

Tutorial
on

Engineer's Waveform Work Bench
(eWWoB)

for

IEEE Std. 802.11a
(5 GHz High-Speed WLAN)

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Introduction

Engineer's Waveform Work Bench (eWVoB) 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. eWVoB is developed on a very powerful computing environment - MATLAB. It can run inside MATLAB or on stand-alone. However, eWVoB is a third-party product of MATLAB. The latter is a product of The MathWorks, Inc.

The hardware platform hosting eWVoB may range from a standard desktop PC, laptop PC, to test or specialty equipment that supports Window-based computing engine.

Product Features

eWVoB 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:

1.1 Test and Measurement

eWVoB 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, eWVoB 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.

1.2 Verification

eWVoB 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.

1.3 System Design

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

Sample Screen Shots

System Diagram (IEEE Std. 802.11a) showing the flow from Data Mode through PSDU Header, OFDM-based Transmit Functions, U/C, PA, Channel Model, A/D, D/C, LNA, Signal Detection, Signal Recovery, Reverse ALL Tx Baseband Functions, Post Data Analysis, and Exit buttons.

IEEE 802.11a Select the Operational Mode (in IEEE 802.11a) dialog box. It lists various modes like 6 Mbps BPSK, 9 Mbps BPSK, 12 Mbps QPSK, 18 Mbps QPSK, 24 Mbps 16-QAM, 36 Mbps 16-QAM, 48 Mbps 64-QAM, and 54 Mbps 64-QAM. The 54 Mbps 64-QAM mode is selected. The PSDU length is set to 4096 bytes.

OFDM Transmit Functions block diagram showing the process from PSDU Header through Scrambler, FEC, Packet Formatting, Interleaver, Serial to Parallel, OFDM mod., Pilot tones insertion, IFFT, Parallel to Serial, Cyclic Prefix & windowing, D/A, and To analog BB/IF/RF.

Up Converter & Power Amplifier settings dialog box. It shows Standard PA Characteristics with AM/AM (dB/dB) set to 1, AM/PM (deg/dB) set to 0, and Operating pt. (dB) below 1-dB compression pt. set to 0. It also lists Tx I/Q Distortion parameters like I/Q Amp. Imbalance (dB) and I/Q Phase Imbalance (degrees).

Advanced Setting for BER Tester dialog box. It shows Viterbi Decoder settings like Path Memory Length (10) and Number of bits for the Quantizer (8). It also has options for Loop Effects like Gain accuracy, Carrier tracking loop, and Timing tracking loop.

BER Reference Curves graph showing Coded BER (in AWGN) for IEEE Std. 802.11a. The graph plots BER on a log scale from 10^{-6} to 10^{-1} against E_b/N_0 (dB) from 0 to 14. It shows curves for BPSK, QPSK, 16-QAM, and 64-QAM with different code rates (1/2, 2/3, 3/4).

Table1. Built-in Parameters

Parameter Description	Remarks
<i>Data Mode</i>	
<i>U/C and PA</i>	
Standard Model - AM/AM conversion (dB/dB) - AM/PM conversion (deg/dB) - Operating point in dB below 1-dB compression point	Pro. Ed. ¹⁾
User-defined Model - User may enter up to 10 transfer points - Operating point	
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)	
<i>Channel Model</i>	
Multipath selection IEEE model - Delay spread (in ns) User-defined paths	Test Vectors only
Eb/No (dB)	BER Tester only
<i>LNA, D/C, and A/D</i>	
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.
User-defined filter characteristics	Pro. Ed.
<i>Viterbi decoding (BER Tester only)</i>	²⁾
Path memory length (in # of the constraint length)	Pro. Ed.
Number of bits in the Quantizer	Pro. Ed.
Quantization boundary	Pro. Ed.
<i>Phase noise related tracking loop effects (in BER Test)</i>	Pro. Ed.
Carrier tracking	Pro. Ed.
Symbol sync	Pro. Ed.
AGC tracking	Pro. Ed.

