Advanced Design System 2017 Update 1

Verification Test Bench

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Verification Test Bench (VTB) and Verification Test Bench (VTB) Component

The Verification Test Bench (VTB) is a SystemVue Data Flow design in a SystemVue workspace. The Verification Test Bench (VTB) component is a regular component in the ADS simulation environment, which is linked to the Verification Test Bench (VTB) in the SystemVue. VTBs enable the circuit designer to make use of sources and measurement setups from SystemVue and verify the performance of a circuit using real world complex modulated signals conforming to advanced wireless standards such as 2G/3G/4G/5G.

From ADS 2017, to install files that are required for the VTB functionality you need to download a separate VTB installer (for Windows only). For Linux, the VTB installer is bundled with ADS installer.

- It is recommended to download compatible ADS and VTB installers to the same directory. After the download, run the ADS installer. This process will automatically install the VTB functionality.
- If you have already installed ADS and find VTB functionality is missing, then you need to download and install the VTB.

Creating VTBs

VTBs are created by a system designer in a compatible SystemVue environment and then used by a circuit designer working in ADS Advanced Design System is an EDA System for high-frequency circuit and system design. . For information on how to create a VTB, refer to the **SystemVue documentation**.

For the list of compatible versions, see ADS and SystemVue Compatibility.

NOTE In a schematic design, you can use only one VTB at a time. Using more than one VTB displays the following error message “Envelope 'VTB1_Env': multiple VTB components are found in the design, VTB1, VTB2”.

Built-in VTB Components

ADS provides some built-in VTB components for the standard wireless standards from SystemVue. They can be accessed from the component palette list or the component library browser in a Schematic view A view is a specific representation of a cell. Each view is a container that can store a file or a database object. Different view types include: schematics, layouts, EM setup, symbols, and EM model. . Following are the list of built-in VTBs available with ADS:

- 5G Advanced Modem Workspaces
- Bluetooth Workspaces
- Communications Workspaces
- DigitalMod Workspaces
- LTE Advanced Workspaces

- LTE Workspaces
- NB IoT Workspaces
- RADAR Workspaces
- WLAN 11ac Workspaces
- WLAN 11ad Workspaces

The corresponding SystemVue workspaces for these builtin-VTB components are installed in your $HPEESOF_DIR/SystemVue.

Customized VTB Components

You can create VTBs in a compatible SystemVue and then use it in your design. For more information on how to create VTBs, refer to **Creating a VTB** in the *SystemVue* documentation. For the list of compatible versions, see ADS and SystemVue Compatibility.

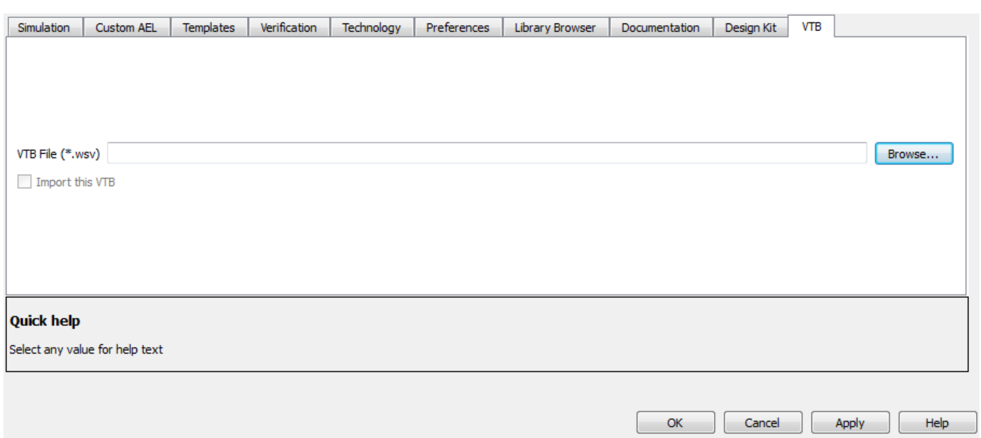
It is recommended to run the VTB in SystemVue before integration. For running the VTB, you may need to bypass the SVE_Link device. Reset the SVE_Link device state before saving the VTB file to be used in ADS.

Each VTB is represented as a single file. After the VTB creation, the file is stored in a directory from where it can be read/accessed to be used in the design.

Importing Customized VTBs

To import a custom VTB, do the following:

1. Click the **Library view** tab from the ADS Main window.
   Select a Library and right-click to select **Configure Library**.
   or
   Select **DesignKits** > **Manage Libraries** from the ADS Main window.
   Click **Configure Library** from the Manage Libraries dialog box.
   The Library Configuration Editor dialog box is displayed.
2. Click the **VTB** tab.



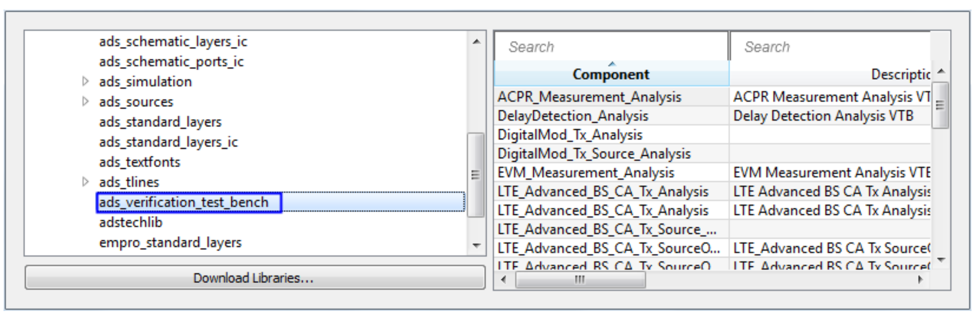
3. Click **Browse** or specify the VTB file name (*.wsv) associated with the library. If the VTB exists, the **Import this VTB** option will be automatically enabled and selected.
4. Click **Apply** followed by **OK**.
   The VTB will be added in the library as a symbol view.

NOTE You can import only one *.wsv file per library. If a library already contains custom VTB components, and you want to import another *.wsv file into the same library, you will be prompted to delete the existing VTB components in that library. If you do not want to delete them, you need to create a new library to import the *.wsv file.

Selecting and Placing the VTB Components

For the built-in VTB components, do the following:

- Select and place a VTB component through the component palette list.
  or
- Select **Insert > Component> Component Library**.
  The Component Library window is displayed.
  Select and place a VTB component from the `ads_verification_test_bench` library available under the ADS Analog /RF Libraries.

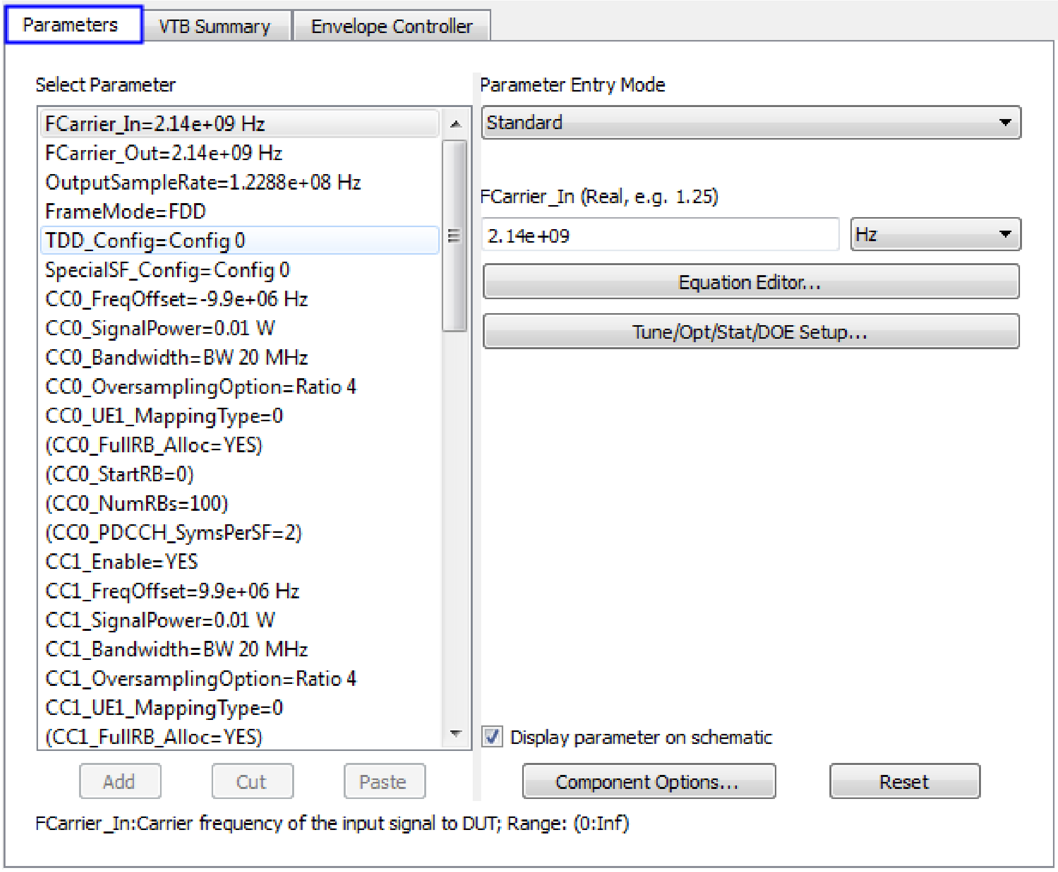


For the customized VTB components, do the following:

- Enter the VTB name in the Component History and press Enter in the Schematic view.
  Click to place the VTB at the desired location in the design.
  or
- Expand the custom Library cell and drag-drop the VTB at the desired location in the design.

Specifying the VTB Component Parameters

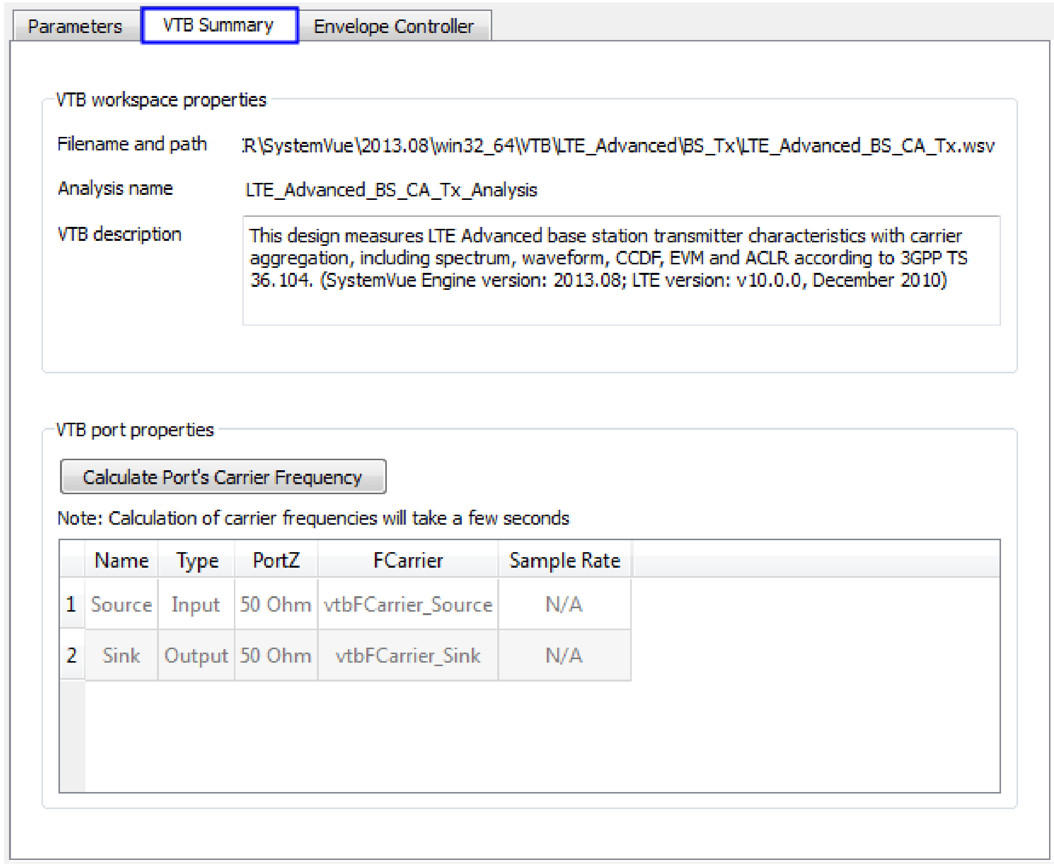
After placing the VTB component, double-click to view the VTB-specific parameters under the Parameters tab as shown in the following figure.



For information on each of the parameters, see the parameters section of the built-in VTB components. You can either specify a value or use equation, nominal, sweep, optimization, or statistical design variables with nominal value to set the VTB parameters.

Viewing the VTB Property Summary

The VTB associated properties are displayed under the VTB Summary tab as shown in the following figure.



It indicates the SystemVue workspace, the design flow analysis, and the test description. It also lists the port properties and you can query the carrier frequency of the ports from the SystemVue engine.

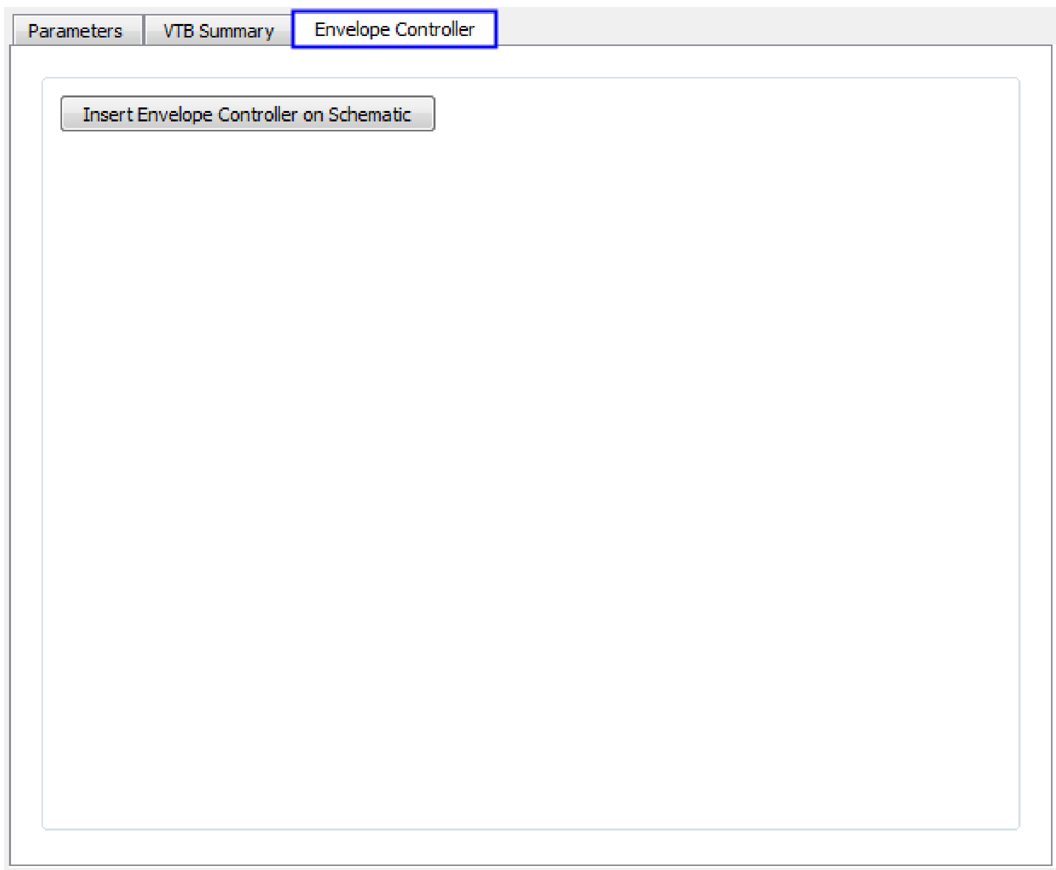
The following table describes the options available under the VTB Summary tab.

Option	Description
Filename and path	Displays the SystemVue workspace name and location.
Analysis name	Displays the VTB name, which is the data flow analysis name in the SystemVue workspace.
VTB description	Displays the description of the Verification Test Bench.
Calculate Port's Carrier Frequency	Query the port's carrier frequencies from the SystemVue Engine. It is an expensive calculation, which blocks the UI until it finishes. The calculation is not available if the parameters contain expressions.
Name	Name of the ports.

Option	Description
Type	Type of the ports, either is input or output.
PortZ	Impedance of the ports. It can be modified in the Parameters tab.
FCarrier	Carrier frequency of the ports.
Sample Rate	Sample rate of the ports.

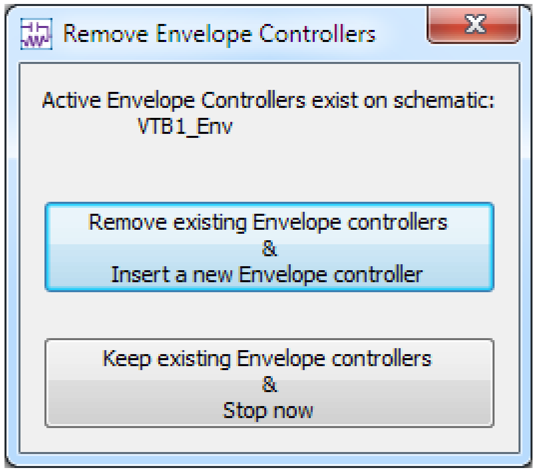
Linking to the Envelope Controller

The Envelope Controller tab is used to link the VTB with the Envelope controller for the cosimulation. It will set up Envelope controller with the fundamental frequencies as the port's carrier frequencies.

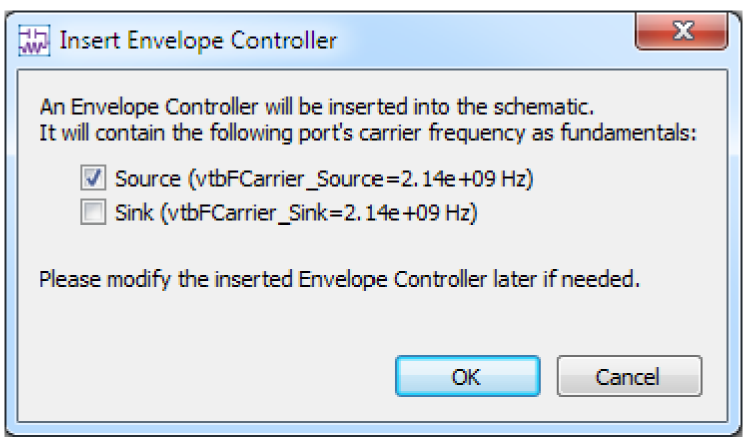


To place the Envelope Controller, click **Insert Envelope Controller on Schematic**. The following steps will take place:

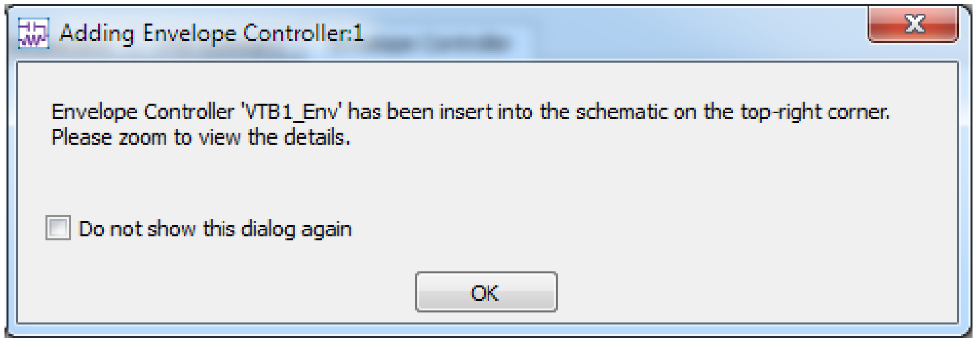
- Before placing the controller, the simulator checks whether there are any active Envelope controllers on the schematic. If an active Envelope controller already exists on the schematic, **Remove Envelope Controllers** dialog box is displayed. It allows you to either keep the existing controller or insert a new one.



- Calculate the port's carrier frequencies if required (for example, you modified the parameters).
- Once the port's carrier frequencies are available, **Insert Envelope Controller** dialog box is displayed with default fundamentals for the controller. If the port's carrier frequencies are the same, there will be only one fundamental for Envelope controller by default. Otherwise, there will be multiple fundamentals, each one corresponding to one port's carrier frequency.



- After you click **OK**, an Envelope controller with initial fundamental setup will be inserted on the schematic. Select **Do not show this dialog again** to avoid the dialog box to be displayed again.



See Also
Using Verification Test Benches (VTBs) Example

5G Advanced Modem Workspaces

VTB workspaces are provided to analyze FBMC transmitter and receiver characteristics respectively

Tx

Transmitter characteristics

- FBMC_Tx
- FBMC_Tx_Source
- 3GPP_NR_DL_Tx
- 3GPP_NR_DL_Tx_Source
- 3GPP_NR_UL_Tx
- 3GPP_NR_UL_Tx_Source

Rx

Receiver characteristics

- FBMC_Rx_AWGN

NOTE In current implementation, there are only one input port and one output port in the SVE_Link model used in LTE workspaces, which means the DUT (design in ADS/GoldenGate environment) should only have one input and one output. In Tx examples, the DUT is connected after the modulator. In Rx examples, the DUT is connected before the demodulator in the Rx chain. Please refer to the help document of each workspace for more information. in which you can find the detailed schematic.

How to set SVE_Link properties in LTE workspaces

Users can optionally define the ***SVE_Link*** properties by setting **DefineProperties** to YES. When **DefineProperties** is set to *YES*, parameters related to ***SVE_Link*** properties, including **InFeedbackLoop**, **SampleRate**, and **InputFcs**, can be defined by values or expressions.

- InFeedbackLoop: Specify whether the SVE_Link is in a feedback loop: NO, YES. In current FBMC examples, there is no feedback loop, hence **InFeedbackLoop** is set to *NO*.
- SampleRate: Sample rate of the signal. In FBMC examples, in the *Equations* tab of the design, **SamplingRate** of the FBMC system is calculated from **SampleRate** and **OversampRatio**.

- InputFcs: Array of characterization frequencies of input envelope signals. In current FBMC examples, there is only one input port in **SVE_Link** model, hence **InputFcs** is set to **[FCarrier_In]**.

Otherwise, when **DefineProperties** is set to *NO*, the VTB process will analyze the full design and provide such information to the integrating tool.

