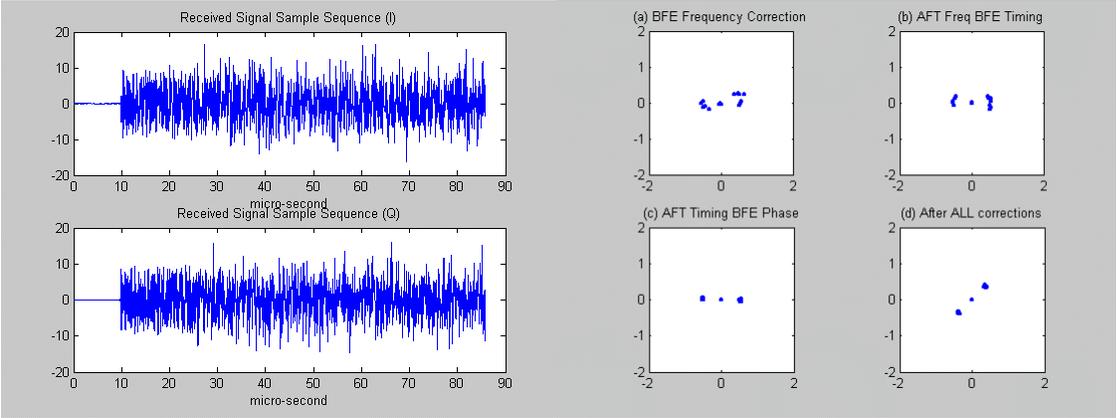
Figure 17a.   Figure 17b.
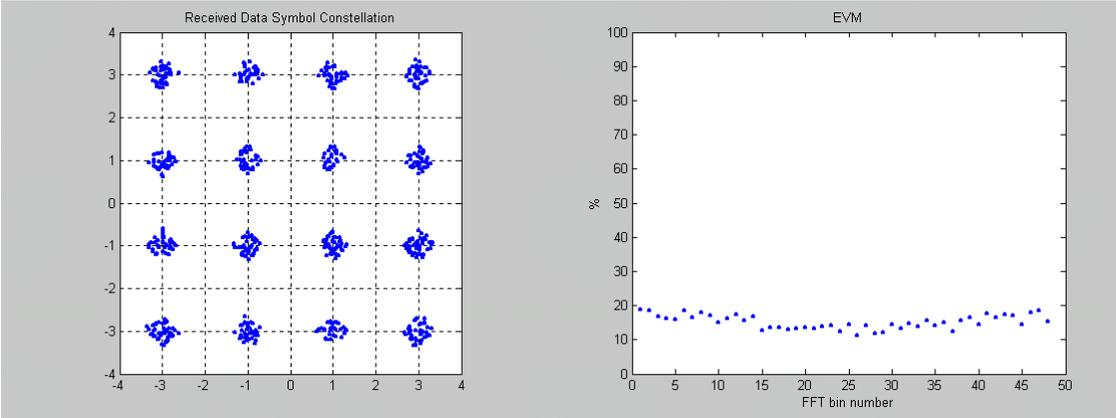
Figure 17c.   Figure 17d.
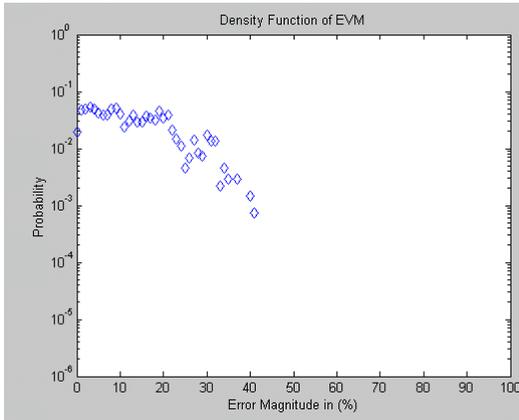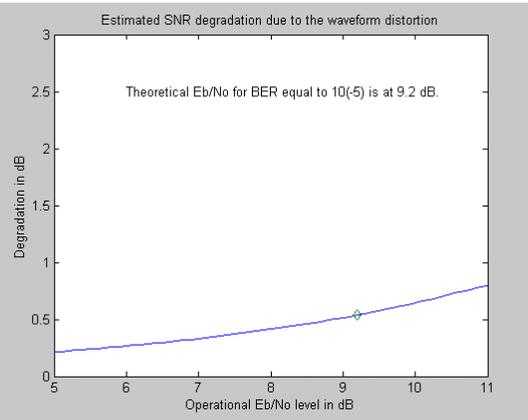
<table>
<tr><td>Figure 17e.</td><td>Figure 17f.</td></tr>
</table>

Moreover, Table 3 and Table 4 exemplify the text files produced from the execution of Test Vector (Export) and Signal Analyzer (Import), respectively.