Note:

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

Sample Outputs

Table 2. Sample Text Report (from MATLAB Command Windows)

```

..... 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.
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```

Sample Output Graphs

The graphs below are the output figures that eWVoB generates for each run. It covers the input waveform, intermediate signal parameter information, and the final waveform integrity results.

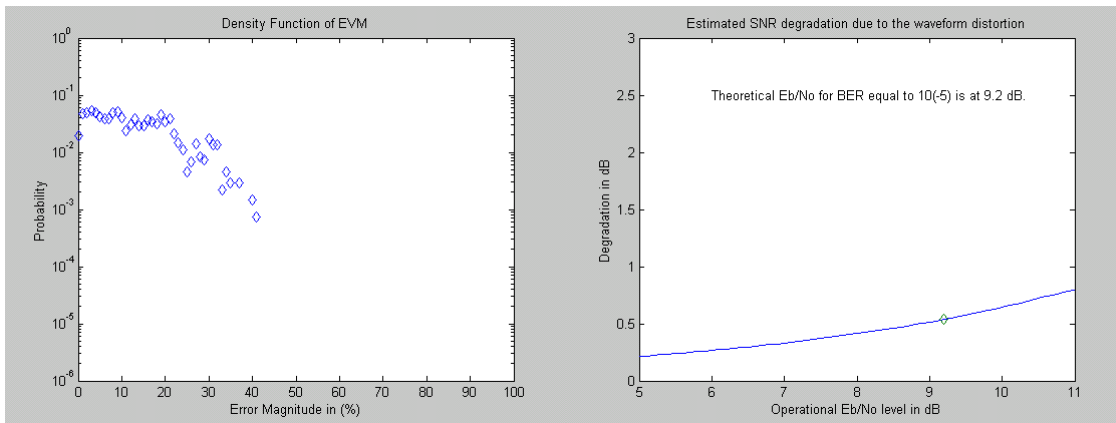
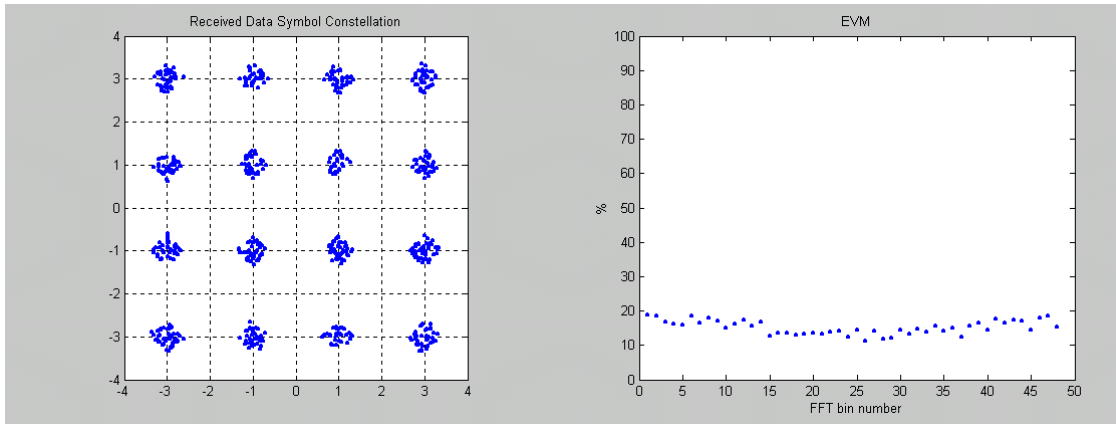
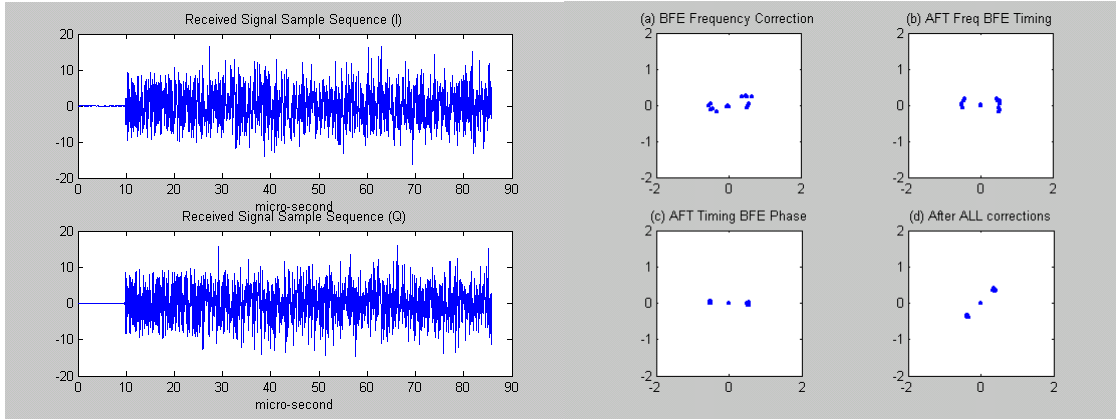


Table 3. A Report File Resulting from Signal Analyzer

```

***** 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 *****

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Contact Us

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

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