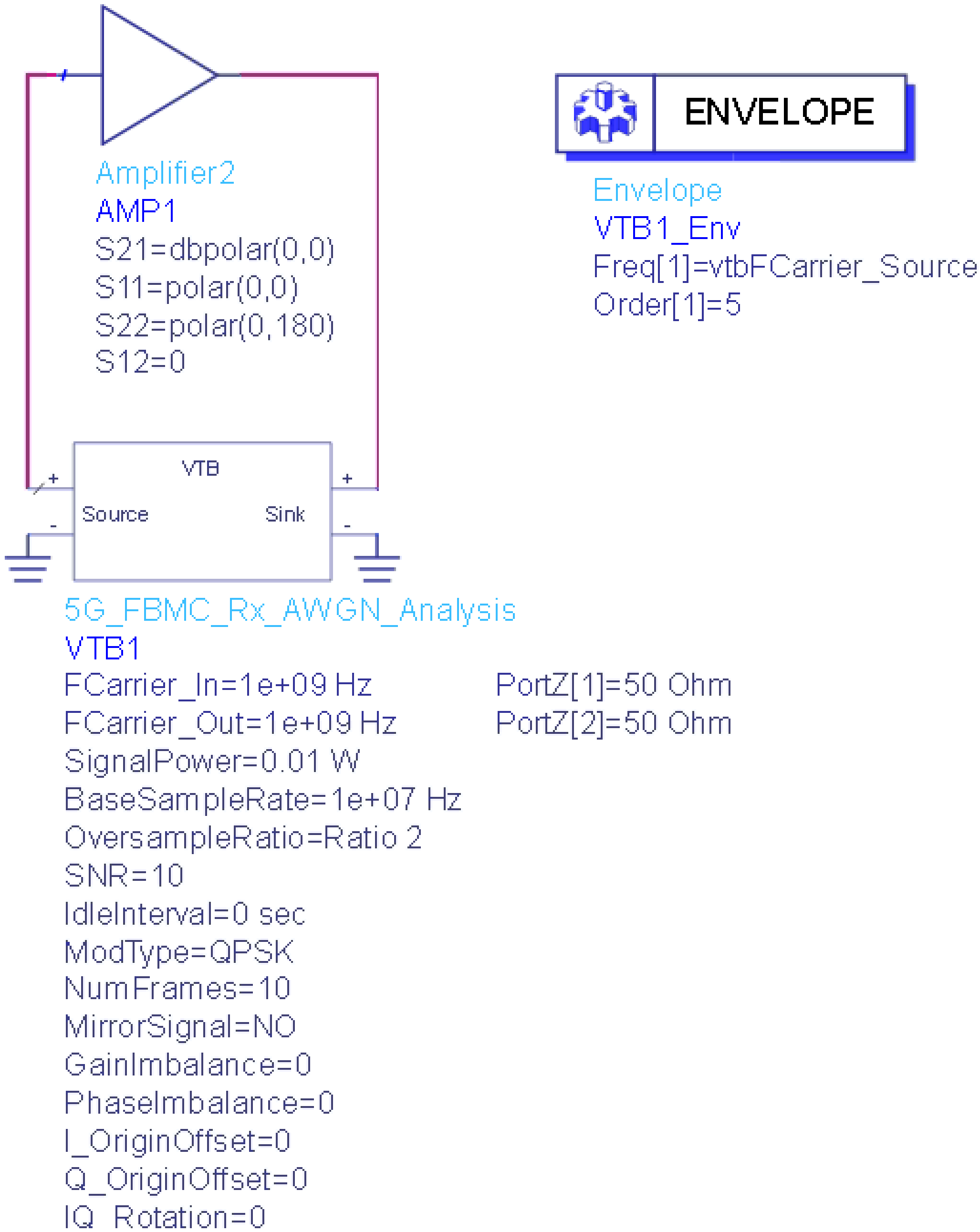
References

1. PHYDYAS, “FBMC physical layer: a primer”, June 2010.
2. 5GNOW_D3.1_v1.0, “5G Waveform Candidate Selection D3.1”, Nov. 2013.

5G_FBMC_Rx_AWGN_Analysis

This workspace provides a VTB test bench to measure the performance of FBMC receiver in AWGN channel.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(SVE_Link in the design) is set by FCarrier_In, while center frequency of the output signal from DUT(SVE_Link in the design) is set by FCarrier_Out.

RF distortions can be introduced by setting parameters GainImbalance, PhaseImbalance, etc.

The transmitted signal mean power is set by SignalPower.

In order to see attenuation of the spectrum, the OversampleRatio parameter is used to define oversample ratio.

The number of simulated frames is set by parameter NumFrames.

Parameter Details

1. FBMC Parameters
   - SNR: Signal to noise ratio used for BER measurement.
   - NumFrames: Number of FBMC frames for simulation.

2. Advanced Parameters

NOTE The following parameters are not exposed in ADS/GoldenGate environment. The default values of these parameters will be used in simulation. To change them, please open the workspace in SystemVue, go to the *Parameters* tab of the design and change the *Default Value* there.

   - NumEqualizerTaps: Number of taps used in equalization for which 0 for one tap, 1 for two taps and 2 for three taps.
   - Tmax: The maximum delay of multipath and the unit of it is second.
   - Fmax: The maximum Doppler frequency and the unit of it is Hz.
   - PhaseTrackingEnable: Using pilot to do phase tracking or not. PhaseTrackingEnable should be disabled when PilotEnable is set to No.

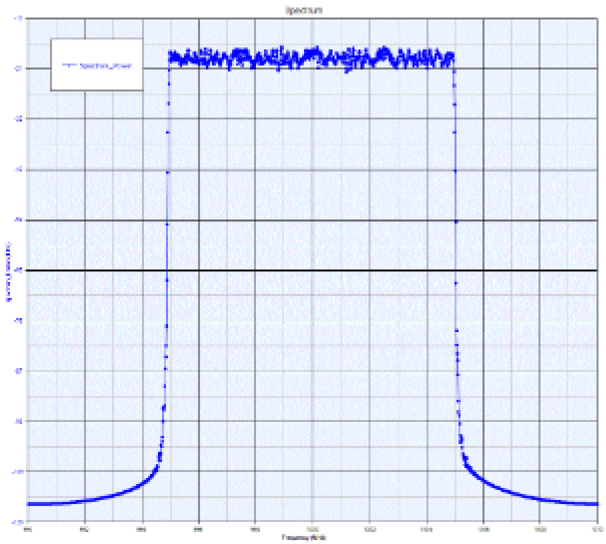
   For detail on other parameter, please refer to FBMC_Tx.

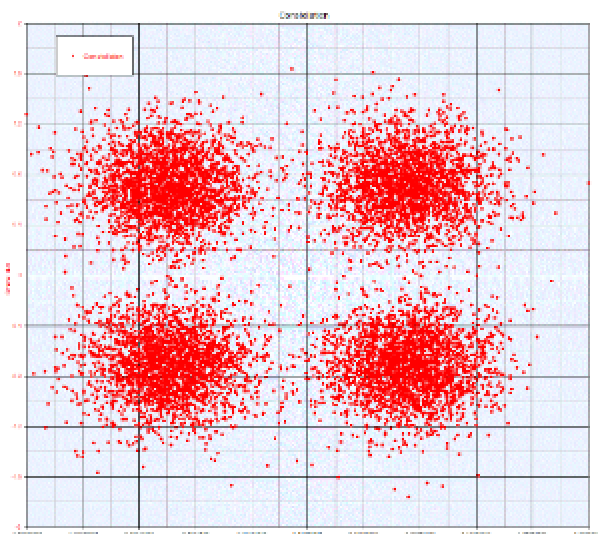
Simulation Results

Try to change the parameters, run 5G_FBMC_Rx_AWGN_Analysis and check the simulation results.

- Graph ***Spectrum*** shows the spectrum of the transmitted signal
- Graph ***Constellation*** shows the constellation of the demodulation FBMC signal
- Table ***BER*** lists the BER of FBMC receiver when SNR = 10

The following graphs would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation. The DUT is shorted to get the following ideal results. The same results will be displayed in SystemVue environment if the **SVE_Link** model is disabled to short.





	B2_BER_Index ( )	B2_BER
1	0	0.01824708

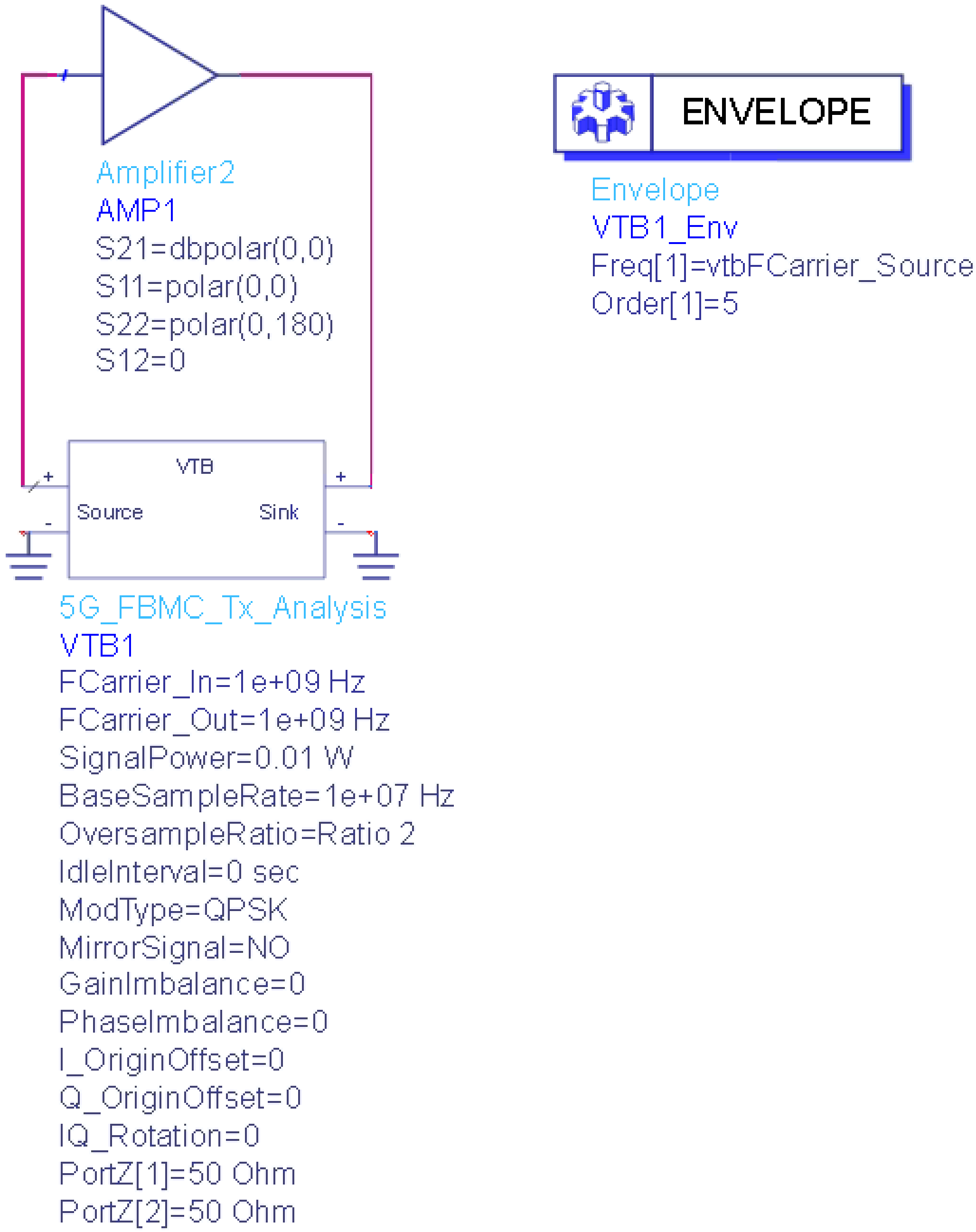
Reference

1. PHYDYAS, “FBMC physical layer: a primer”, June 2010
2. 5GNOW_D3.1_v1.0, “5G Waveform Candidate Selection D3.1”, Nov. 2013

5G_FBMC_Tx_Analysis

This VTB design provides a VTB test bench to measure the FBMC transmitter characteristics including spectrum, waveform and CCDF.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(SVE_Link in the design) is set by FCarrier_In, while center frequency of the output signal from DUT(SVE_Link in the design) is set by FCarrier_Out.

RF distortions can be introduced by setting parameters GainImbalance, PhaseImbalance, etc.

The transmitted signal mean power is set by SignalPower.

In order to see attenuation of the spectrum, the OversampleRatio parameter is used to define oversample ratio.

Parameter Details

1. RF Parameters
   - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
   - FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
   - SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
   - MirrorSignal: Mirror signal about carrier
   - GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
   - PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
   - I_OriginOffset: I origin offset. Range: (-∞:+∞)
   - Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
   - IQ_Rotation: IQ rotation. Range: (-∞:+∞)
2. FBMC Parameters
   - SampleRate: basic sample rate without oversample in FBMC system
   - ModeType: modulation type of constellation.
   - IdleInterval: idle time at the begin of each frame and the units is second.
   - OversampleRatio: Over-sampling ratio option. Oversampling ratio 1, ratio 2, ratio 4, ratio 8, ration 16, ratio 32 and ration 64 are supported in this downlink source

3. Advanced Parameters

> **NOTE** The following parameters are not exposed in ADS/GoldenGate environment. The default values of these parameters will be used in simulation. To change them, please open the workspace in SystemVue, go to the *Parameters* tab of the design and change the *Default Value* there.

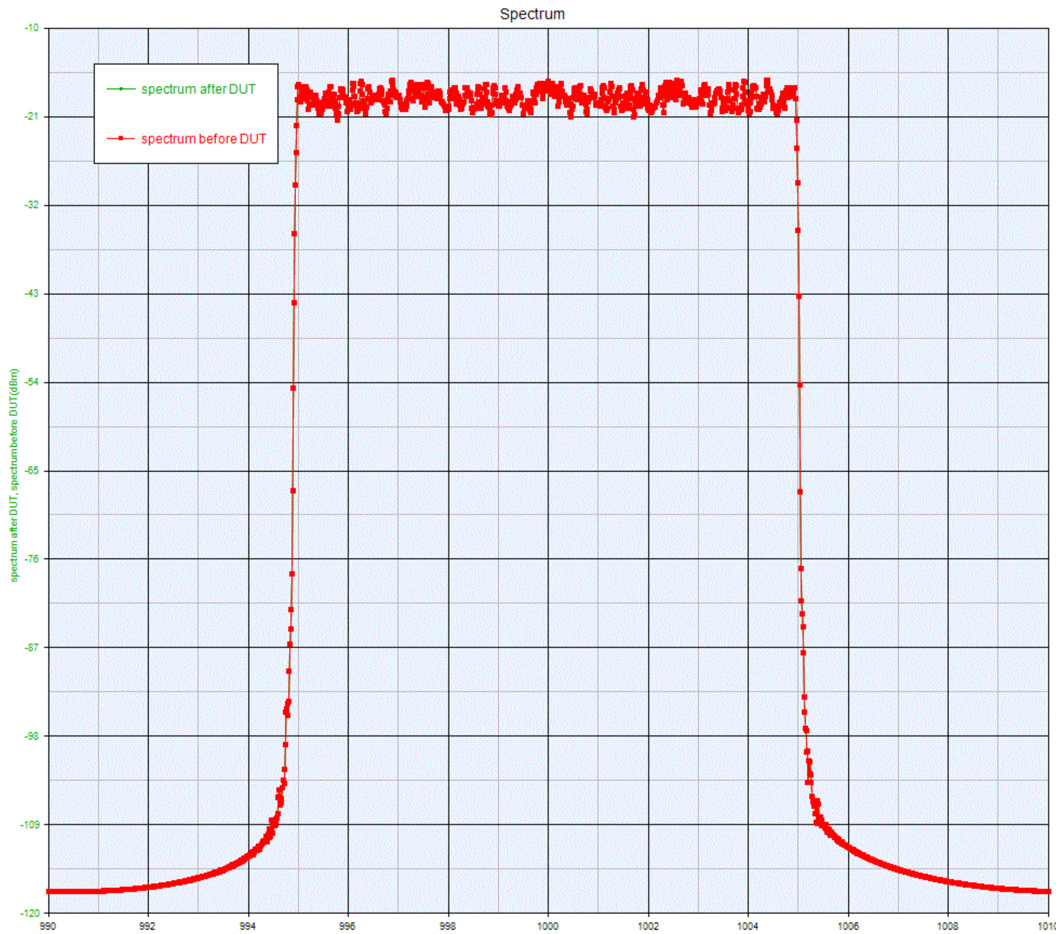
- PilotEnable: Whether use pilots in data symbols or not.
- PilotIndex: To set the index of subcarriers in data symbols used for pilot when PilotEnable is set to Yes.
- PilotSequese: Pilot value sequence and active only when PilotEnable is set to Yes. The length of it should be equal to the length of PilotIndex.
- FilterOverlapFactor: Filter overlap factor for FBMC systems.
- FilterCoef: Filter coefficients of the filter bank used in FBMC systems. The length of FilterCoef should be equal to FilterOverlapFactor.
- ZC_RootIndex1: Root index for the first ZC sequence used in this example.
- ZC_RootIndex2: Root index for the second ZC sequence used in this example.
- FilterBankStructure: Two filter bank implementation structures could be used in FBMC systems. And 0 is for Extended_IFFT and 1 is for PPN_IFFT.
- NumPreambleSyms: Number of preamble symbols in one frame.
- NumDateSyms: Number of preamble symbols in one frame.
- NumSubcarriers: Number of subcarriers in one preamble symbol or in one data symbol.
- ActiveSubcAlloc: Active subcarriers index in data symbols.

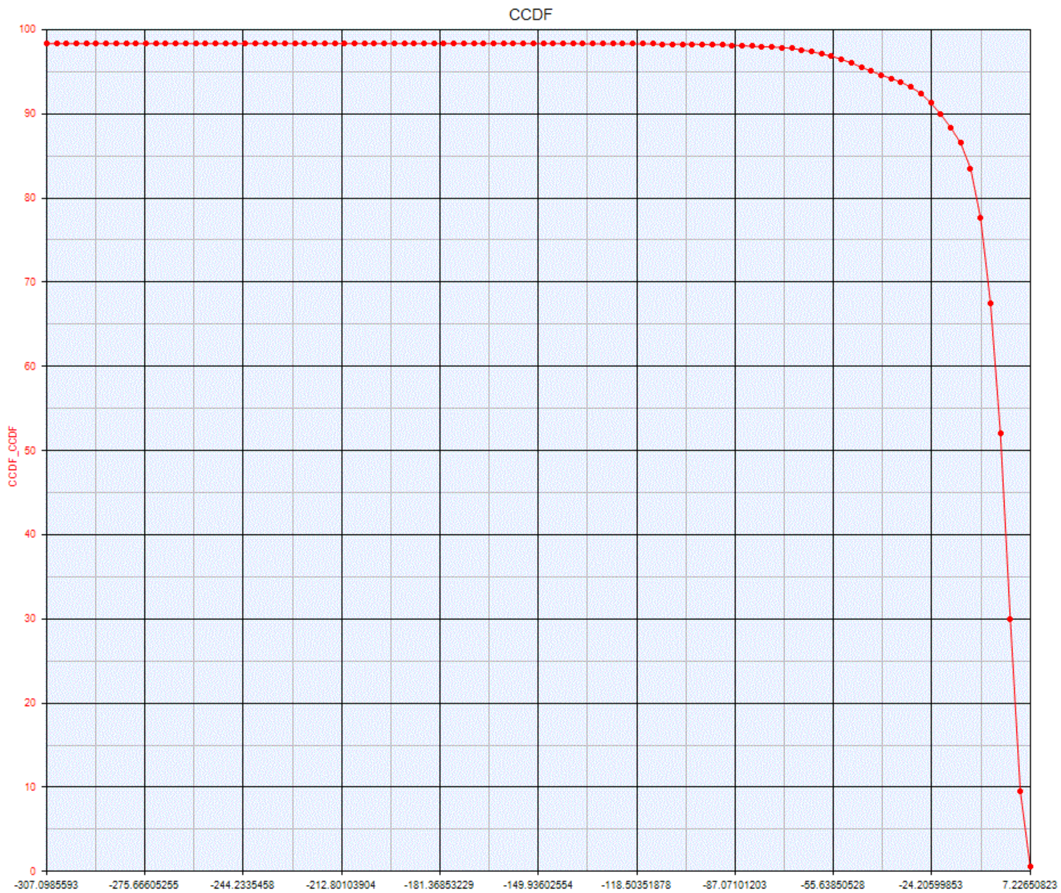
Simulation Results

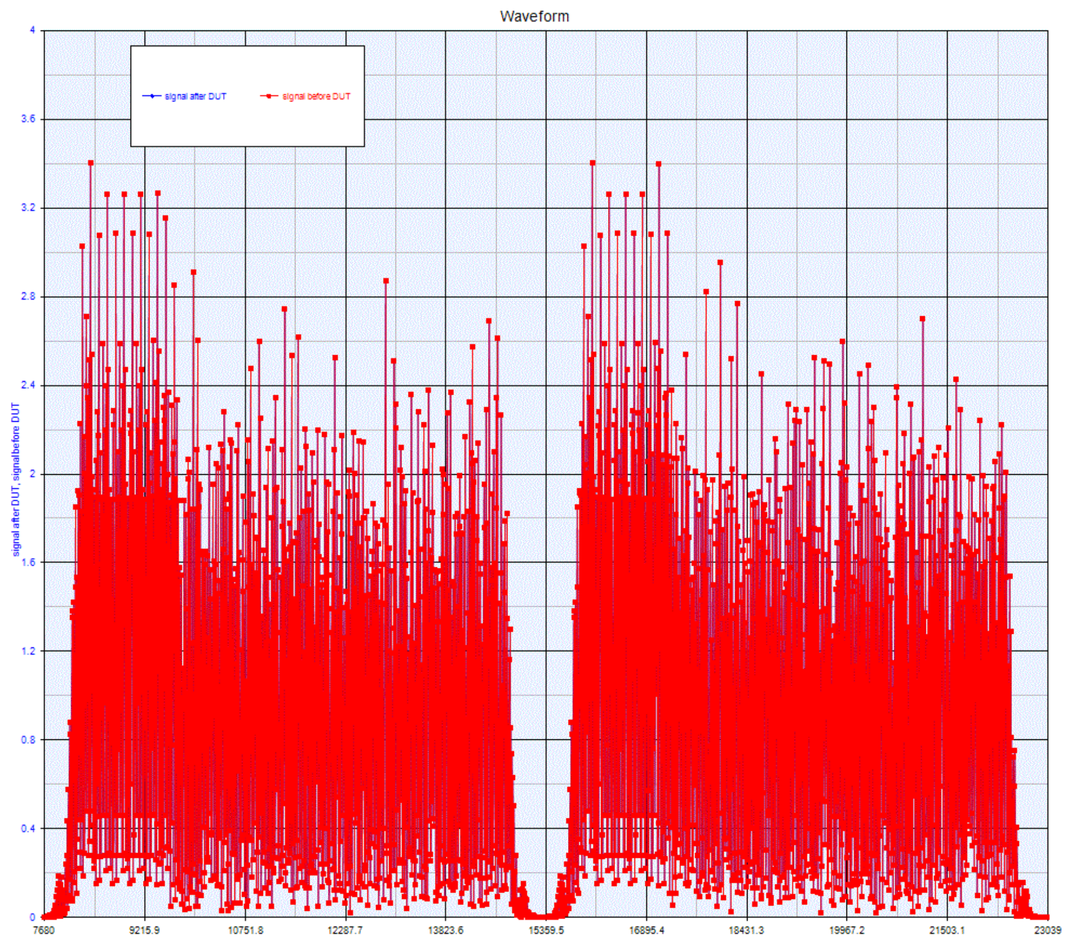
Try to change the parameters, run 5G_FBMC_Tx_Analysis and check the simulation results.