Table 3. Information File for the Export Data

```
The information in this file is referenced to the data file
\userdata\11a_sample.bny
Data Mode: 16-QAM, r=3/4, 36 Mbps
There are 100 bytes of PSDU as follows:

04 02 00 2E 00 60 08 CD 37 A6
00 20 D6 01 3C F1 00 60 08 AD
3B AF 00 00 4A 6F 79 2C 20 62
72 69 67 68 74 20 73 70 61 72
6B 20 6F 66 20 64 69 76 69 6E
69 74 79 2C 0A 44 61 75 67 68
74 65 72 20 6F 66 20 45 6C 79
73 69 75 6D 2C 0A 46 69 72 65
2D 69 6E 73 69 72 65 64 20 77
65 20 74 72 65 61 DA 57 99 ED
```

Table 4. A Report File from Signal Analyzer

```
******************** Waveform Analysis Report ********************
                    24-Jan-2002  @13:44:14
The name of the input File Under Test is \userdata\11a_sample.bny.

The LONG PREAMBLE starts at 9.600000 micro-sec from the beginning of the
data file.
The initial signal phase is a random variable.
The initial frequency correction is    -0.047 KHz.
The final frequency correction is    -0.001 KHz.
The estimated gain setting is     0.01 dB.
Data Rate = 36 Mbps.
Modulation= 16-QAM, FEC Code Rat= 3/4, Length of PSDU = 100 bytes.

The decoded service field contains 0000.
The decoded data sequence is shown as follows:
Interpretation: When you read two 8-bit characters like "04" "7B",
           the bit sequence for transmission (prior to scrambler, etc.) is
               (LSB first out) 00100000 11011110

04 02 00 2E 00 60 08 CD 37 A6
00 20 D6 01 3C F1 00 60 08 AD
3B AF 00 00 4A 6F 79 2C 20 62
72 69 67 68 74 20 73 70 61 72
6B 20 6F 66 20 64 69 76 69 6E
69 74 79 2C 0A 44 61 75 67 68
74 65 72 20 6F 66 20 45 6C 79
73 69 75 6D 2C 0A 46 69 72 65
2D 69 6E 73 69 72 65 64 20 77
65 20 74 72 65 61 DA 57 99 ED


The overall EVM is   8.10%.
Figure 4: The EVM distribution as a function of frequency bin.
Figure 5: PDF of EVM as function of its magnitude in (%).
Figure 6: Predicted SNR losses as function of operating Eb/No level.

******************  End of Report  ******************
```

The important message shown in these two tables is that eWWoB can not only analyze the waveform samples for the integrity but also demodulate and decode the standard-compliant bit sequence which makes it a very convenient tool for the "turnkey" test and measurement solution.

6 File Conventions in eWWoB

eWWoB generates data file(s) from each run for the purpose of documentation. They are explained in this section. The notation *filename* is the user-defined file name that is asked to enter during execution.

6.1 File Definition

Filename.bny	The output file from Test Vector containing the waveform samples of the binary format.
Filename.dat	The output file from Test Vector containing the waveform samples of the ASCII format.
*Filename*_info.txt	The data file contains the "mode" information associated with the output sample file *filename*.bny or *filename*.dat.
*Filename*_PLCP.txt	The data file contains some part of PLCP numerical data.
*Filename*_UT.txt	The output file from Signal Analyzer contains the analysis results from the selected imported file *filename*.bny or *filename*.dat.
*Filename*_n.fig	The graphic files saved by the user contains the information defined in section 5, in which 'n' is a number from 1 to 6.
PLCPtmp.txt	A temporary file contains some part of PLCP numerical data each time a frame of data is generated. It is overwritten every time until it is saved into a user-defined flename.
Linktmp.txt	A temporary file contains all printed results from Link Design. This file can be renamed to a user-defined name for later use at the end of each run. Should the user choose not to rename it, the content will be overwritten in the next run.
BERtmp.txt	A temporary file contains all printed results from BER/PER Test. This file can be renamed to a user-defined name for later use at the end of each run. Should the user choose not to rename it, the content will be overwritten in the next run.

6.2 File Format

The main information in the import/export data files is signal samples, which are represented by complex representation (I/Q). For the binary format, the data are stored in sequential manner. There are three pieces of information preceding the I/Q sample pairs. They are (p, q, IF) in which p and q are integers and combined to represent the sampling rate as $p/q*20$ MHz or $p/q*11$ MHz, and IF is the intermediate frequency in kHz where the signal is sampled. In summary, the data set contains {p, q, IF, I, Q, I, Q, I, Q, ...}, and they are all real or floating point numbers, even though p and q are integers.

The same information applies to the ASCII format, and that the data are arranged in human readable format as follows:

```
p
q
IF
I, Q
I, Q
…
…
```

7   Print Screens and Retrieve Graphs

All the screens in eWWoB can be printed using the same screen shot function provided by Windows. More specifically, hit the keys ALT+Print Screen on the keyboard and the active screen will be stored in the clipboard. Once in the clipboard, it can be saved to any word files for printing. All the screens displayed in this document are obtained from the same screen shot functions. The graphics saved by eWWoB can be retrieved for review any time when the screen of the System Diagram is active. Place the cursor inside the System Diagram screen and right click the mouse. All the figures in the folder $\userdata will be displayed for choice to open.

8   Contact Us

Please contact us by sending email to the following address if you have any questions, comments, or corrections:

support@commaccess.com.