- Graph ***Spectrum*** shows the spectrum of the transmitted signal
- Graph ***CCDF*** shows the Complementary Cumulative Distribution Function of the transmitted signal.
- Graph ***Waveform*** shows the transmitted time domain waveform

The following graphs would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation. The DUT is shorted to get the following ideal results. The same results will be displayed in SystemVue environment if the **SVE_Link** model is disabled to short.




CCDF
CCDF_CCDF
100
90
80
70
60
50
40
30
20
10
0
-307.0985593
-275.66605255
-244.2335458
-212.80103904
-181.36853229
-149.93602554
-118.50351878
-87.07101203
-55.63850528
-24.20599853
7.22650823



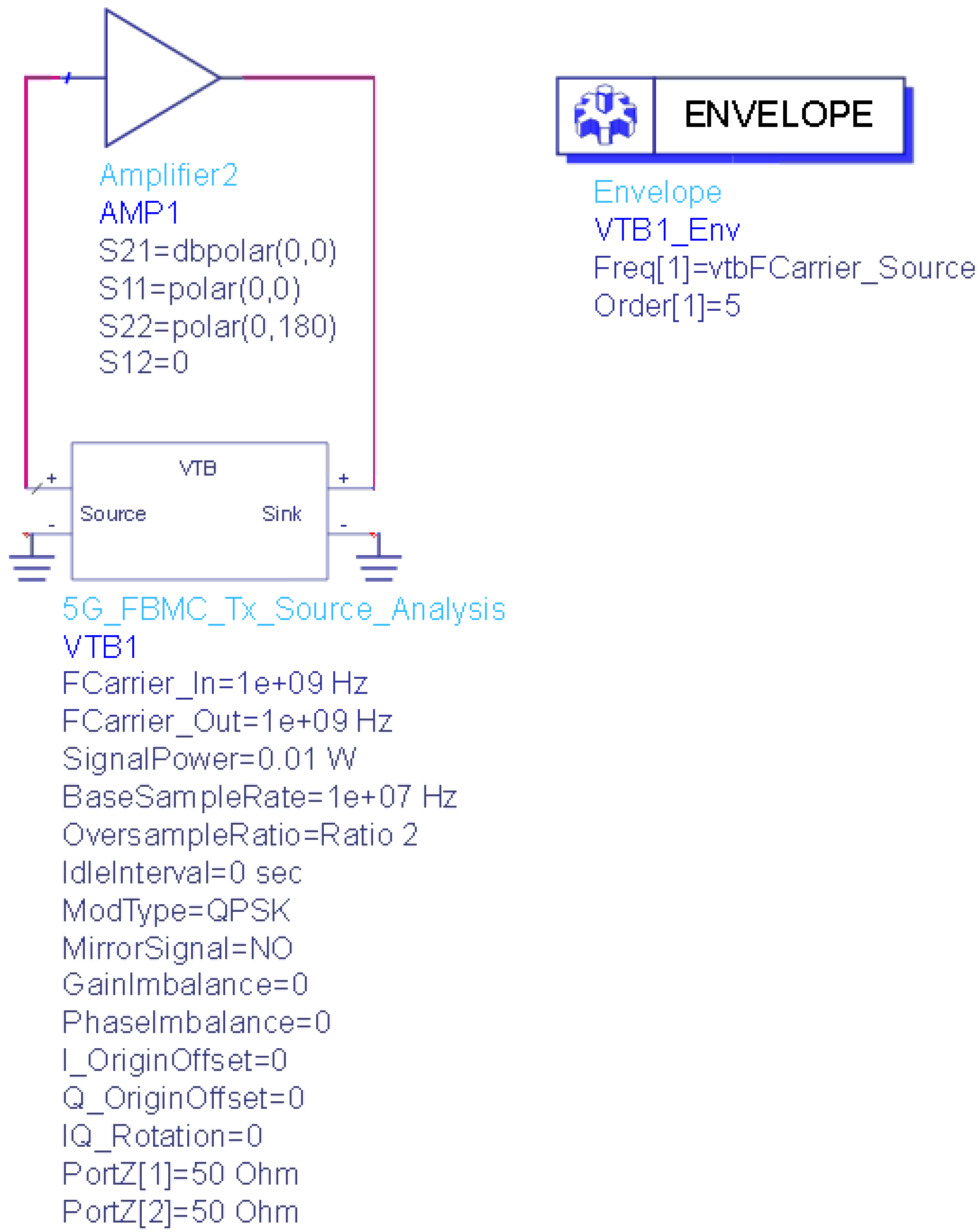
Reference

1. PHYDYAS, “FBMC physical layer: a primer”, June 2010
2. 5GNOW_D3.1_v1.0, “5G Waveform Candidate Selection D3.1”, Nov. 2013

5G_FBMC_Tx_Source_Analysis

This workspace provides a VTB test bench to generate the FBMC transmitter signal.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(SVE_Link in the design) is set by FCarrier_In, while center frequency of the output signal from DUT(SVE_Link in the design) is set by FCarrier_Out.

RF distortions can be introduced by setting parameters GainImbalance, PhaseImbalance, etc.

The transmitted signal mean power is set by SignalPower.

In order to see attenuation of the spectrum, the OversampleRatio parameter is used to define oversample ratio.

Parameter Details

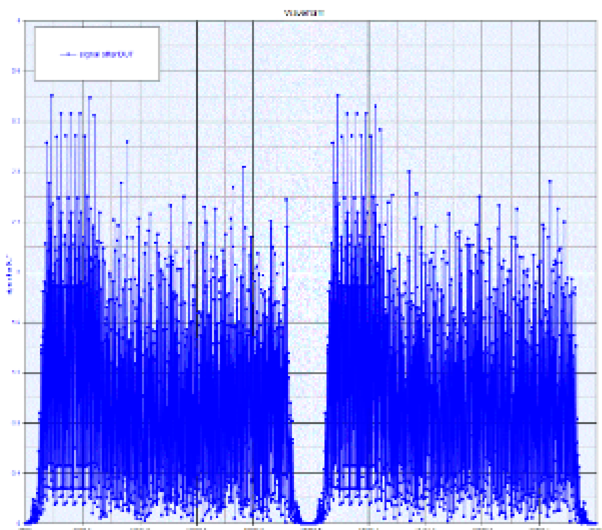
For details on other parameters, please refer to FBMC_Tx.

Simulation Results

Try to change the parameters, run 5G_FBMC_Tx_Source_Analysis and check the simulation results.

- Graph ***Spectrum*** shows the spectrum of the transmitted signal

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



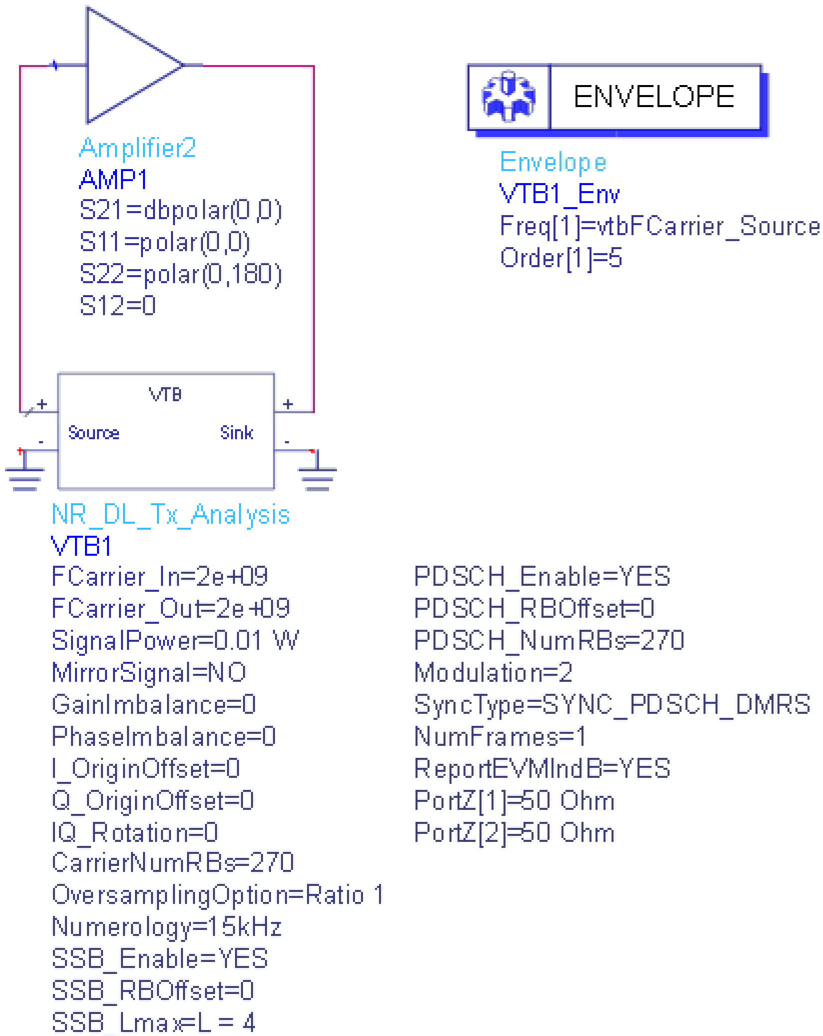
Reference

1. PHYDYAS, “FBMC physical layer: a primer”, June 2010.
2. 5GNOW_D3.1_v1.0, “5G Waveform Candidate Selection D3.1”, Nov. 2013.

NR_DL_Tx_Analysis

This workspace provides a VTB test bench to measure 3GPP new radio (NR) transmitter characteristics including spectrum, waveform, CCDF, EVM.

The schematic of the design in ADS is shown below.



The centre frequency of the input signal to DUT (***SVE_Link*** in the design***)*** is set by **FCarrier_In**, while centre frequency of the output signal from DUT (***SVE_Link*** in the design***)*** is set by **FCarrier_Out**.

RF distortions in the modulator can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

There is no SSB for **Numerology** 2 (60kHz) according to the specification. And SSB for 240kHz is not supported now. When the **Numerology** is set 2 and 4, **SSB_Enable** should be set to NO. Synchronization is done using different pilot according to **SyncType**. Please do not use SSB to do synchronization when **SSB_Enable** is set to NO and it is the same case for PDSCH_DMRS. BWP is defined occupy the whole bandwidth of component carrier. Frequency location of SSB in component carrier are defined by **SSB_RBOffset**. SSB RB offset is according to the beginning of component carrie. RB offset of SSB is based on 15kHz for Numerology 0 and Numerology1, and based on 60kHz for Numerology 3 which is defined in specification 38.211. **PDSCH_RBOffset** and **PDSCH_NumRBs** define the frequency location of PDSCH in BWP. PDSCH RB offset is according to the beginning of BWP. Please make sure BWP and SSB is in the component carrier (**CarrierNumRBs**) and PDSCH is in the BWP. A low pass filter is added in EVM model and and the bandwidth of this filter is set as the same of bandwidth of component carrier.

SignalPower is defined the power of PDSCH, if SSB is in the location of PDSCH, SignalPower equals to the power of the transmitter. If SSB is outside PDSCH, signal power of transmitter is a bit bigger than **SignalPower.**

The number of simulated frames for EVM measurements is set by parameter **NumFrames.**

The measurement length of EVM model is set to one frame.

Parameter Details

1. RF Parameters
    - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
    - FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
    - SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
    - MirrorSignal: Mirror signal about carrier
    - GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
    - PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
    - I_OriginOffset: I origin offset. Range: (-∞:+∞)
    - Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
    - IQ_Rotation: IQ rotation. Range: (-∞:+∞)
2. LTE Parameters
    - CarrierNumRBs: Number of RBs in one component carrier based on specific numerology
    - OversamplingOption: Over-sampling ratio option.
    - Numerology: Numerology for BWP, support one numerology now
    - SSB_Enable: SS/PBCH bolck enable or not
    - SSB_RBOffset: The starting RB index of resource blocks allocated to SS/PBCH bolck in the whole bandwidth based on 15kHz or 60kHz
    - SSB_Lmax: Number of SS/PBCH bolck candidates for a half frame with SS/PBCH bolcks.
    - PDSCH_Enagle: Enable or disable PDSCH and its DMRS transmission
    - PDSCH_RBOffset: The starting RB index of resource blocks allocated to the user
    - PDSCH_NumRBs: Number of resource blocks(RBs) for each PDSCH

- Modulation: Modulation orders in each slot(1:QPSK;2:16QAM;3:64QAM;4:256QAM)
- SyncType: Synchronization type, synchronization by SSB or by PDSCH_DMRS
- NumFrames: Number of frames for EVM measurement
- ReportEVMIndB: specifies the EVM units in dB or not and is only valid for the result in dataset

3. Advanced Parameters

NOTE The following parameters are not exposed in ADS/GoldenGate environment. The default values of these parameters will be used in the simulation. To change them, please open the workspace in SystemVue, go to the *Parameters* tab of the design and change the *Default Value* there. To expose them to ADS/GoldenGate environment, please also open the workspace in SystemVue, go to *Parameters* tab and change the *Hide Condition* to *false* or simply delete the *Hide Condition*.

- BWP_RBOffset: The starting RB index of resource blocks allocated to every BWP in the whole bandwidth. The default value is set to *0*. Please also update the value of **BWP_NumRBs**, because the default of **BWP_NumRBs** is set to CarrierNumRBs.
- SSB_Periodicity: SS/PBCH block transmission period. The default value is set to *5 ms*. Active, only when **SSB_Enable** is set to **YES.**
- PDSCH_StartOFDMSym: The index for the first OFDM symbol allocated to each PDSCH. The default value is set to *0*.
- PDSCH_NumOFDMSyms: Number of OFDM symbols for each PDSCH. The default value is set to *14*. PDSCH is occupy all symbols in the slots.

Simulation Results

Try to change the parameters, run ***NR_DL_Tx_Analysis*** and check the simulation results.

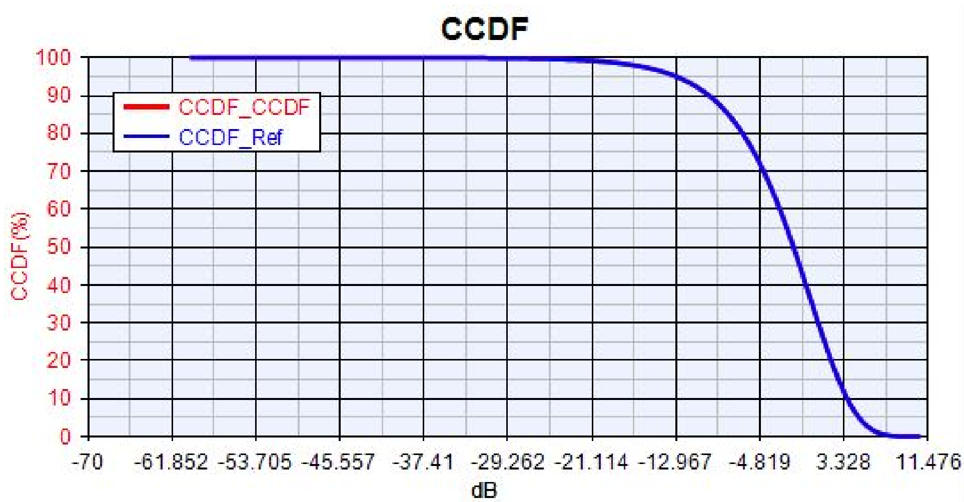
- Graph ***CCDF*** shows the Complementary Cumulative Distribution Function of the transmitted signal
- Graph ***Constellation*** shows the constellation of each physical channel and signal. The constellation of PDSCH, PBCH, PSS and SSS are included. PDSCH DMRS is shown in PDSCH channel and PBCH DMRS is shown in PBCH. If Modulation is changed, please select different input for PDSCH constellation.
- Table ***Error Summary*** shows average EVM, peak EVM, frequency errors and other measured results of each frame got from EVM model
- Table ***EVM*** lists EVM of each physical channel and signal

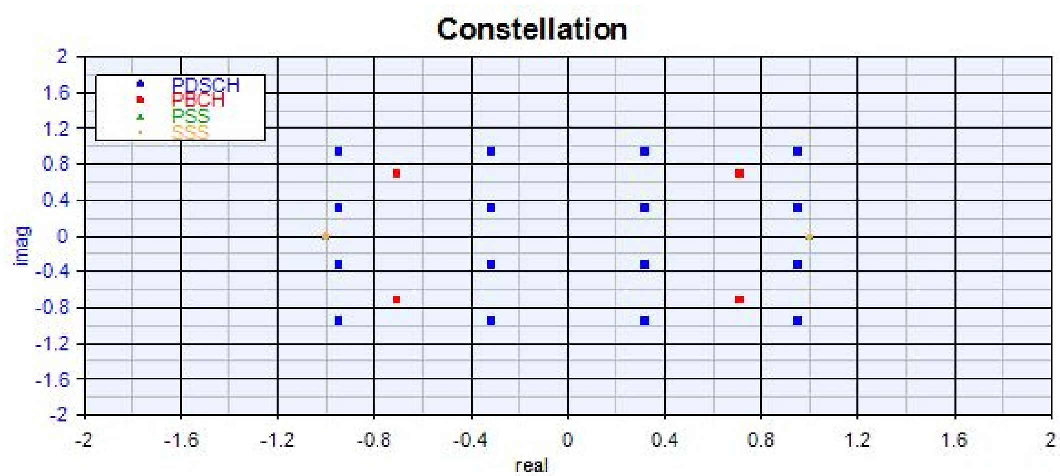
- Graph ***NormalizedEqualizerChannelFrequencyResponse*** shows the normalized equalizer channel frequency response got from EVM model for all valid subcarrier of PDSCH and SSB. It is the average channel frequency response in one slot which means the value on one subcarrier is the average of all values on that subcarrier in all symbols in one slot.

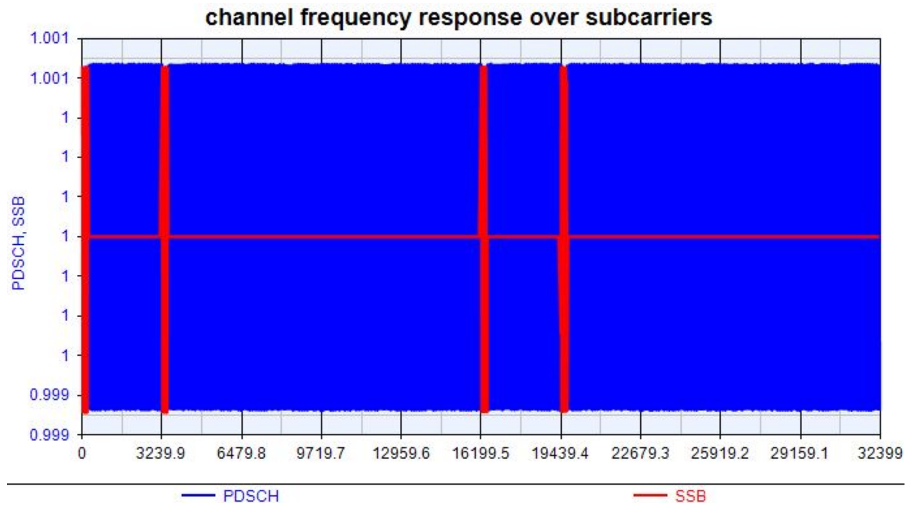
- Graph ***Spectrum*** shows the spectrum of the transmitted signal

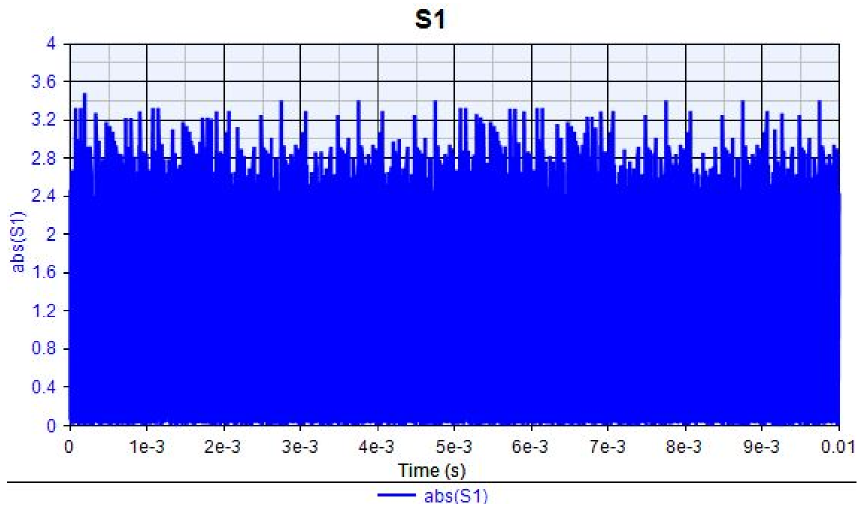
- Graph ***Waveform*** shows the transmitted time domain waveform

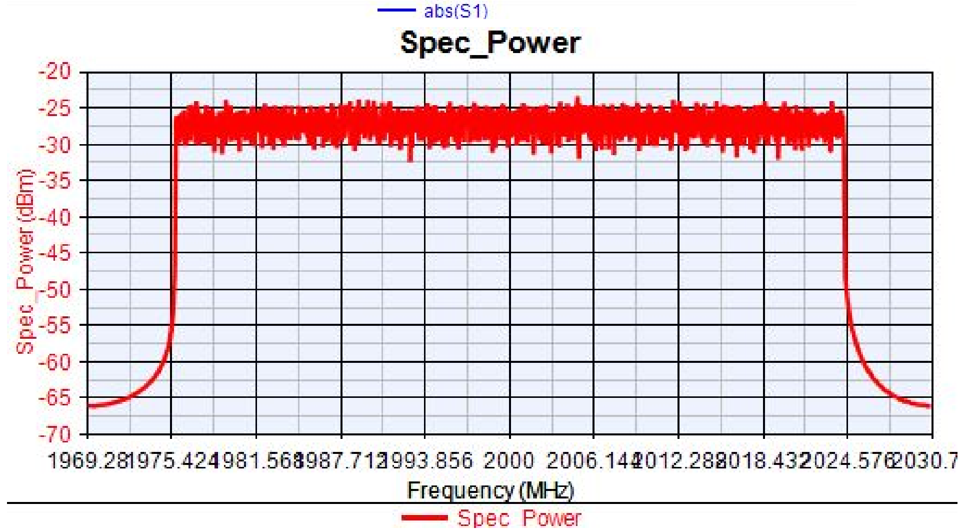
The following graphs would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation. The DUT is shorted to get the following ideal results. The same results will be displayed in SystemVue environment if the **SVE_Link** model is disabled to short.











Index	N1_EVM_Frame	N1_EVM	N1_EVMPk	N1_FreqErr	N1_IQOffset	N1_SymClkErr	N1_SyncCorr	N1_TimeOff...
1	0	-118.941	-108.095	194.3e-9	-136.024	31.05e-15	1	50e-6

Index	N1_PBCHEVM_Frame	N1_PBCHEVM	N1_PSSEVM	N1_SSSEVM	N1_PDSCHEVM	N1_PDSCHDMRSEVM
1	0	-124.766	-126.352	-126.202	-118.874	-119.262

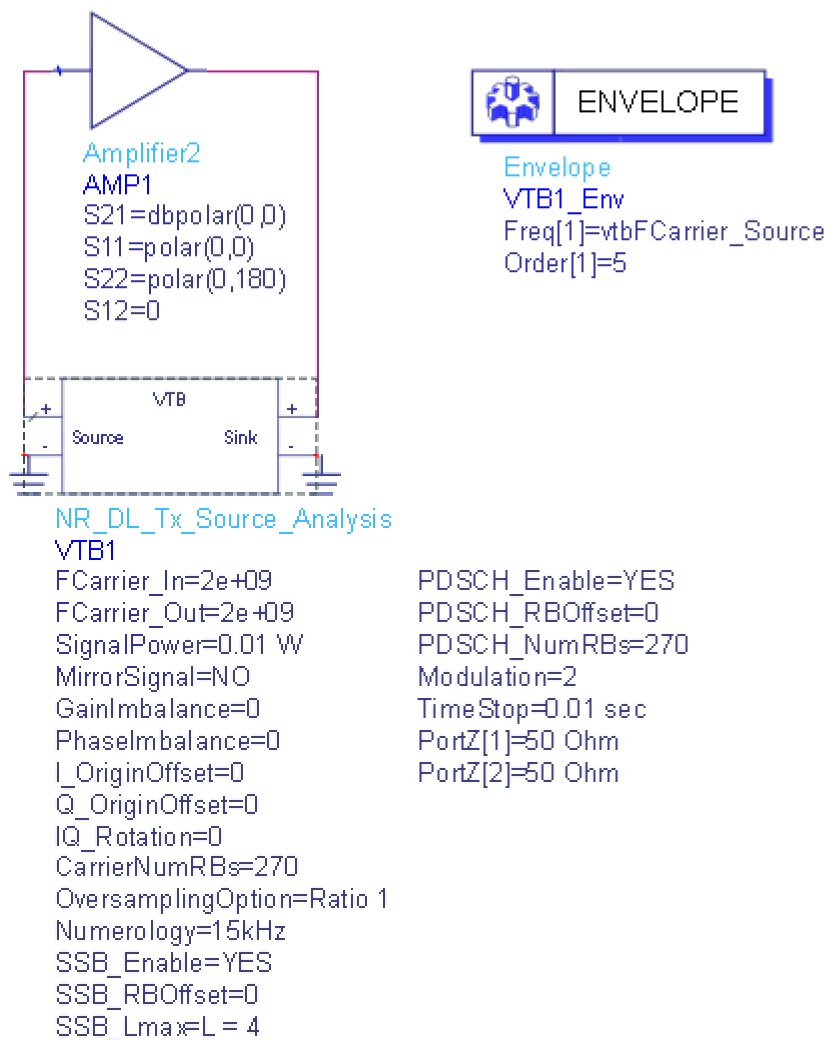
Reference

1. 3GPP TS 38.211 v15.0.0 "Physical Channels and Modulation", Dec. 2017.

NR_DL_Tx_Source_Analysis

This workspace provides a VTB test bench to generate 3GPP new radio (NR) downlink signal.

The schematic of the design in ADS is shown below.



The centre frequency of the input signal to DUT (***SVE_Link*** in the design***)*** is set by **FCarrier_In**, while centre frequency of the output signal from DUT (***SVE_Link*** in the design***)*** is set by **FCarrier_Out**.

RF distortions in the modulator can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

There is no SSB for **Numerology** 2 (60kHz) according to the specification. And SSB for 240kHz is not supported now. When the **Numerology** is set 2 and 4, **SSB_Enable** should be set to NO. BWP is defined occupy the whole bandwidth of component carrier. Frequency location of SSB in component carrier are defined by **SSB_RBOffset**. SSB RB offset is according to the beginning of component carrie. RB offset of SSB is based on 15kHz for Numerology 0 and Numerology1, and based on 60kHz for Numerology 3 which is defined in specification 38.211. **PDSCH_RBOffset** and **PDSCH_NumRBs** define the frequency location of PDSCH in BWP. PDSCH RB offset is according to the beginning of BWP. Please make sure BWP and SSB is in the component carrier (**CarrierNumRBs**) and PDSCH is in the BWP. A low pass filter is added in EVM model and and the bandwidth of this filter is set as the same of bandwidth of component carrier.

SignalPower is defined the power of PDSCH, if SSB is in the location of PDSCH, SignalPower equals to the power of the transmitter. If SSB is outside PDSCH, signal power of transmitter is a bit bigger than **SignalPower.**

A sink is used to save the generate signal from 0 to **TimeStop**.

Parameter Details

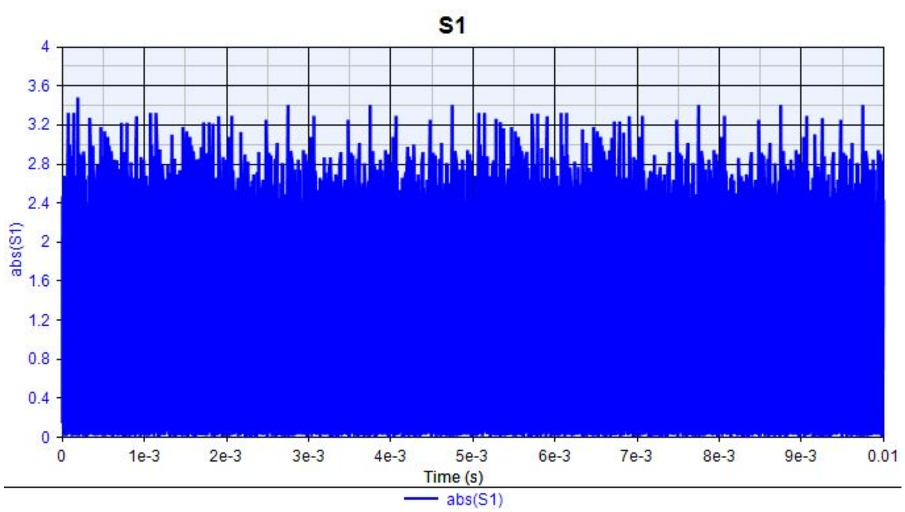
- TimeStop: Stop time of data collection. Range: (0:+∞)
- For details on other parameters, please refer to 3GPP_NR_DL_Tx.

Simulation Results

Try to change the parameters, run **NR_DL_Tx_Source_Analysis** and check the simulation results.

- Graph ***Waveform*** shows the transmitted time domain waveform

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



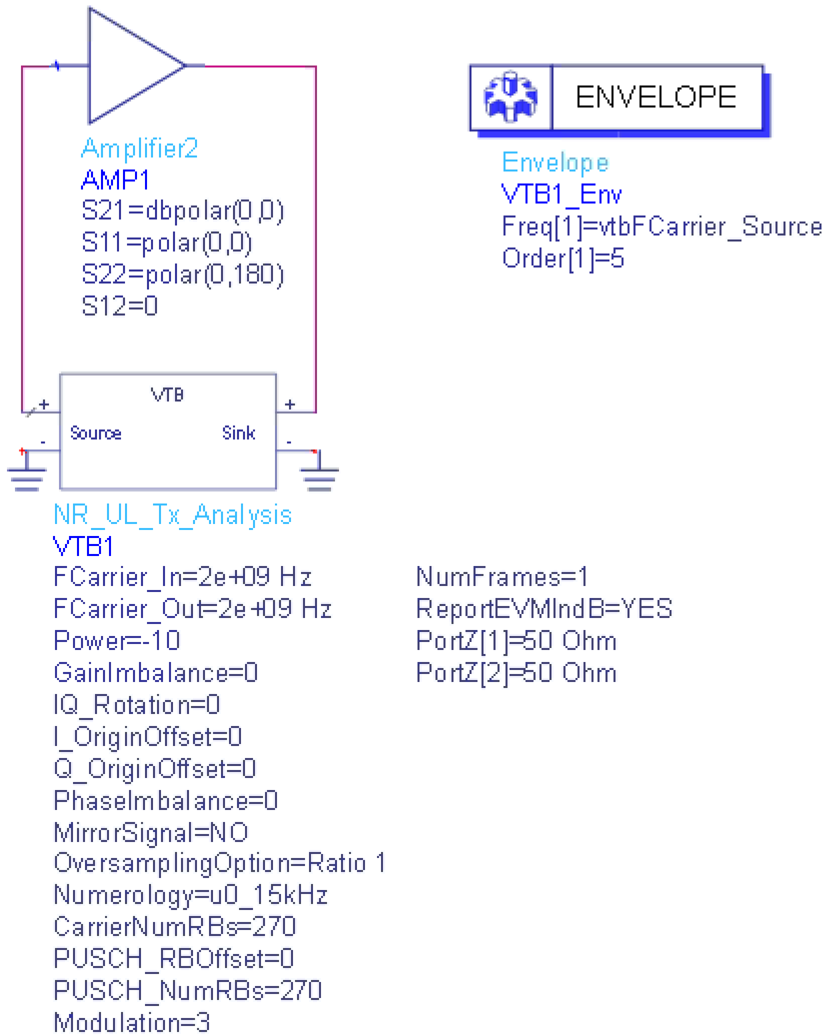
Reference

1. 3GPP TS 38.211 v15.0.0 "Physical Channels and Modulation", Dec. 2017.

NR_UL_Tx_Analysis

This VTB design measures 3GPP 5G NR uplink transmitter characteristics, including spectrum, waveform, CCDF, and EVM according to 3GPP TS 38.101.

The schematic of the design in ADS is shown below.



The center frequency of the input signal to DUT(***SVE_Link*** in the design***)*** is set by **FCarrier_In**, while center frequency of the output signal from DUT(***SVE_Link*** in the design***)*** is set by **FCarrier_Out**.

RF distortions in the modulator can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

The signal's full bandwidth is determined by **CarrierNumRBs** and **Numerology** . Bandwidth = **CarrierNumRBs** * 12 * 15kHz * 2^**Numerology**. PUSCH can take entire or partial of the bandwidth, whose loaction is defined by **PUSCH_RBOffset** and **PUSCH_NumRBs.** Note, **PUSCH_RBOffset** + **PUSCH_NumRBs** should not be greater than **CarrierNumRBs**.

Modulation determines the modulation format.

The number of simulated frames for EVM measurements is set by **NumFrames**.

Parameter Details

1. RF Parameters
    - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
    - FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
    - Power: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
    - MirrorSignal: Mirror signal about carrier
    - GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
    - PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
    - I_OriginOffset: I origin offset. Range: (-∞:+∞)
    - Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
2. NR Parameters
    - CarrierNumRBs: Number of RBs in one component carrier based on specific numerology
    - OversamplingOption: Over-sampling ratio option.
    - Numerology: Numerology for BWP, support one numerology now
    - PUSCH_RBOffset: The starting RB index of resource blocks allocated to the PUSCH
    - PUSCH_NumRBs: Number of resource blocks(RBs) for the PUSCH
    - Modulation: Modulation orders in each slot(0:pi/4 BPSK;1:QPSK;2:16QAM;3:64QAM;4:256QAM)
    - NumFrames: Number of frames for EVM measurement.
    - ReportEVMIndB: The EVM unit in dB or percentage.

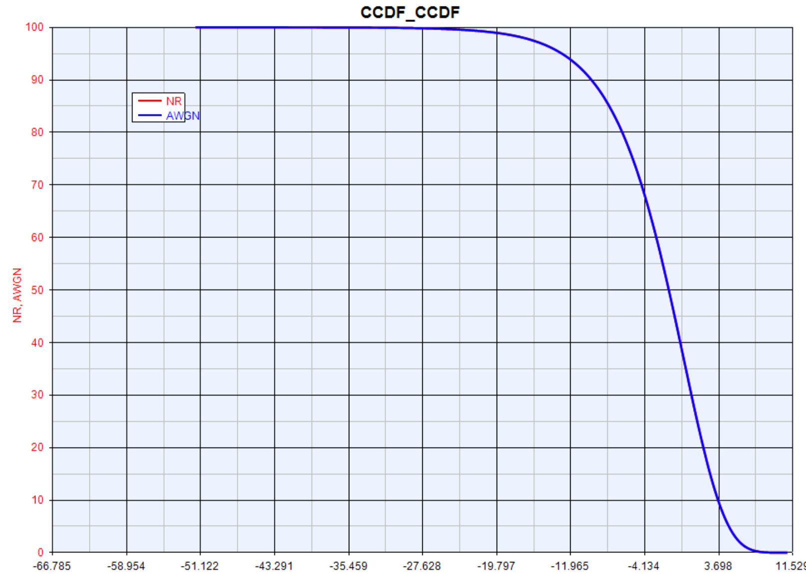
Simulation Results

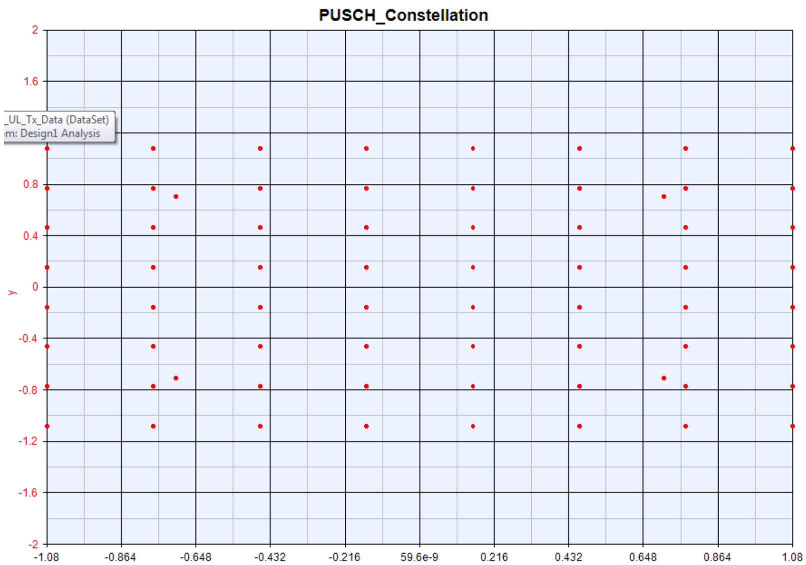
Try to change the parameters, run **NR_UL_Tx_Analysis** and check the simulation results.

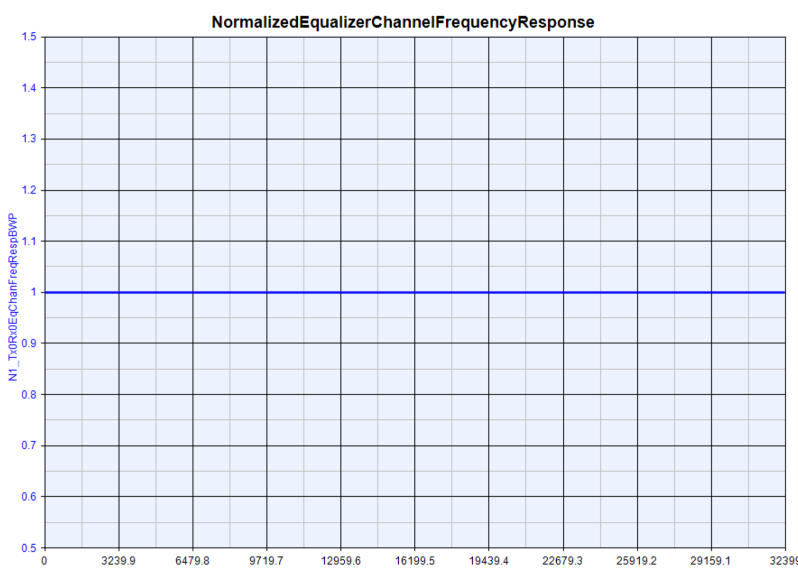
- Graph ***CCDF*** shows the Complementary Cumulative Distribution Function of the transmitted signal

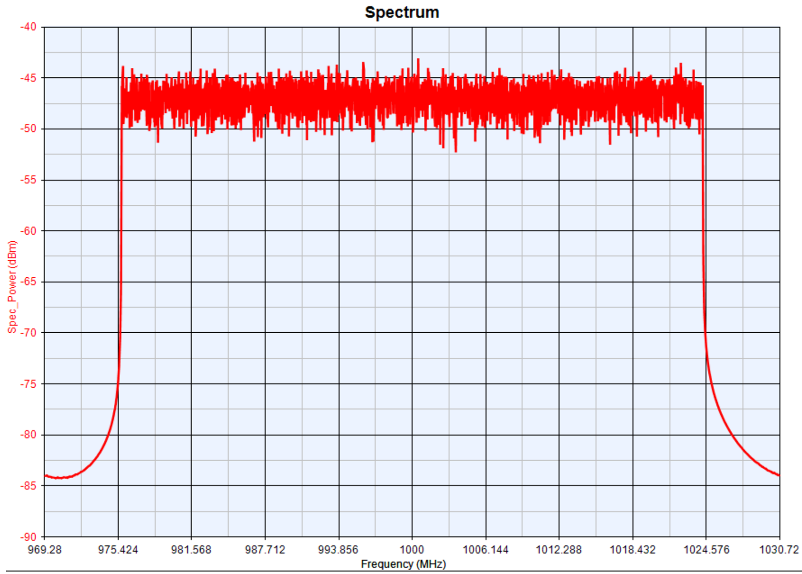
- Graph ***Constellation*** shows the constellation of PUSCH.
- Table ***Error Summary*** shows average EVM(dB), peak EVM(dB), frequency errors(Hz), IQ Offset(dB), Symbol Clock Error, Sync Correlation and Time Offset(s) of PUSCH.
- Table ***EVM*** shows average EVM in dB of PUSCH and DMRS of PUSCH.
- Graph ***NormalizedEqualizerChannelFrequencyResponse*** shows the normalized equalizer channel frequency response of PUSCH.
- Graph ***Spectrum*** shows the spectrum of the aggregated signal
- Graph ***Waveform*** shows the transmitted time domain waveform

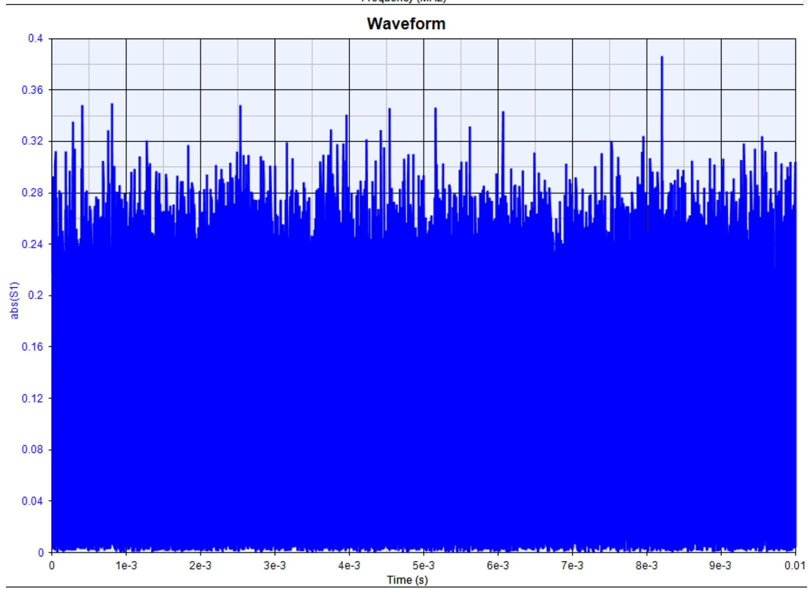
The following graphs would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation. The DUT is shorted to get the following ideal results. The same results will be displayed in SystemVue environment if the **SVE_Link** model is disabled to short.


CCDF_CCDF
NR
AWGN
NR, AWGN
100
90
80
70
60
50
40
30
20
10
0
-66.785
-58.954
-51.122
-43.291
-35.459
-27.628
-19.797
-11.965
-4.134
3.698
11.529


PUSCH_Constellation
_UL_Tx_Data (DataSet)
m: Design1 Analysis
y
2
1.6
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
-2
-1.08
-0.864
-0.648
-0.432
-0.216
59.6e-9
0.216
0.432
0.648
0.864
1.08


NormalizedEqualizerChannelFrequencyResponse
N1_Tx0Rx0EqChanFreqRespBWP
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0
3239.9
6479.8
9719.7
12959.6
16199.5
19439.4
22679.3
25919.2
29159.1
32399





ErrorSummary

In...	EVM	Peak E...	Frequency Er...	IQ Off...	Symbol Clock Er...	Sync Correlat...	Time Off...
1	-100.29	-92.728	2.532e-3	-141.625	62.47e-12	1	100e-6

EVM

Index	.	PUSCH E...	PUSCH DMRS E...
1	.	-100.285	-100.332

References

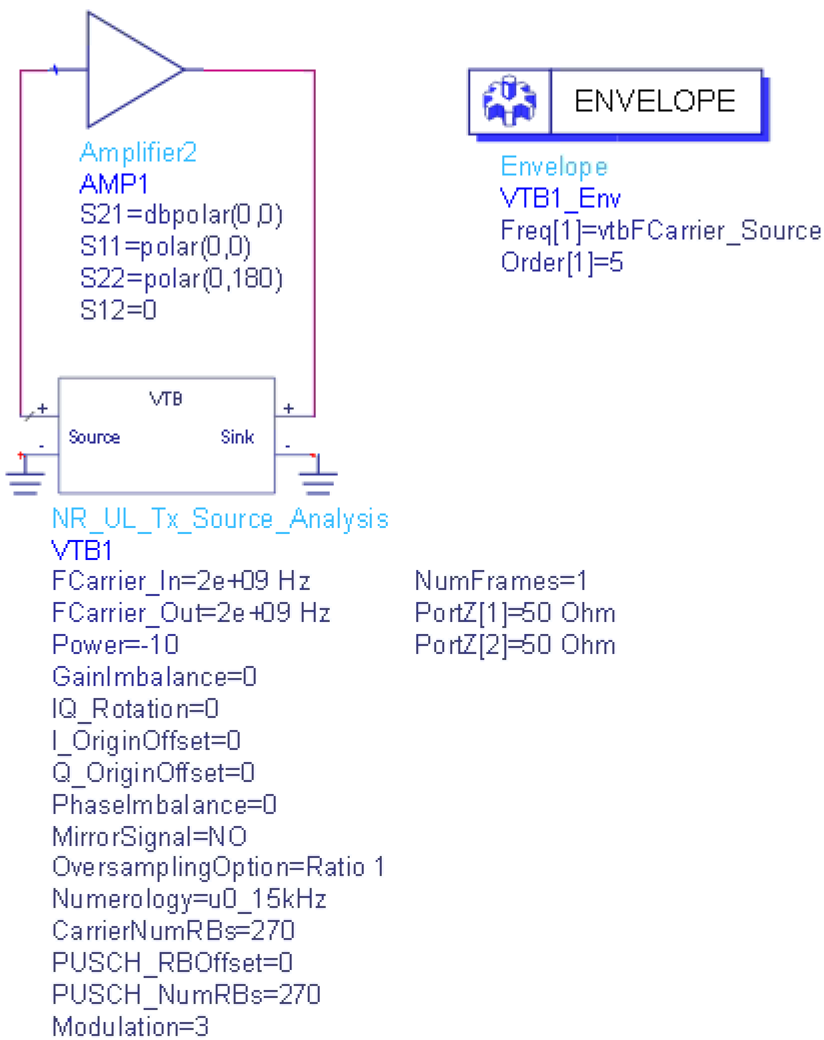
1. 3GPP TS 38.211 v15.0.0, "Physical Channels and Modulation", December 2017.

2. 3GPP TS 38.211 v1.2.0, "Physical Channels and Modulation", November 2017.
3. 3GPP TS 38.212 v15.0.0, "Multiplexing and channel coding", December 2017.
4. 3GPP TS 38.213 v15.0.0, "Physical layer procedures for control", December 2017.
5. 3GPP TS 38.214 v15.00, "Physical layer procedures for data", December 2017
6. 3GPP TS 38.101 v15.0.0, "User Equipment(UE) radio transmission and reception", December 2017.

NR_UL_Tx_Source_Analysis

This VTB design displays 3GPP 5G NR uplink transmitting signal.

The schematic of the ADS is shown below,



The center frequency of the input signal to DUT(***SVE_Link*** in the design***)*** is set by **FCarrier_In**, while center frequency of the output signal from DUT(***SVE_Link*** in the design***)*** is set by **FCarrier_Out**.

The signal's full bandwidth is determined by **CarrierNumRBs** and **Numerology** . Bandwidth = **CarrierNumRBs** * 12 * 15kHz * 2^**Numerology**. PUSCH can take entire or partial of the bandwidth, whose loaction is defined by **PUSCH_RBOffset** and **PUSCH_NumRBs.** Note, **PUSCH_RBOffset** + **PUSCH_NumRBs** should not be greater than **CarrierNumRBs**.

Modulation determines the modulation format.

The number of frames to output is set by **NumFrames**.

RF distortions in the modulator can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

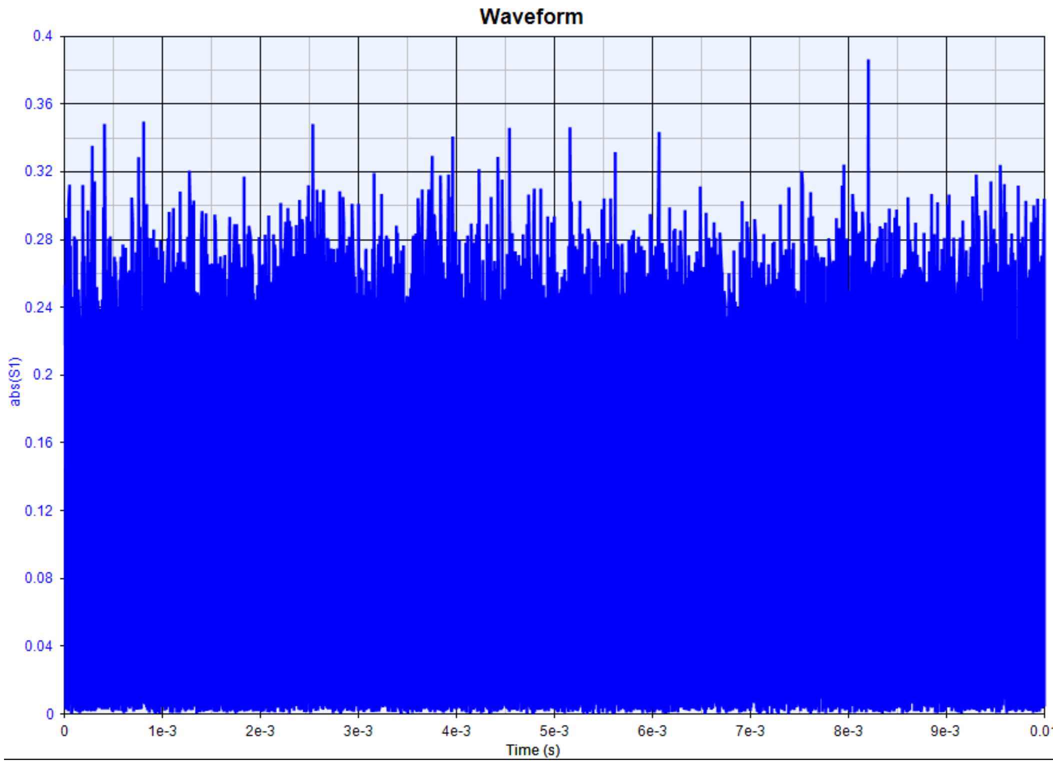
Parameter Details

1. RF Parameters
    - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
    - FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
    - Power: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
    - MirrorSignal: Mirror signal about carrier
    - GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
    - PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
    - I_OriginOffset: I origin offset. Range: (-∞:+∞)
    - Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
2. NR Parameters
    - CarrierNumRBs: Number of RBs in one component carrier based on specific numerology
    - OversamplingOption: Over-sampling ratio option.
    - Numerology: Numerology for BWP, support one numerology now
    - PUSCH_RBOffset: The starting RB index of resource blocks allocated to the PUSCH
    - PUSCH_NumRBs: Number of resource blocks(RBs) for the PUSCH
    - Modulation: Modulation orders in each slot(0:pi/4 BPSK;1:QPSK;2: 16QAM;3:64QAM;4:256QAM)
    - NumFrames: Number of frames for waveform.

Simulation Results

Try to change the parameters, run ***NR_UL_Tx_Source_Analysis*** and check the graph of **Waveform** which shows the transmitted time domain waveform

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



References

1. 3GPP TS 38.211 v15.0.0, "Physical Channels and Modulation", December 2017.
2. 3GPP TS 38.211 v1.2.0, "Physical Channels and Modulation", November 2017.
3. 3GPP TS 38.212 v15.0.0, "Multiplexing and channel coding", December 2017.
4. 3GPP TS 38.213 v15.0.0, "Physical layer procedures for control", December 2017.
5. 3GPP TS 38.214 v15.00, "Physical layer procedures for data", December 2017

Bluetooth Workspaces

VTB workspaces are provided to analyze Bluetooth transmitter and receiver characteristics according to [1] [2] and [3]

Tx

Bluetooth_BDR_Source

Bluetooth_BDR_Tx

Bluetooth_EDR_Source

Bluetooth_EDR_Tx

Bluetooth_LE_Source

Bluetooth_LE_Tx

Rx

Bluetooth_CoACInterferencePerformance

Bluetooth_EDR_Sensitivity

Bluetooth_withWLANInterference

NOTE In current implementation, there are only one input port and one output port in the SVE_Link model used in Bluetooth workspaces, which means the DUT (design in ADS/GoldenGate environment) should only have one input and one output. In Tx examples, the DUT is connected after the modulator. In Rx examples, the DUT is connected before the demodulator in the Rx chain. Please refer to the help document of each workspace for more information. in which you can find the detailed schematic.

How to set SVE_Link properties in Bluetooth workspaces

Users can optionally define the ***SVE_Link*** properties by setting **DefineProperties** to YES. When **DefineProperties** is set to *YES*, parameters related to ***SVE_Link*** properties, including **InFeedbackLoop**, **SampleRate**, and **InputFcs**, can be defined by values or expressions.

- InFeedbackLoop: Specify whether the SVE_Link is in a feedback loop: NO, YES. In WLAN 802.11ac examples, there is no feedback loop, hence **InFeedbackLoop** is set to *NO*.
- SamplesRae: Sample of the signal. In Bluetooth examples, in the *Equations* tab of the design, **SampleRate** is calculated as SamplesPerSym x 1e6.

- InputFcs: Array of characterization frequencies of input envelope signals. In WLAN 802.11ac examples, there is only one input port in **SVE_Link** model, hence **InputFcs** is set to **[FCarrier_In]**.

Otherwise when **DefineProperties** is set to *NO*, the VTB process will analyze the full design and provide such information to the integrating tool.

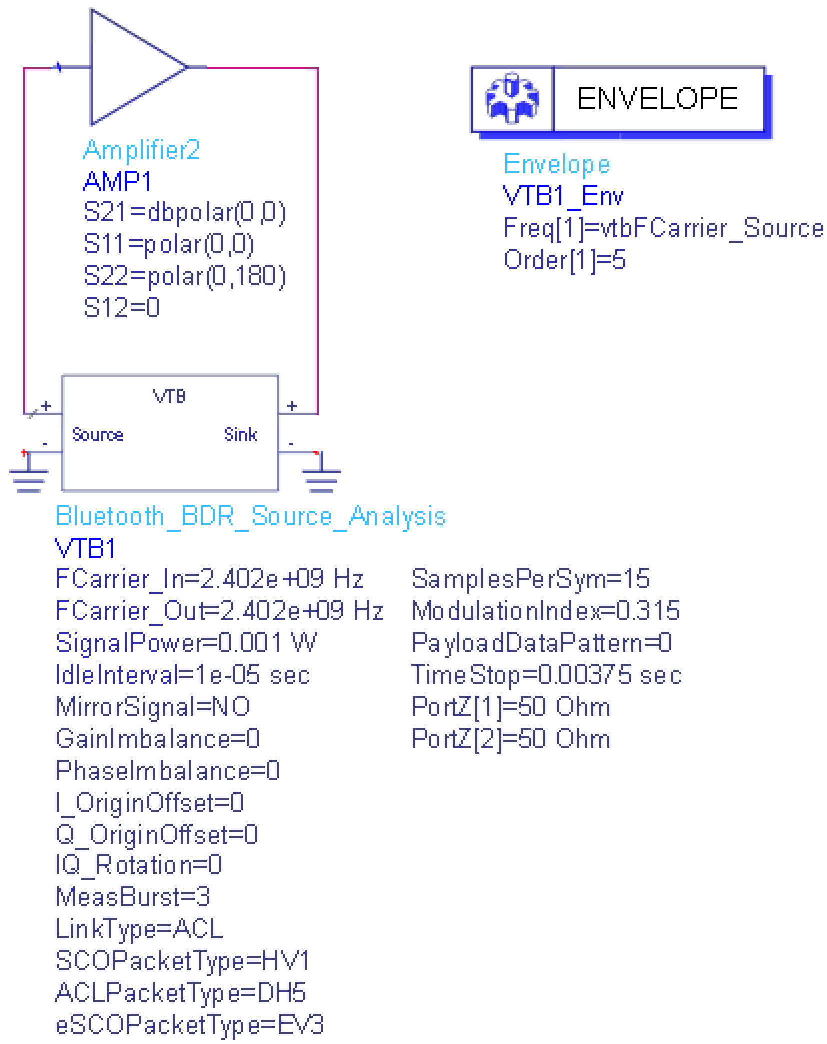
Reference

1. BLUETOOTH SPECIFICATION Version 2.1 + EDR, 26 July 2007.
2. BLUETOOTH SPECIFICATION Version 4.0 + EDR, 30 June 2010.
3. BLUETOOTH TEST SPECIFICATION Ver. 1.2/2.0/2.0 + EDR/2.1/2.1 + EDR, 27 December

Bluetooth_BDR_Source_Analysis

This workspace provides a VTB test bench to generate Bluetooth basic data rate signal.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_In***, while center frequency of the output signal from DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_Out***.

The transmitted signal mean power is set by ***SignalPower***.

RF distortions can be introduced by setting parameters ***GainImbalance, PhaseImbalance***, etc.

A sink is used to save the generated signal from 0 to ***TimeStop***.

To generate the BDR signal used to measure the modulation characteristics DeltaF1 and DeltaF2, the defined payload data patterns should be used by set the parameter ***PayloadDataPatten*** in the schematic and run the Analysis.

> *For DeltaF1, we should set the* ***PayloadDataPatten*** *as 0 i.e. (1 1 1 1 0 0 0 0)*
>
> *For DeltaF2, we should set the* ***PayloadDataPatten*** *as 1 i.e. (1 0 1 0 1 0 1 0)*

To generate the BDR signal used to measure the BER, the ***PayloadDataPattern*** should be set to 2 (PN9) or 3 (PN15).

Parameter Details

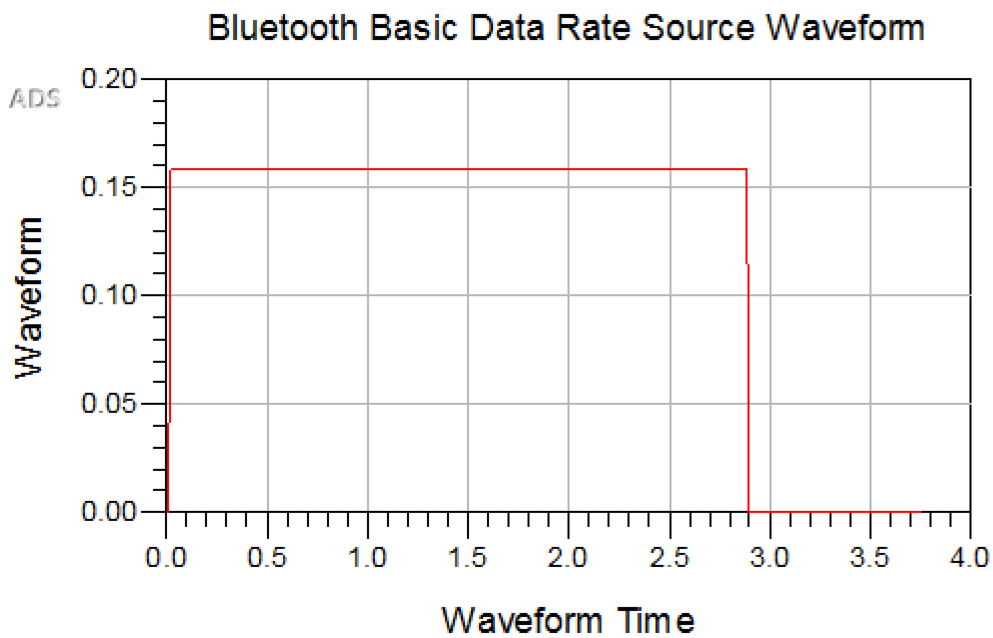
1. RF Parameters
   - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
   - FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
   - SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
   - MirrorSignal: Mirror signal about carrier
   - GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
   - PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
   - I_OriginOffset: I origin offset. Range: (-∞:+∞)
   - Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
   - IQ_Rotation: IQ rotation. Range: (-∞:+∞)
2. Bluetooth Parameters
   - **LinkType**: the link type of the packet. It can be set to SCO, ACL or eSCO.
   - **SCOPacketType**: packet type for SCO Basic. The supported SCO packet type are: 5;HV1;6;HV2;7;HV3. This parameter is active only in case of LinkType is set to SCO.
   - **ACLPacketType**: packet type for ACL Basic. The supported ACL packet type are 4;DH1; 10;DM3; 11;DH3; 14;DM5; 15;DH5. This parameter is active only in case of LinkType is set to ACL.
   - **eSCOPacketType**: packet type for eSCO Basic. The supported eSCO packet type are: 7;EV3; 12;EV4; 13;EV5. This parameter is active only in case of LinkType is set to eSCO.
   - **SamplesPerSym**: number of samples per symbol.
   - **ModulationIndex**: the modulation index of GFSK.
   - **PayloadDataPattern**: payload data pattern. 0 for pattern (1 1 1 1 0 0 0 0); 1 for pattern (1 0 1 0 1 0 1 0); 2 for PN9 and 3 for PN15

Simulation Results

Try to change the parameters, run *Bluetooth_BDR_Source_Analysis* and check the simulation results.

- Graph ***BDR_Waveform*** shows the transmitted time domain waveform

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



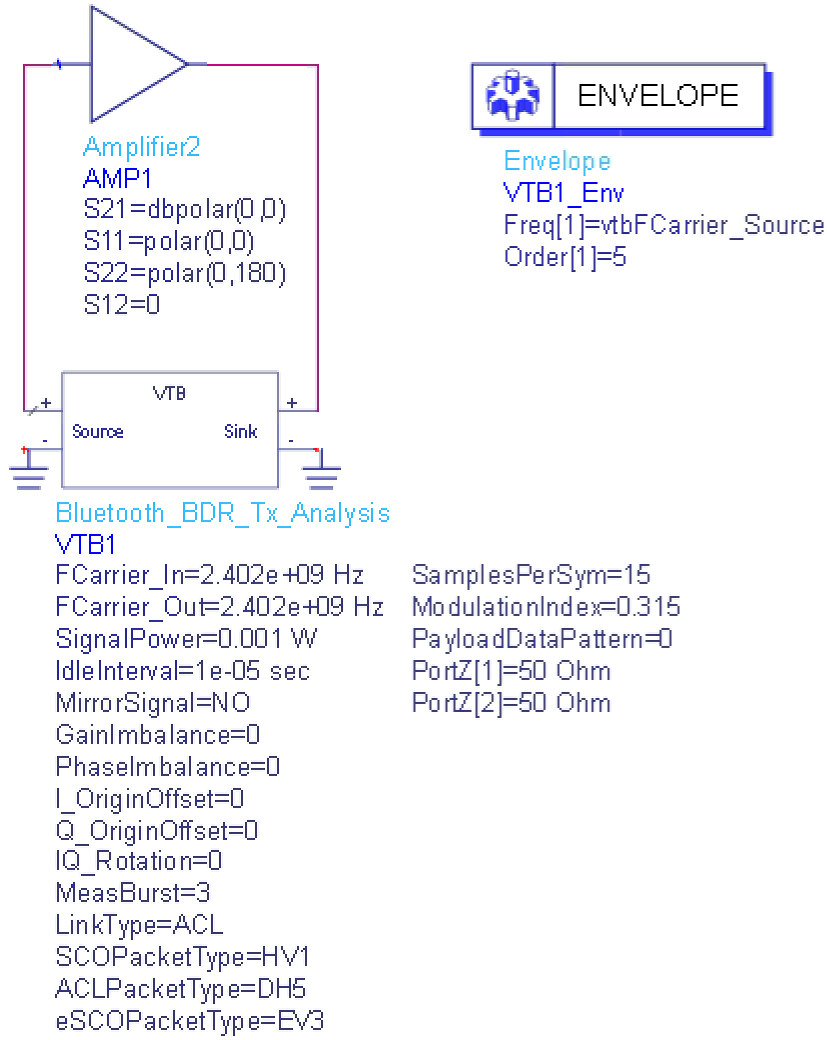
Reference

1. BLUETOOTH SPECIFICATION Version 2.1 + EDR, 26 July 2007.
2. BLUETOOTH SPECIFICATION Version 4.0 + EDR, 30 June 2010.
3. BLUETOOTH TEST SPECIFICATION Ver. 1.2/2.0/2.0 + EDR/2.1/2.1 + EDR, 27 December

Bluetooth_BDR_Tx_Analysis

This workspace provides a VTB test bench to analyze output power, modulation characteristics, ICFT(initial carrier frequency tolerance) and the carrier frequency drift of Bluetooth basic data rate source.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_In***, while center frequency of the output signal from DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_Out***.

The transmitted signal mean power is set by ***SignalPower***.

RF distortions can be introduced by setting parameters ***GainImbalance, PhaseImbalance***, etc.

The number of bursts for measurements is specified by ***MeasBurst***.

Try to change the parameters, run ***Bluetooth_BDR_Tx_Analysis*** and check the simulation results.

To measure the modulation characteristics DeltaF1 and DeltaF2, the defined payload data patterns should be used by set the parameter ***PayloadDataPatten*** in the schematic and run the Analysis.

For DeltaF1, we should set the ***PayloadDataPatten*** *as 0 i.e. (1 1 1 1 0 0 0 0)*

*For DeltaF2, we should set the **PayloadDataPatten** as 1 i.e. (1 0 1 0 1 0 1 0)*

In the case of modulation characteristics test, the reported BER results are not correct. To measure the BER, the ***PayloadDataPattern*** should be set to 2 (PN9) or 3 (PN15).

Parameter Details

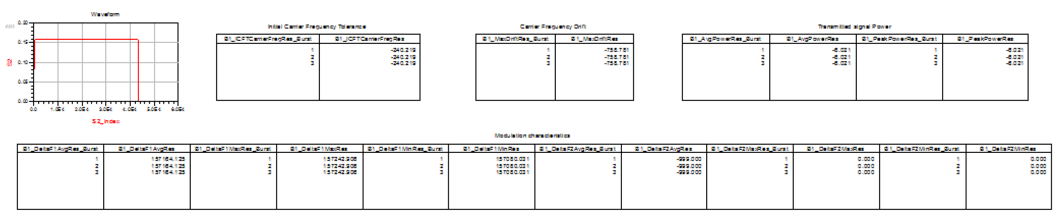
1. RF Parameters
   - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
   - FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
   - SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
   - MirrorSignal: Mirror signal about carrier
   - GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
   - PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
   - I_OriginOffset: I origin offset. Range: (-∞:+∞)
   - Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
   - IQ_Rotation: IQ rotation. Range: (-∞:+∞)
2. Bluetooth Parameters
   - **LinkType**: the link type of the packet. It can be set to SCO, ACL or eSCO.
   - **SCOPacketType**: packet type for SCO Basic. The supported SCO packet type are: 5;HV1;6;HV2;7;HV3. This parameter is active only in case of LinkType is set to SCO.
   - **ACLPacketType**: packet type for ACL Basic. The supported ACL packet type are 4;DH1; 10;DM3; 11;DH3; 14;DM5; 15;DH5. This parameter is active only in case of LinkType is set to ACL.
   - **eSCOPacketType**: packet type for eSCO Basic. The supported eSCO packet type are: 7;EV3; 12;EV4; 13;EV5. This parameter is active only in case of LinkType is set to eSCO.
   - **SamplesPerSym**: number of samples per symbol.
   - **ModulationIndex**: the modulation index of GFSK.
   - **PayloadDataPattern**: payload data pattern. 0 for pattern (1 1 1 1 0 0 0 0); 1 for pattern (1 0 1 0 1 0 1 0); 2 for PN9 and 3 for PN15

Simulation Results

Try to change the parameters, run *Bluetooth_BDR_Tx_Analysis* and check the simulation results.

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

- Table ***BDR_ICFT*** shows initial carrier frequency tolerance of the transmitted signal
- Table ***BDR_MaxDriftRes*** lists carrier frequency drift for each burst
- Table ***BDR_ModCharacteristics*** shows the modulation characteristics of each burst
- Graph ***BDR_PowerRes*** shows the power of the transmitted signal
- Graph ***BDR_Waveform*** shows the transmitted time domain waveform



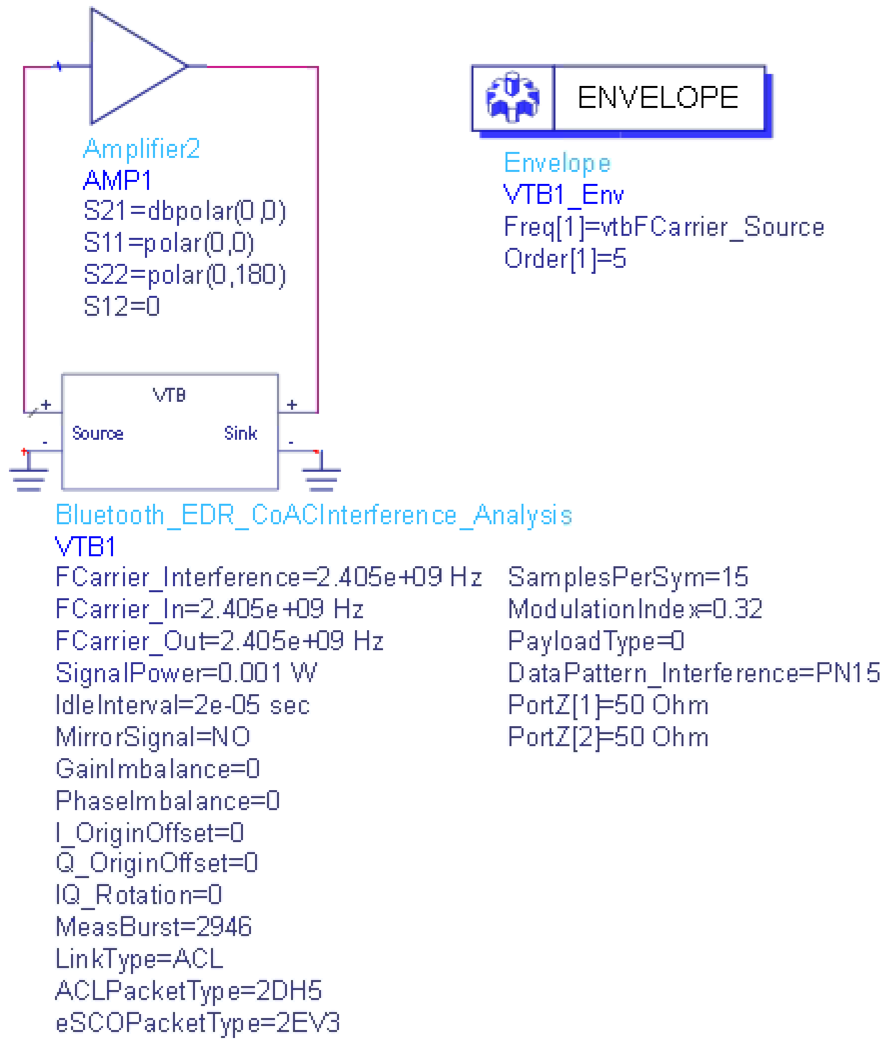
Reference

1. BLUETOOTH SPECIFICATION Version 2.1 + EDR, 26 July 2007.
2. BLUETOOTH SPECIFICATION Version 4.0 + EDR, 30 June 2010.
3. BLUETOOTH TEST SPECIFICATION Ver. 1.2/2.0/2.0 + EDR/2.1/2.1 + EDR, 27 December

Bluetooth_EDR_CoACInterference_Analysis

This workspace provides a VTB test bench to analyze Bluetooth Rx performance in the presence of co-/adjacent channel Bluetooth interference.

A simple design in ADS to use this VTB is shown below.



The test procedure refers to 5.1.24 TP/RCV/CA/09/C (EDR C/I Performance).

- The default wanted signal and interferer are pi/4-DQPSK modulated packet 2-DH5. To test 8DPSK signal, please reset the packet type in Parameters.
- This design gives the co-channel interference test of the lowest operation frequency using a minimum number of 16 000 000 payload bits as the default configuration. The operation frequency and signal power of the wanted signal and interferer are set in the Parameters. Users can change the parameters for other test case with reference 5.1.24 TP/RCV/CA /09/C (EDR C/I Performance) of Bluetooth Test Specification Ver. 1.2/2.0/2. 0+EDR/2.1/2.1+EDR.

The center frequency of the input signal to DUT (*SVE_Link* in the design*)* is set by *FCarrier_In*, while center frequency of the output signal from DUT (*SVE_Link* in the design*)* is set by *FCarrier_Out*.

The transmitted wanted signal mean power is set by *SignalPower*.

RF distortions can be introduced by setting parameters ***GainImbalance, PhaseImbalance***, etc.

The number of bursts for BER measurements is specified by ***MeasBurst***.

Try to change the parameters, run ***Bluetooth_EDR_CoACInterference_Analysis*** and check the simulation results.

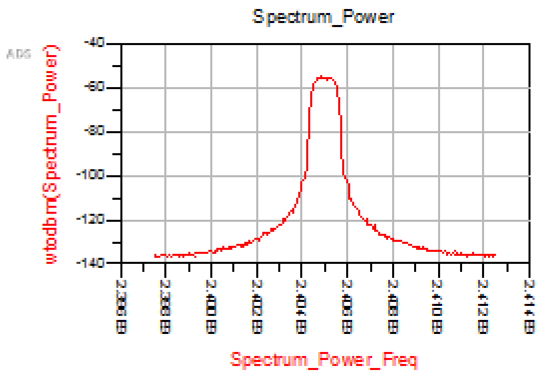
Parameter Details

1. RF Parameters
   - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
   - FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
   - SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
   - MirrorSignal: Mirror signal about carrier
   - GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
   - PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
   - I_OriginOffset: I origin offset. Range: (-∞:+∞)
   - Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
   - IQ_Rotation: IQ rotation. Range: (-∞:+∞)
2. Bluetooth Parameters
   - **LinkType**: the link type of the packet. It can be set to ACL or eSCO.
   - **ACLPacketType**: packet type for ACL EDR. The supported ACL packet type are: 4:2DH1; 8:3DH1; 10:2DH3; 11:3DH3; 14: 2DH5; 15:3DH5. This parameter is active only in case of LinkType is set to ACL .
   - **eSCOPacketType**: packet type for eSCO EDR. The supported eSCO packet type are: 6:2EV3; 7:3EV3; 12: 2EV5; 13:3EV5. This parameter is active only in case of LinkType is set to eSCO.
   - **SamplesPerSym**: number of samples per symbol.
   - **ModulationIndex**: the modulation index of GFSK.
   - **PayloadDataPattern**: payload data pattern. 0 for PN9 and 1 for PN15

Simulation Results

Try to change the parameters, run **Bluetooth_EDR_CoACInterference_Analysis** and check the simulation results.

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



B2_BER_Index	B2_BER
0	0.000

- Table ***EDR_CoACInterference_BER*** shows the decoded bits error rate of the transmitted signal with co-channel or adjacent channel interference.
- Graph ***EDR_CoCInterference_Spectrum_Power*** shows the spectrum of the wanted signal and the interfering signal.

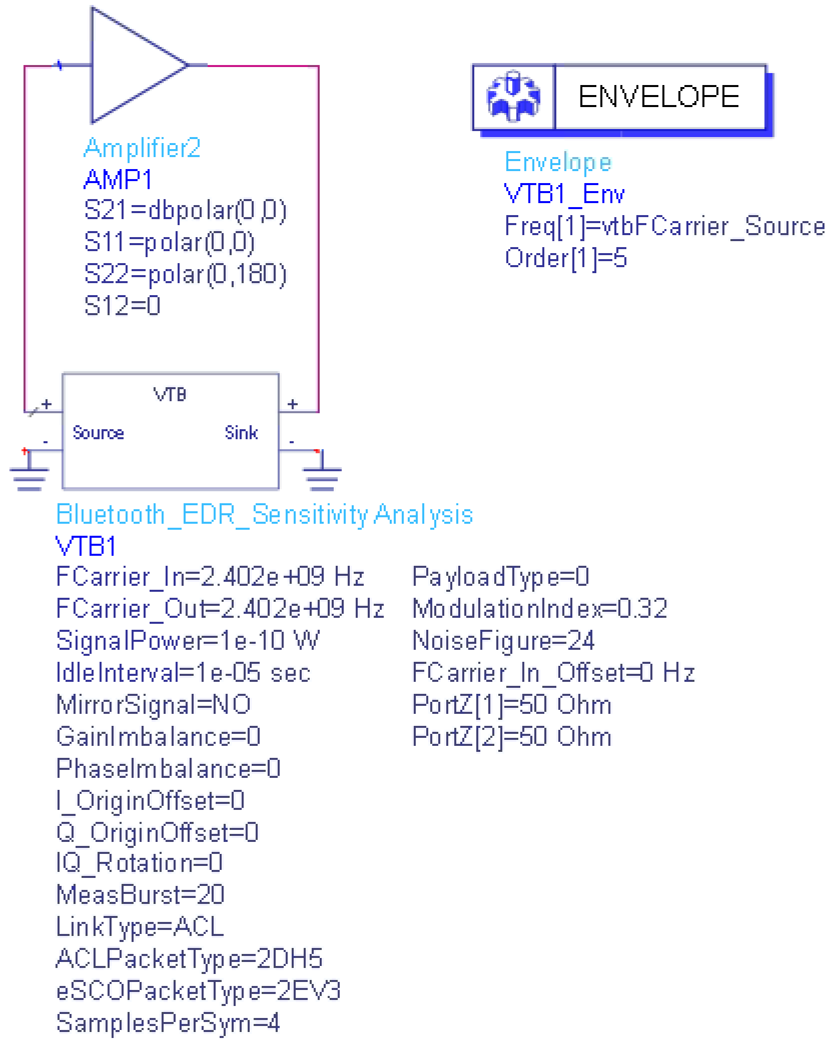
Reference

1. BLUETOOTH SPECIFICATION Version 2.1 + EDR, 26 July 2007.
2. BLUETOOTH SPECIFICATION Version 4.0 + EDR, 30 June 2010.
3. BLUETOOTH TEST SPECIFICATION Ver. 1.2/2.0/2.0 + EDR/2.1/2.1 + EDR, 27 December

Bluetooth_EDR_Sensitivity_Analysis

This workspace provides a VTB test bench to analyze EDR Sensitivity using a non-ideal transmitter of the Bluetooth EDR signals .

A simple design in ADS to use this VTB is shown below.



The test procedure refers to 5.1.22 RCV/CA/07/C (EDR Sensitivity).

- The packet type is 2-DH5 with pi/4- DQPSK modulation and with the maximum length payload containing PN9. To test other packet type, please reset the LinkType and ACLPacketType or eSCOPacketType.
- The input power to the receiver is -70dBm
- This examples gives one step of Sensitivity test procedure with the lowest operation frequency using 20 packets according to Table 5.9 in 5.1.22 RCV /CA/07/C (EDR Sensitivity). To complete all test steps of 5.1.22 RCV/CA/07 /C (EDR Sensitivity), please reset the FCarrier_In_Offset, ModulationIndex according to Table 5.9 in 5.1.22 RCV/CA/07/C (EDR Sensitivity) and run ***Bluetooth_EDR_Sensitivity Analysis.***
- To get the mid and highest operating frequency test result, please re-set the ***FCarrier_In*** and other parameters in the Parameters and run it.

The center frequency of the input signal to DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_In***, while center frequency of the output signal from DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_Out***.

The transmitted wanted signal mean power is set by ***SignalPower***.

RF distortions can be introduced by setting parameters ***GainImbalance, PhaseImbalance***, etc.

The number of bursts for BER measurements is specified by ***MeasBurst***.

Parameter Details

1. RF Parameters
   - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
   - FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
   - SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
   - MirrorSignal: Mirror signal about carrier
   - GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
   - PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
   - I_OriginOffset: I origin offset. Range: (-∞:+∞)
   - Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
   - IQ_Rotation: IQ rotation. Range: (-∞:+∞)
2. Bluetooth Parameters
   - **LinkType**: the link type of the packet. It can be set to ACL or eSCO.
   - **ACLPacketType**: packet type for ACL EDR. The supported ACL packet type are: 4:2DH1; 8:3DH1; 10:2DH3; 11:3DH3; 14: 2DH5; 15:3DH5. This parameter is active only in case of LinkType is set to ACL .
   - **eSCOPacketType**: packet type for eSCO EDR. The supported eSCO packet type are: 6:2EV3; 7:3EV3; 12: 2EV5; 13:3EV5. This parameter is active only in case of LinkType is set to eSCO.
   - **SamplesPerSym**: number of samples per symbol.
   - **ModulationIndex**: the modulation index of GFSK.
   - **PayloadDataPattern**: payload data pattern. 0 for PN9 and 1 for PN15

Simulation Results

Try to change the parameters, run **Bluetooth_EDR_Sensitivity_Analysis** and check the simulation results.

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

B2_BER_Index	B2_BER
0	0.000

- Table ***EDR_BER*** shows the decoded bits error rate of the transmitted signal with specific Noise figure.

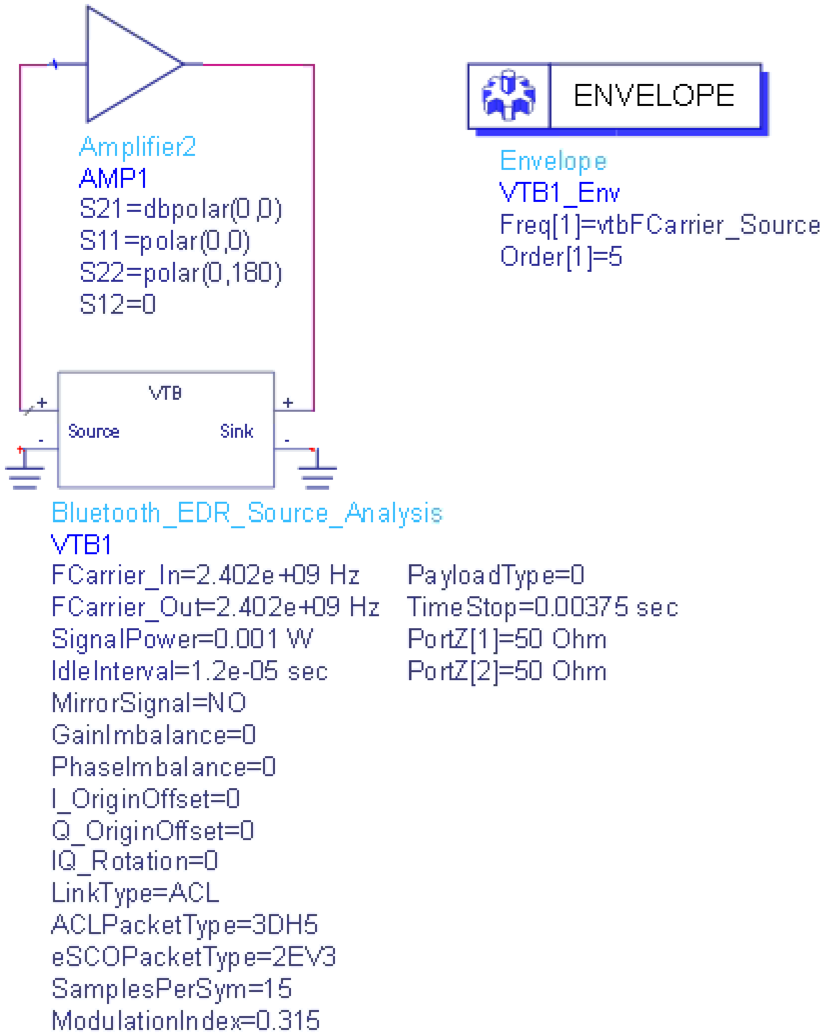
Reference

1. BLUETOOTH SPECIFICATION Version 2.1 + EDR, 26 July 2007.
2. BLUETOOTH SPECIFICATION Version 4.0 + EDR, 30 June 2010.
3. BLUETOOTH TEST SPECIFICATION Ver. 1.2/2.0/2.0 + EDR/2.1/2.1 + EDR, 27 December

Bluetooth_EDR_Source_Analysis

This workspace provides a VTB test bench to generate Bluetooth Enhanced Data Rate signal.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_In***, while center frequency of the output signal from DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_Out***.

The transmitted signal mean power is set by ***SignalPower***.

RF distortions can be introduced by setting parameters ***GainImbalance, PhaseImbalance***, etc.

A sink is used to save the generated signal from 0 to ***TimeStop***.

Parameter Details

1. RF Parameters
    - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)

- FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
- SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
- MirrorSignal: Mirror signal about carrier
- GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
- PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
- I_OriginOffset: I origin offset. Range: (-∞:+∞)
- Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
- IQ_Rotation: IQ rotation. Range: (-∞:+∞)

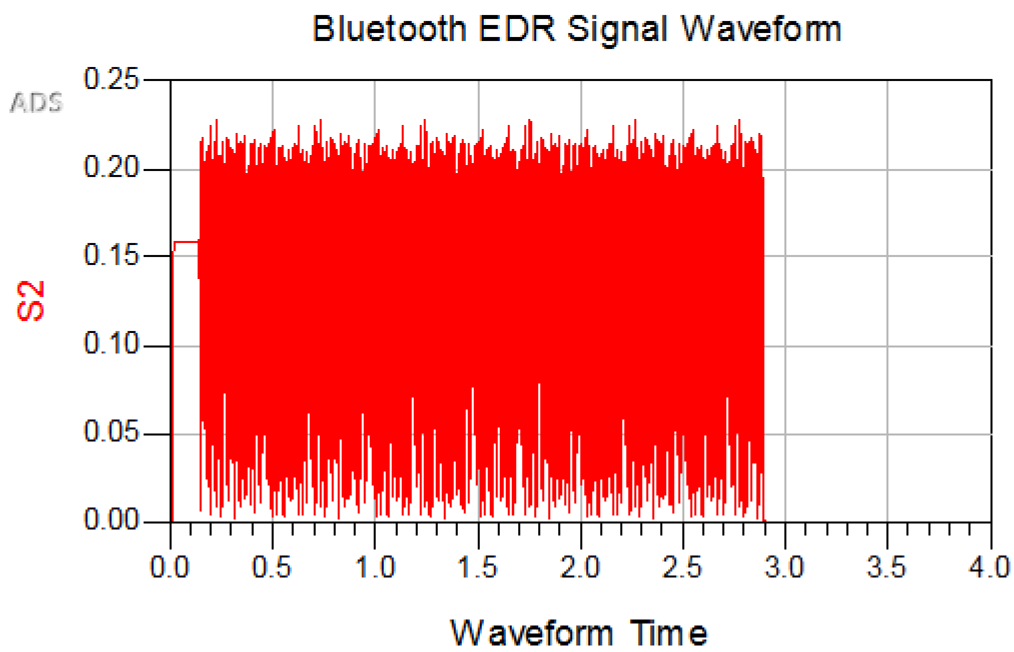
2. Bluetooth Parameters
   - **LinkType**: the link type of the packet. It can be set to ACL or eSCO.
   - **ACLPacketType**: packet type for ACL EDR. The supported ACL packet type are: 4:2DH1; 8:3DH1; 10:2DH3; 11:3DH3; 14: 2DH5; 15:3DH5. This parameter is active only in case of LinkType is set to ACL .
   - **eSCOPacketType**: packet type for eSCO EDR. The supported eSCO packet type are: 6:2EV3; 7:3EV3; 12: 2EV5; 13:3EV5. This parameter is active only in case of LinkType is set to eSCO .
   - **SamplesPerSym**: number of samples per symbol.
   - **ModulationIndex**: the modulation index of GFSK.
   - **PayloadDataPattern**: payload data pattern. 0 for PN9 and 1 for PN15.

Simulation Results

Try to change the parameters, run **Bluetooth_EDR_Source_Analysis** and check the simulation results.

- Graph ***EDR_Waveform*** shows the transmitted time domain waveform

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



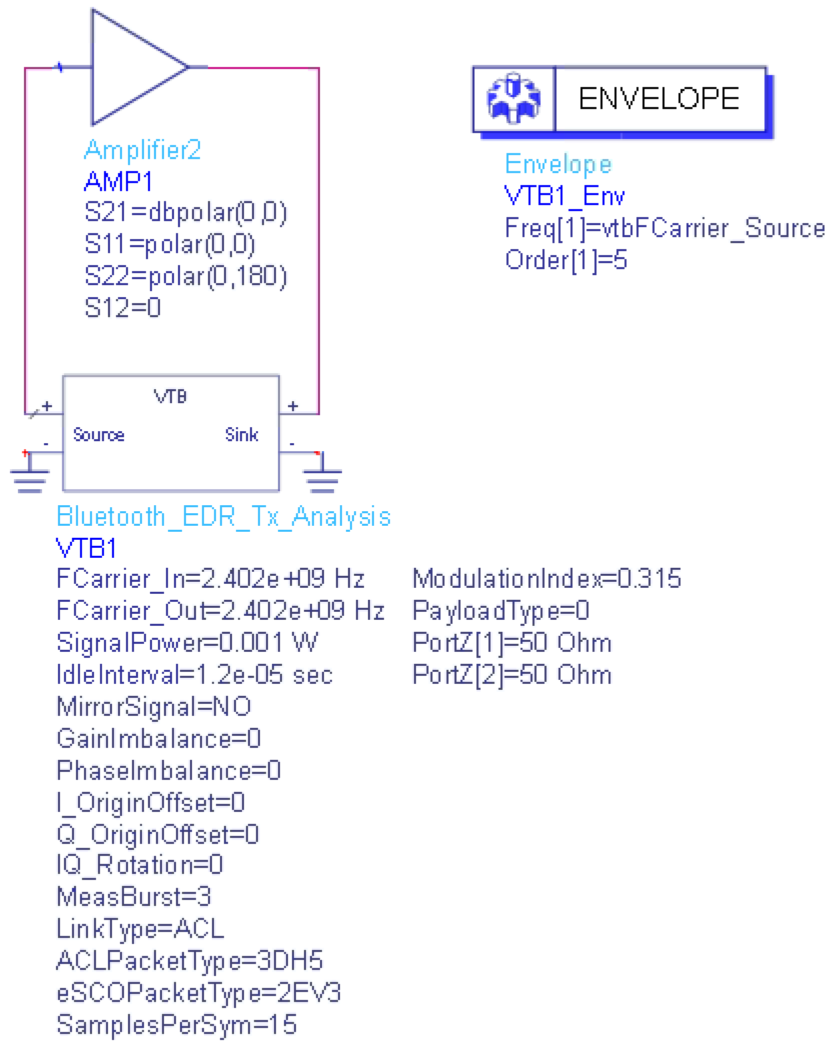
Reference

1. BLUETOOTH SPECIFICATION Version 2.1 + EDR, 26 July 2007.
2. BLUETOOTH SPECIFICATION Version 4.0 + EDR, 30 June 2010.
3. BLUETOOTH TEST SPECIFICATION Ver. 1.2/2.0/2.0 + EDR/2.1/2.1 + EDR, 27 December

Bluetooth_EDR_Tx_Analysis

This workspace provides a VTB test bench to analyze output power, carrier frequency stability and modulation accuracy and BER of the Bluetooth Enhanced Data Rate signals .

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_In***, while center frequency of the output signal from DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_Out***.

The transmitted signal mean power is set by ***SignalPower***.

RF distortions can be introduced by setting parameters ***GainImbalance, PhaseImbalance***, etc.

The number of bursts for measurements is specified by ***MeasBurst***.

Try to change the parameters, run ***Bluetooth_EDR_Tx_Analysis*** and check the simulation results.

Parameter Details

1. RF Parameters
   - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)

- FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
- SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
- MirrorSignal: Mirror signal about carrier
- GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
- PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
- I_OriginOffset: I origin offset. Range: (-∞:+∞)
- Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
- IQ_Rotation: IQ rotation. Range: (-∞:+∞)

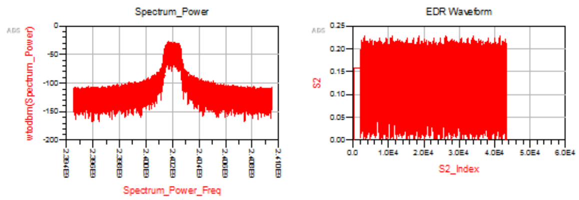
2. Bluetooth Parameters
    - LinkType: the link type of the packet. It can be set to ACL or eSCO.
    - ACLPacketType: packet type for ACL EDR. The supported ACL packet type are: 4:2DH1; 8:3DH1; 10:2DH3; 11:3DH3; 14: 2DH5; 15:3DH5. This parameter is active only in case of LinkType is set to ACL .
    - eSCOPacketType: packet type for eSCO EDR. The supported eSCO packet type are: 6:2EV3; 7:3EV3; 12: 2EV5; 13:3EV5. This parameter is active only in case of LinkType is set to eSCO.
    - SamplesPerSym: number of samples per symbol.
    - ModulationIndex: the modulation index of GFSK.
    - PayloadDataPattern: payload data pattern. 0 for PN9 and 1 for PN15

Simulation Results

Try to change the parameters, run *Bluetooth_EDR_Tx_Analysis* and check the simulation results.

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

- Table ***EDR_BER_Res*** shows the decoded bits error rate of the transmitted signal
- Table ***EDR_FCStability_ModAccuracy*** lists carrier frequency stability for each burst
- Table ***EDR_PowerRes*** shows the Power of each burst
- Graph **EDR_*Spectrum_Power*** shows the spectrum of the transmitted signal
- Graph **EDR_*Waveform*** shows the transmitted time domain waveform



BER

EDR_Meas_BerRes_Burst	EDR_Meas_BerRes
1	0.000
2	0.000
3	0.000

Power

...EDRDPSKPowerRes_Burst	...Meas_EDRDPSKPowerRes	...EDRGFSKPowerRes_Burst	...Meas_EDRGFSKPowerRes
1	-6.020	1	-6.021
2	-6.020	2	-6.021
3	-6.020	3	-6.021

EVM

...ms_percent_Burst	...EVM_rms_percent	...VM_percent_Burst	...akDEVM_percent	...eDEVMRes_Burst	...rcentileDEVMRes	...reqErrorRes_Burst	...lockFreqErrorRes	...qOffsetRes_Burst	...derFreqOffsetRes
1	0.561	1	1.231	1	1.110	1	-10.847	1	16.539
2	0.561	2	1.231	2	1.110	2	-10.847	2	16.539
3	0.561	3	1.231	3	1.110	3	-10.847	3	16.539

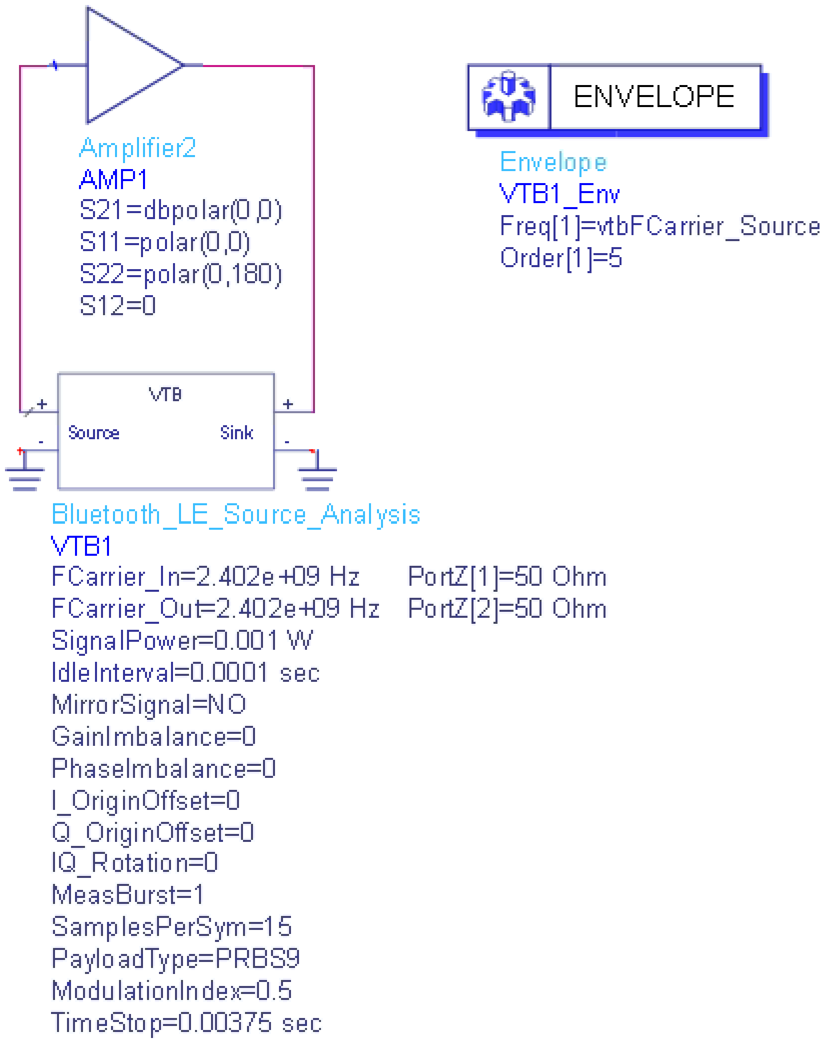
Reference

1. BLUETOOTH SPECIFICATION Version 2.1 + EDR, 26 July 2007.
2. BLUETOOTH SPECIFICATION Version 4.0 + EDR, 30 June 2010.
3. BLUETOOTH TEST SPECIFICATION Ver. 1.2/2.0/2.0 + EDR/2.1/2.1 + EDR, 27 December

Bluetooth_LE_Source_Analysis

This workspace provides a VTB test bench to generate Bluetooth Low Energy signal.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_In***, while center frequency of the output signal from DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_Out***.

The transmitted signal mean power is set by ***SignalPower***.

RF distortions can be introduced by setting parameters ***GainImbalance, PhaseImbalance***, etc.

A sink is used to save the generated signal from 0 to ***TimeStop***.

To generate the BDR signal used to measure the modulation characteristics DeltaF1 and DeltaF2, the defined payload data patterns should be used by set the parameter ***PayloadDataPatten*** in the schematic and run the Analysis.

> *For DeltaF1, we should set the **PayloadDataPatten** as 0 i.e. (1 1 1 1 0 0 0 0)*
>
> *For DeltaF2, we should set the **PayloadDataPatten** as 1 i.e. (1 0 1 0 1 0 1 0)*

To generate the LE signal used to measure the BER, the ***PayloadDataPattern*** should be set to 2 (PN9) or 3 (PN15).

Parameter Details

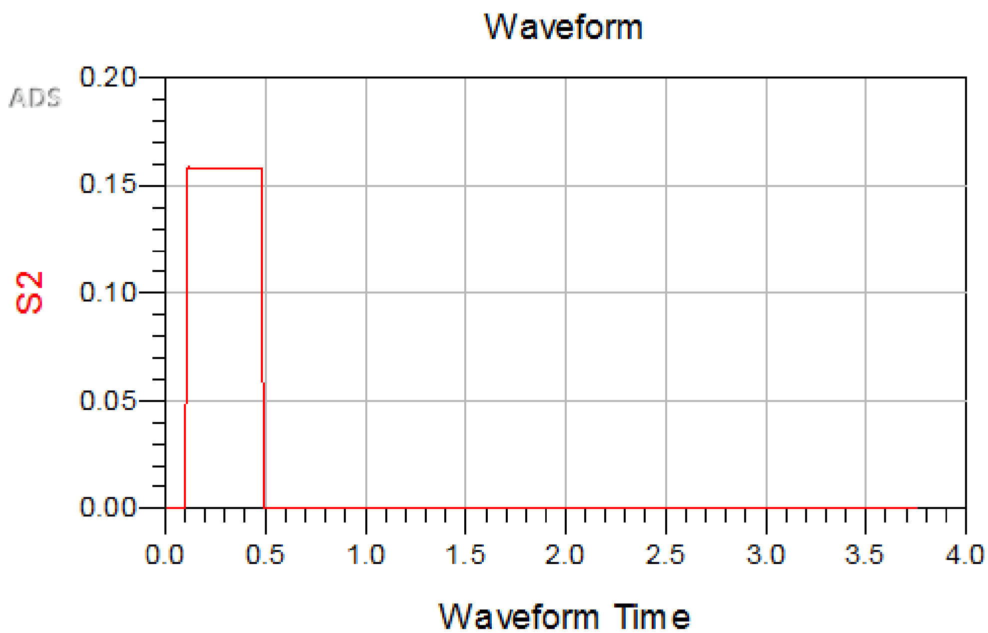
1. RF Parameters
    - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
    - FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
    - SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
    - MirrorSignal: Mirror signal about carrier
    - GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
    - PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
    - I_OriginOffset: I origin offset. Range: (-∞:+∞)
    - Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
    - IQ_Rotation: IQ rotation. Range: (-∞:+∞)
2. Bluetooth Parameters
    - **SamplesPerSym**: number of samples per symbol.
    - **ModulationIndex**: the modulation index of GFSK.
    - **PayloadDataPattern**: payload data pattern. 0 for pattern (1 1 1 1 0 0 0 0); 1 for pattern (1 0 1 0 1 0 1 0); 2 for PN9 and 3 for PN15

Simulation Results

Try to change the parameters, run **Bluetooth_LE_Source_Analysis** and check the simulation results.

- Graph ***LE_Waveform*** shows the transmitted time domain waveform

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



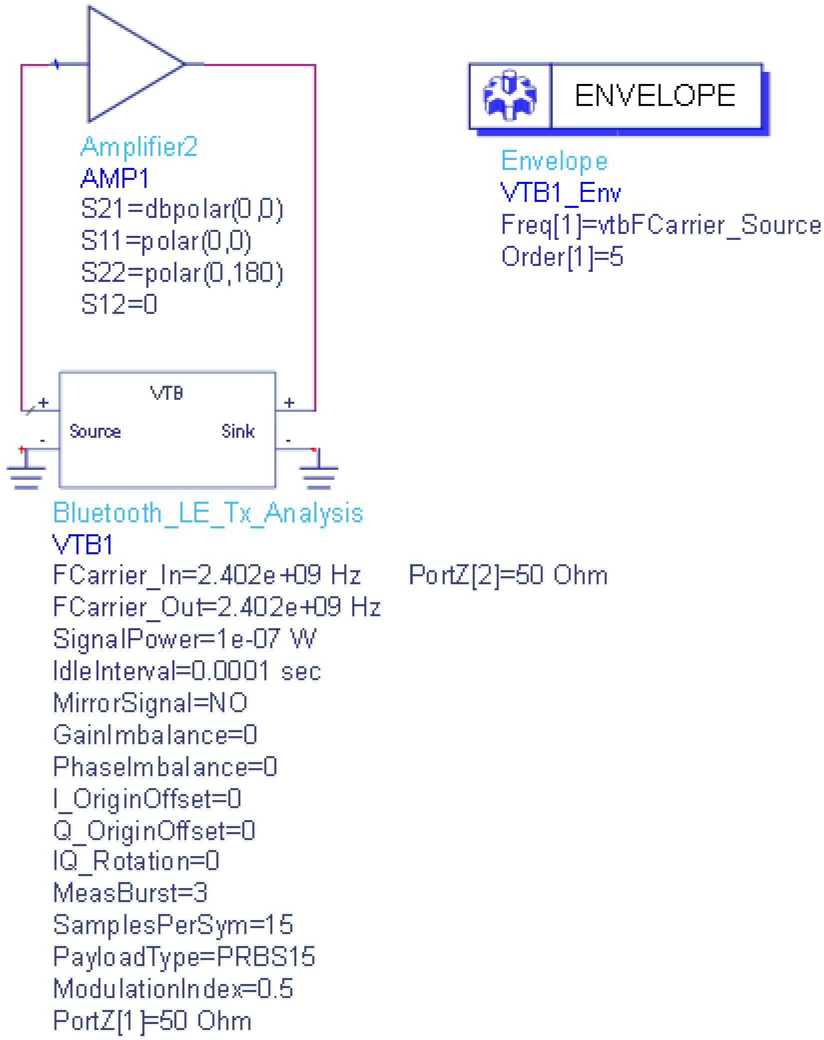
Reference

1. BLUETOOTH SPECIFICATION Version 2.1 + EDR, 26 July 2007.
2. BLUETOOTH SPECIFICATION Version 4.0 + EDR, 30 June 2010.
3. BLUETOOTH TEST SPECIFICATION Ver. 1.2/2.0/2.0 + EDR/2.1/2.1 + EDR, 27 December

Bluetooth_LE_Tx_Analysis

This workspace provides a VTB test bench to analyze output power, modulation characteristics, ICFT(initial carrier frequency tolerance) and the carrier frequency drift of Bluetooth Low Energy signal.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_In***, while center frequency of the output signal from DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_Out***.

The transmitted signal mean power is set by ***SignalPower***.

RF distortions can be introduced by setting parameters ***GainImbalance, PhaseImbalance***, etc.

The number of bursts for measurements is specified by ***MeasBurst***.

Try to change the parameters, run ***Bluetooth_LE_Tx_Analysis*** and check the simulation results.

To measure the modulation characteristics DeltaF1 and DeltaF2, the defined payload data patterns should be used by set the parameter ***PayloadDataPatten*** in the schematic and run the Analysis.

*For DeltaF1, we should set the **PayloadDataPatten** as 0 i.e. (1 1 1 1 0 0 0 0)*

*For DeltaF2, we should set the **PayloadDataPatten** as 1 i.e. (1 0 1 0 1 0 1 0)*

In the case of modulation characteristics test, the reported BER results are not correct. To measure the BER, the ***PayloadDataPattern*** should be set to 2 (PN9) or 3 (PN15).

Parameter Details

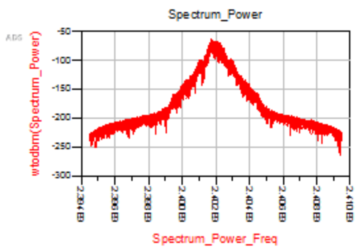
1. RF Parameters
    - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
    - FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
    - SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
    - MirrorSignal: Mirror signal about carrier
    - GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
    - PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
    - I_OriginOffset: I origin offset. Range: (-∞:+∞)
    - Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
    - IQ_Rotation: IQ rotation. Range: (-∞:+∞)
2. Bluetooth Parameters
    - **SamplesPerSym**: number of samples per symbol.
    - **ModulationIndex**: the modulation index of GFSK.
    - **PayloadDataPattern**: payload data pattern. 0 for PN9, 1 for pattern (11110000); 2 for pattern (10101010); 3 for PN15, 4 for (11111111), 5 for (00000000), 6 for (00001111) and 7 for (0101010101)

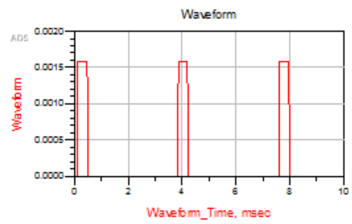
Simulation Results

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

- Table ***LE_BER*** shows the BER
- Table ***LE_ICFT*** shows initial carrier frequency tolerance of the transmitted signal
- Table ***LE_MaxDriftRes*** lists carrier frequency drift for each burst
- Table ***LE_ModCharacteristics*** shows the modulation characteristics of each burst

- Table ***LE_PeakPower*** shows the peak power of the transmitted signal
- Graph ***LE_Spectrum_Power*** shows the spectrum of the transmitted signal
- Graph ***LE_Waveform*** shows the transmitted time domain waveform





BER

B1_BerRes_Burst	B1_BerRes
1	0.000
2	0.000
3	0.000

Initial Carrier Frequency Tolerance

B1_ICFTCarrierFreqRes_Burst	B1_ICFTCarrierFreqRes
1	-247.833
2	-247.833
3	-247.833

Power

B1_PeakPowerRes_Burst	B1_PeakPowerRes
1	-46.021
2	-46.021
3	-46.021

Carrier Frequency Drift

B1_MaxDriftRes_Burst	B1_MaxDriftRes
1	7027.670
2	7027.670
3	7027.670

Modulation Characteristics

...Res_Burst	...F1AvgRes	...Res_Burst	...F1MaxRes	...Res_Burst	...F1MinRes	...Res_Burst	...F2AvgRes	...Res_Burst	...F2MaxRes	...Res_Burst	...F2MinRes
1	250449.516	1	259758.719	1	239721.766	1	229652.156	1	238961.625	1	219766.469
2	250449.516	2	259758.719	2	239721.766	2	229652.156	2	238961.625	2	219766.469
3	250449.516	3	259758.719	3	239721.766	3	229652.156	3	238961.625	3	219766.469

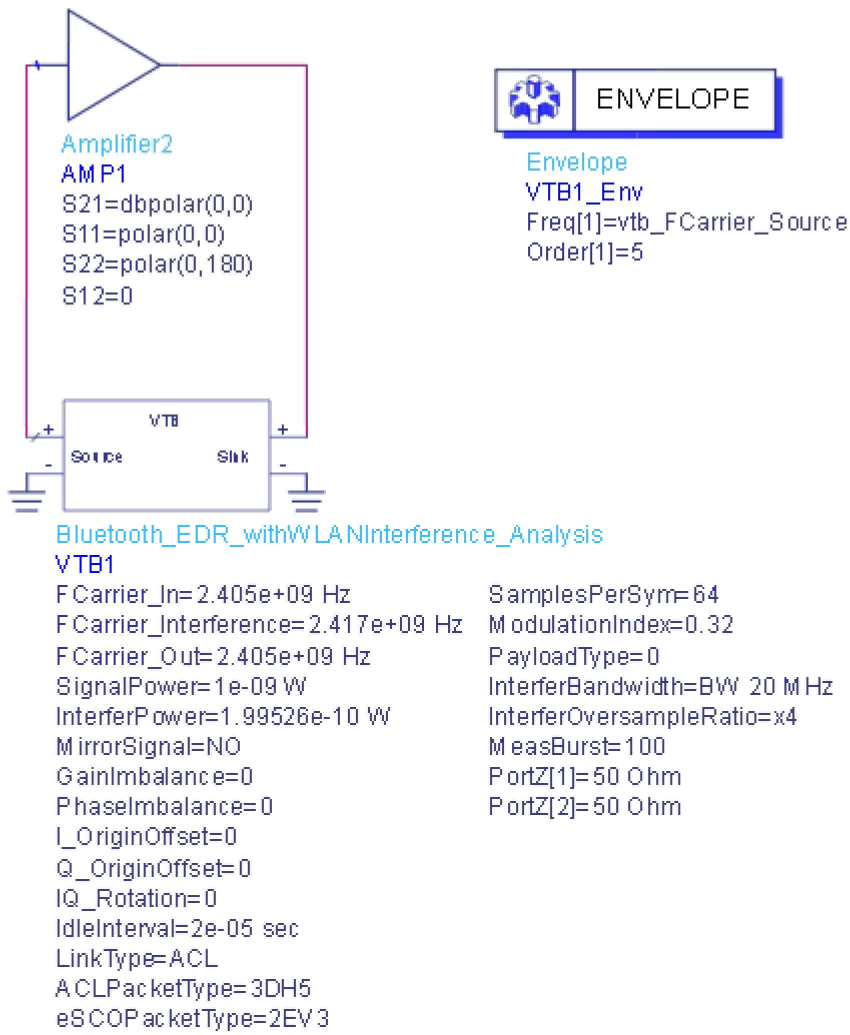
Reference

1. BLUETOOTH SPECIFICATION Version 2.1 + EDR, 26 July 2007.
2. BLUETOOTH SPECIFICATION Version 4.0 + EDR, 30 June 2010.
3. BLUETOOTH TEST SPECIFICATION Ver. 1.2/2.0/2.0 + EDR/2.1/2.1 + EDR, 27 December

Bluetooth_EDR_withWLANInterference_Analysis

This workspace provides a VTB test bench to analyze Bluetooth Rx performance in the presence of adjacent channel WLAN interference..

A simple design in ADS to use this VTB is shown below.



The test procedure refers to 5.1.24 TP/RCV/CA/09/C (EDR C/I Performance).

- The Bluetooth signal operation frequency is 2.405 GHz. and the interferer is the WLAN 11n 20MHz signal which works on 2.417 GHz.
- In the default test configuration, Bluetooth packet type is 3-DH5 with 8DPSK modulation and with the maximum length payload containing PN9. To test other packet type, please reset the LinkType and ACLPacketType or eSCOPacketType.
- The operation frequency and signal power of the wanted signal and interferer as well as the number of test bursts are set in the Parameters. Users can edit the Parameters for other test case

The center frequency of the input signal to DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_In***, while center frequency of the output signal from DUT (***SVE_Link*** in the design***)*** is set by ***FCarrier_Out***.

The transmitted wanted signal mean power is set by ***SignalPower***.

RF distortions can be introduced by setting parameters ***GainImbalance, PhaseImbalance***, etc.

The number of bursts for BER measurements is specified by ***MeasBurst***.

Try to change the parameters, run ***Bluetooth_EDR_withWLANInterference_Analysis*** and check the simulation results.

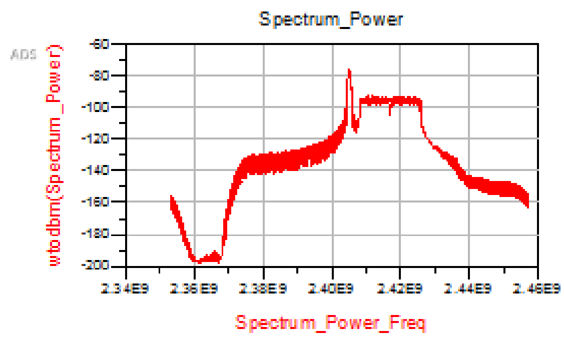
Parameter Details

1. RF Parameters
    - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
    - FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
    - SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
    - MirrorSignal: Mirror signal about carrier
    - GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
    - PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
    - I_OriginOffset: I origin offset. Range: (-∞:+∞)
    - Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
    - IQ_Rotation: IQ rotation. Range: (-∞:+∞)
2. Bluetooth Parameters
    - **LinkType**: the link type of the packet. It can be set to ACL or eSCO.
    - **ACLPacketType**: packet type for ACL EDR. The supported ACL packet type are: 4:2DH1; 8:3DH1; 10:2DH3; 11:3DH3; 14: 2DH5; 15:3DH5. This parameter is active only in case of LinkType is set to ACL .
    - **eSCOPacketType**: packet type for eSCO EDR. The supported eSCO packet type are: 6:2EV3; 7:3EV3; 12: 2EV5; 13:3EV5. This parameter is active only in case of LinkType is set to eSCO.
    - **SamplesPerSym**: number of samples per symbol.
    - **ModulationIndex**: the modulation index of GFSK.
    - **PayloadDataPattern**: payload data pattern. 0 for PN9 and 1 for PN15

Simulation Results

Try to change the parameters, run ***Bluetooth_EDR_withWLANInterference_Analysis*** and check the simulation results.

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



B2_BER_Index	B2_BER
0	0.000

- Table ***EDR_withWLANInterference_BER*** shows the decoded bits error rate of the transmitted signal with co-channel or adjacent channel interference.
- Graph ***EDR_withWLANInterference_Spectrum_Power*** shows the spectrum of the wanted signal and the interfering signal.

Reference

1. BLUETOOTH SPECIFICATION Version 2.1 + EDR, 26 July 2007.
2. BLUETOOTH SPECIFICATION Version 4.0 + EDR, 30 June 2010.
3. BLUETOOTH TEST SPECIFICATION Ver. 1.2/2.0/2.0 + EDR/2.1/2.1 + EDR, 27 December

Communications Workspaces

A single workspace (**VTB_Example**) is provided with a few simple VTB designs that demonstrate the basic VTB features. These VTB designs are provided just for demonstration purposes. In order to run them, you ONLY need the basic SystemVue license. There are three VTB designs inside this workspace:

- EVM_Measurement
- QAM16_SER_vs_EbNo
- ACPR_Measurement

ACPR_Measurement_Analysis

This VTB design demonstrates how VTBs can be set up to post-process simulation data. It measures ACPR for a modulated signal. The symbol rate and the modulation format of the signal can be set using VTB parameters. The modulator output power is also set using a VTB parameter. The signal at the output of the modulator goes through a non-linear amplifier whose output 1 dB compression point is a VTB parameter.

ACPR is measured by computing the spectrum power in different bands using a custom ACPR function defined inside the SystemVue workspace.

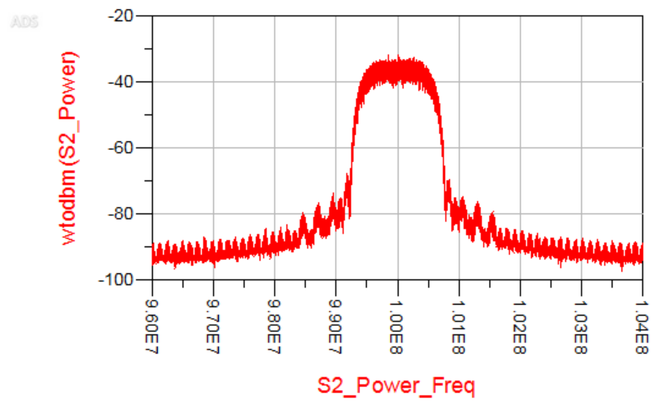
CAUTION This ACPR function is for demonstration purposes only. It does NOT comply with any standard.

Parameter Details

- Modulation: Modulation format (choose from BPSK, QPSK, 8-PSK, 16-PSK, 16-QAM, 32-QAM, 64-QAM, 128-QAM, 256-QAM, 512-QAM, 1024-QAM, Star 16-QAM, Star 32-QAM)
- SymbolRate: Symbol rate
- FCarrier: Carrier frequency
- RF_Power: Modulator output power delivered to a load of RefR
- P1dB: Output 1 dB compression point
- RefR: Reference resistance for power calibration

Simulation Results

Simulation results include the output spectrum and a table of four ACPR values, for the two adjacent channels above (*MyACPRPlus1_dB*, *MyACPRPlus2_dB*) and below (*MyACPRMinus1_dB*, *MyACPRMinus2_dB*) the main channel.



MyACPRPlus1_dB	MyACPRMinus1_dB	MyACPRPlus2_dB	MyACPRMinus2_dB
-42.595	-42.533	-53.361	-53.429

Change the *P1dB* parameter and observe the changes in the spectrum and ACPR values.

EVM_Measurement_Analysis

This VTB design performs an EVM measurement on a modulated signal. The symbol rate and modulation format of the signal can be set through the VTB parameters. The modulator output power, as well as certain modulation impairments, can also be set using the VTB parameters.

Parameter Details

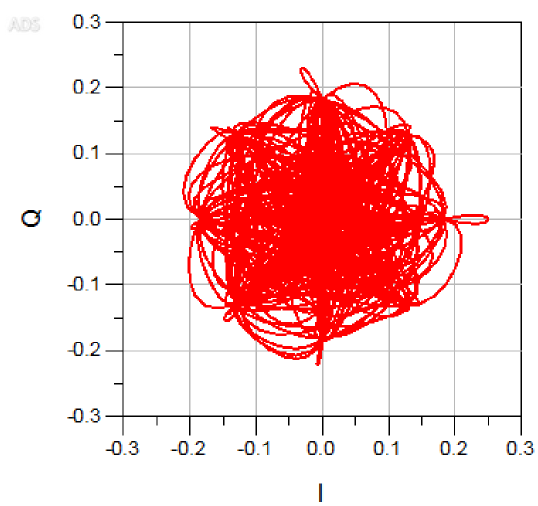
- Modulation: Modulation format (choose from BPSK, QPSK, 8-PSK, 16-PSK, 16-QAM, 32-QAM, 64-QAM, 128-QAM, 256-QAM, 512-QAM, 1024-QAM, Star 16-QAM, Star 32-QAM)
- SymbolRate: Modulated signal symbol rate
- FCarrier: Carrier frequency
- RF_Power: Modulator output power delivered to a load of RefR
- RefR: Reference resistance for power calibration
- GainImb: Modulator gain imbalance
- PhaseImb: Modulator phase imbalance
- IQ_Offset: Complex IQ offset
- NoiseDensity: Noise density (Power/Hz)
- NumSymbols: Number of symbols used for EVM measurement

Simulation Results

The simulation results include an errors summary table and a trajectory plot. Please note that in the errors summary table the IQ Offset, Gain Imb, and Droop are shown in linear scale (absolute values). To see them in dB you need to apply the $20*\log_{10}()$ function.

E1_Errors_Summary

EVM =	0.099 %rms	0.221	% pk	at sym 451.000
Mag Err =	0.072 %rms	0.197	% pk	at sym 409.000
Phase Err =	0.001 rad	%rms	0.005 rad	deg pk at sym 25.000
Freq Err =	0.001 Hz			
IQ Offset =	0.000 Relative			
Quad Err =	-0.000 rad			
Gain Imb =	1.000 Relative			
Droop =	1.000 Relative			



QAM16_SER_vs_EbNo_Analysis

This VTB design uses the BER_IS model to efficiently compute a BER waterfall curve for a 16-QAM system. VTB parameters include the signal symbol rate, modulator output power, and range of SNR values over which BER is computed.

CAUTION This VTB design is NOT designed to handle DUTs that introduce arbitrary delays, phase rotations, etc.

Parameter Details

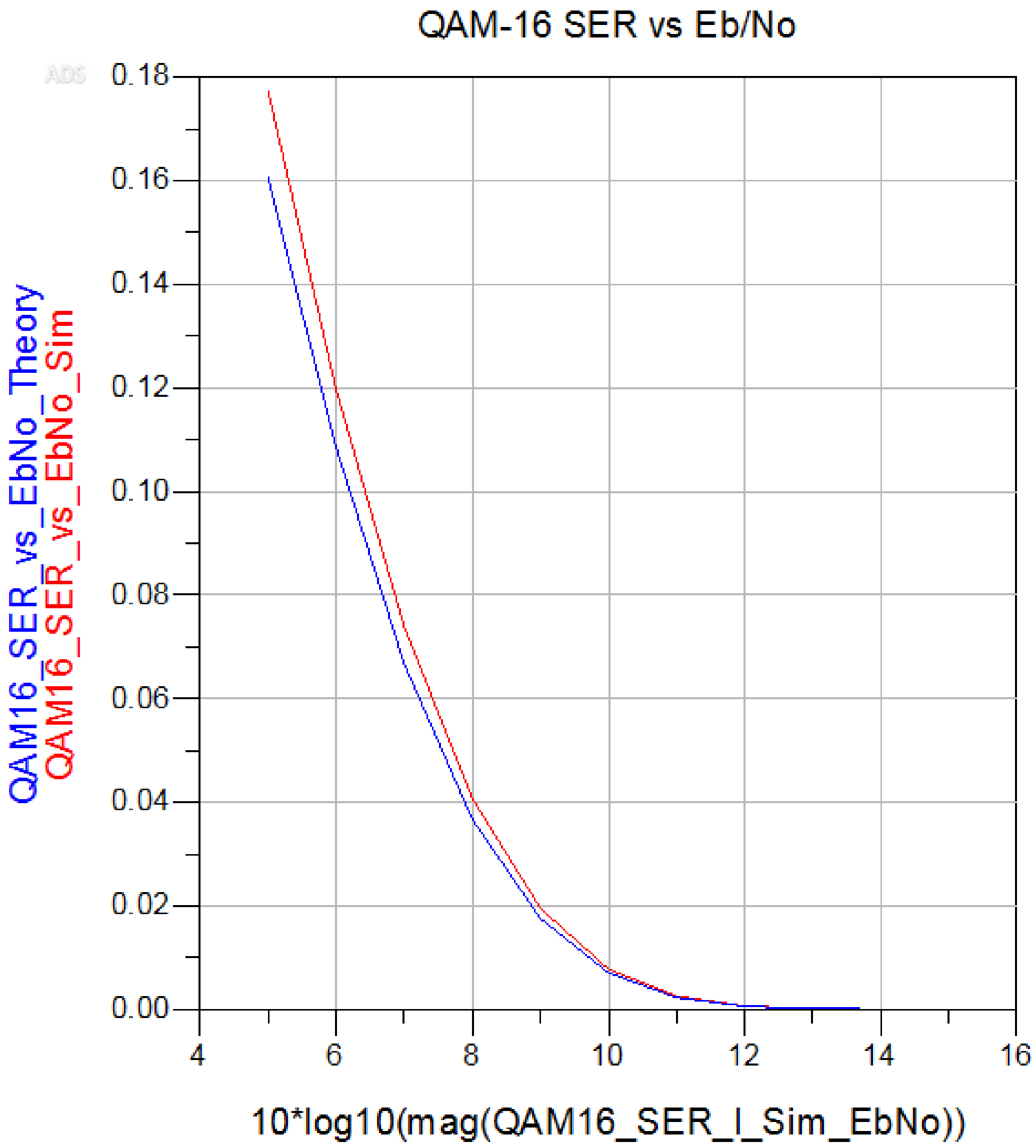
- SymbolRate: 16-QAM symbol rate
- FCarrier: Carrier frequency
- RF_Power: Modulator output power delivered to a load of RefR
- RefR: Reference resistance for power calibration

- DUT_Gain: DUT linear power gain
- SNR_Start: SNR start value
- SNR_Step: SNR step value
- SNR_NumSteps: SNR number of steps

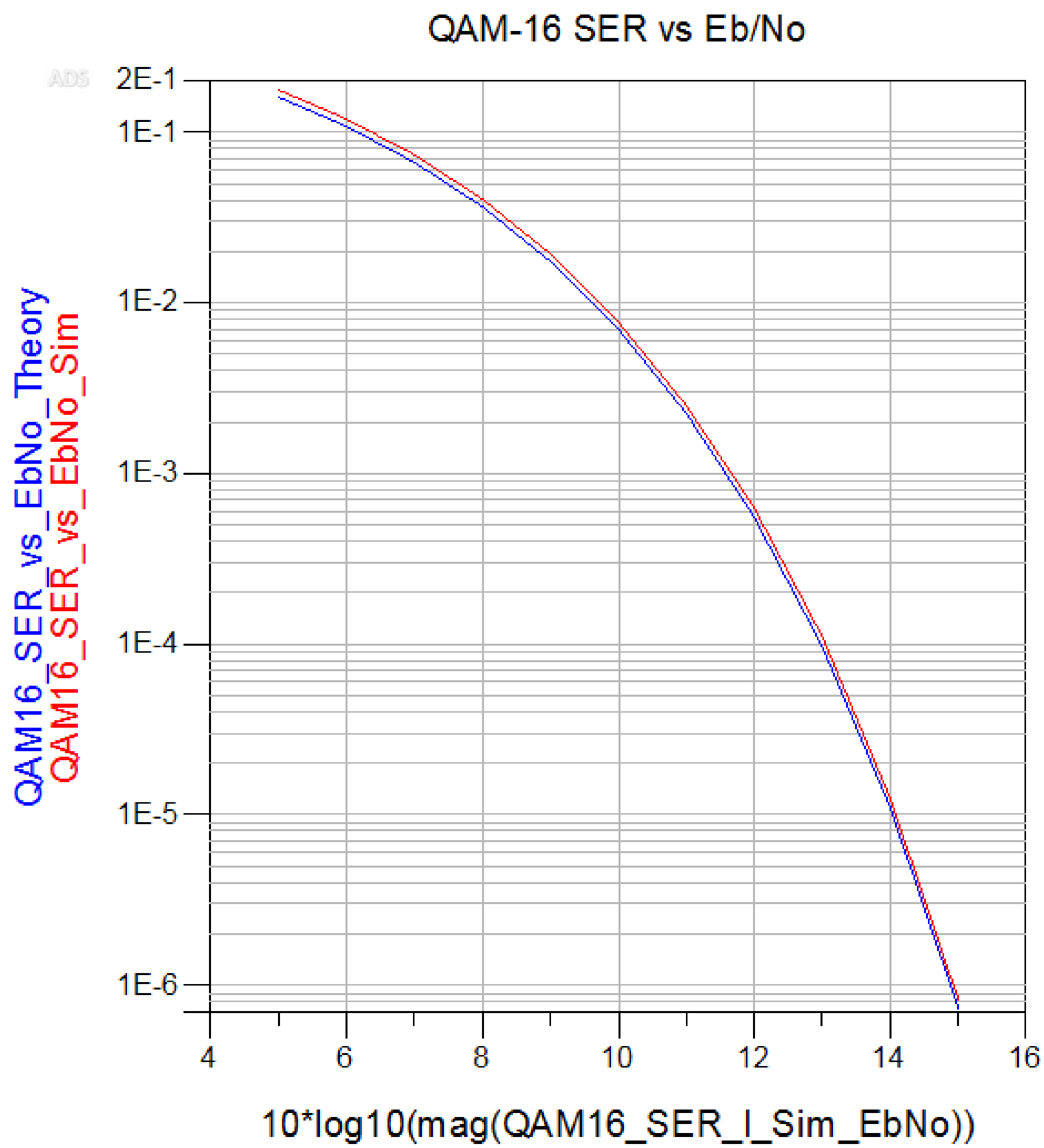
DUT_Gain is the linear power gain of the DUT that is connected to the VTB. This is needed so that the values at the input of the VTB (output of the DUT) are scaled properly before they are processed to compute BER (the default detection thresholds used by the BER_IS model assume input signal levels equally spaced between -1 and 1).
SNR values refer to E_b/N_o

Simulation Results

Simulation results include the simulated BER curve along with the theoretical BER curve. Note that by default the graph is NOT using a logarithmic scale on the y-axis.



To see the typical BER waterfall curve change the y-axis to use a log scale


QAM-16 SER vs Eb/No
ADS
2E-1
1E-1
1E-2
1E-3
1E-4
1E-5
1E-6
QAM16_SER_vs_EbNo_Theory
QAM16_SER_vs_EbNo_Sim
4
6
8
10
12
14
16
10*log10(mag(QAM16_SER_I_Sim_EbNo))

DigitalMod Workspaces

VTB workspaces are provided to analyze the most basic digital modulation signal transmitter.

Tx

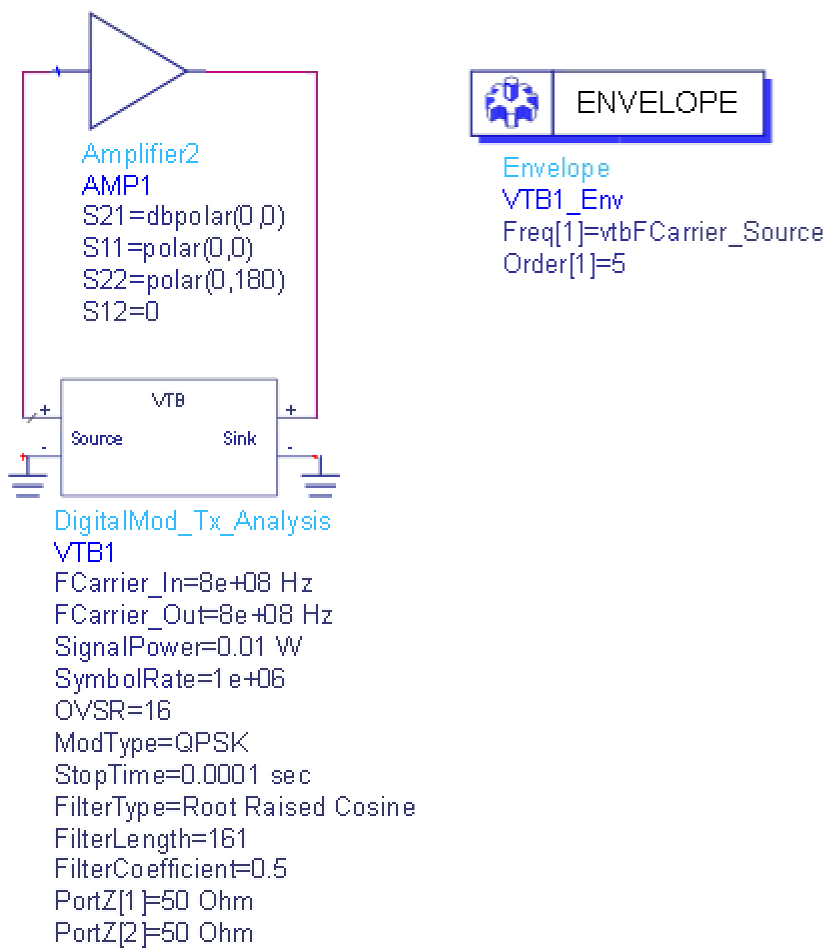
- DigitalMod_Tx
- DigitalMod_Tx_Source

DigitalMod_Tx_Analysis

This VTB design demonstrates the signal generation of the most common modulation formats. The message is modulated with the specified format and up-converted into RF signal.

Schematic

A simple design in ADS to use this VTB is shown below.

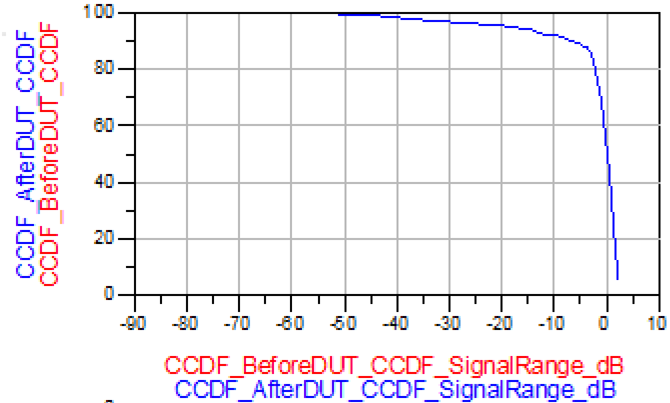


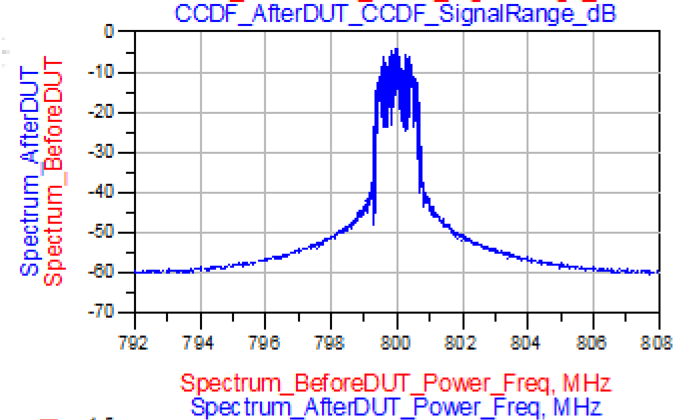
Parameter Details

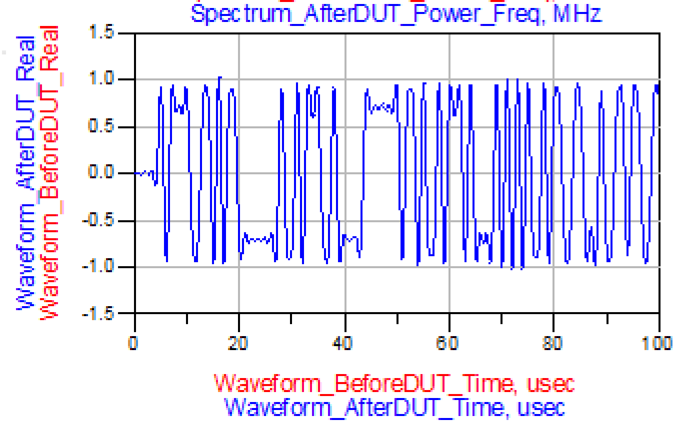
1. FCarrier_In: The frequency of the carrier of the input end, [0, inf).
2. FCarrier_Out: The frequency of the carrier of the output end, [0, inf).
3. SignalPower: The power of transmit signal power over 50ohm, (-inf, inf).
4. SymbolRate: The symbol rate of the current communication system, (0, inf).
5. OVSR: The oversampling ratio, that is the number of samples that each symbol lasts, [1, inf).
6. ModType: The digital modulation format. BPSK, QPSK, 8-PSK, 16-PSK, 16-QAM, 32-QAM, 64-QAM, 128-QAM, 256-QAM, 512-QAM, 1024-QAM, 2048-QAM, 4096-QAM, 16-APSK, 32-APSK, Star 16-QAM, Star 32-QAM, Custom APSK, DQPSK, pi/4 DQPSK, Offset QPSK, SOQPSK-MIL, SOQPSK-TG, D8PSK, EDGE-8PSK, pi/8 D8PSK, MSK, GMSK, M-ary CPM, Multi-h CPM, CQPSK, pi/4-CQPSK, IJF-OQPSK, FQPSK, EFQPSK, 2FSK, 4FSK, 8FSK, 16FSK, DBPSK, pi/2 DBPSK
7. StopTime: The stop time of data collection in seconds, [0, inf).
8. FilterType: The type of pulse shaping filter.
9. FilterLength: The length of pulse shaping filter, [1, inf).
10. FilterCoeffcient: The coefficient of the current type of pulse shaping filter, [0, 1].

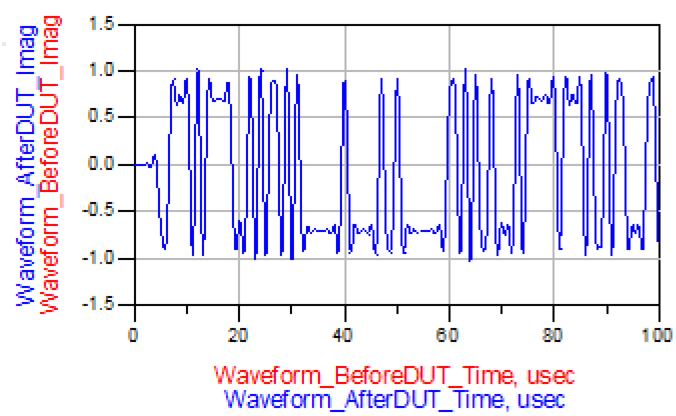
Simulation Results

The spectrum, CCDF and waveform are plotted in figures.









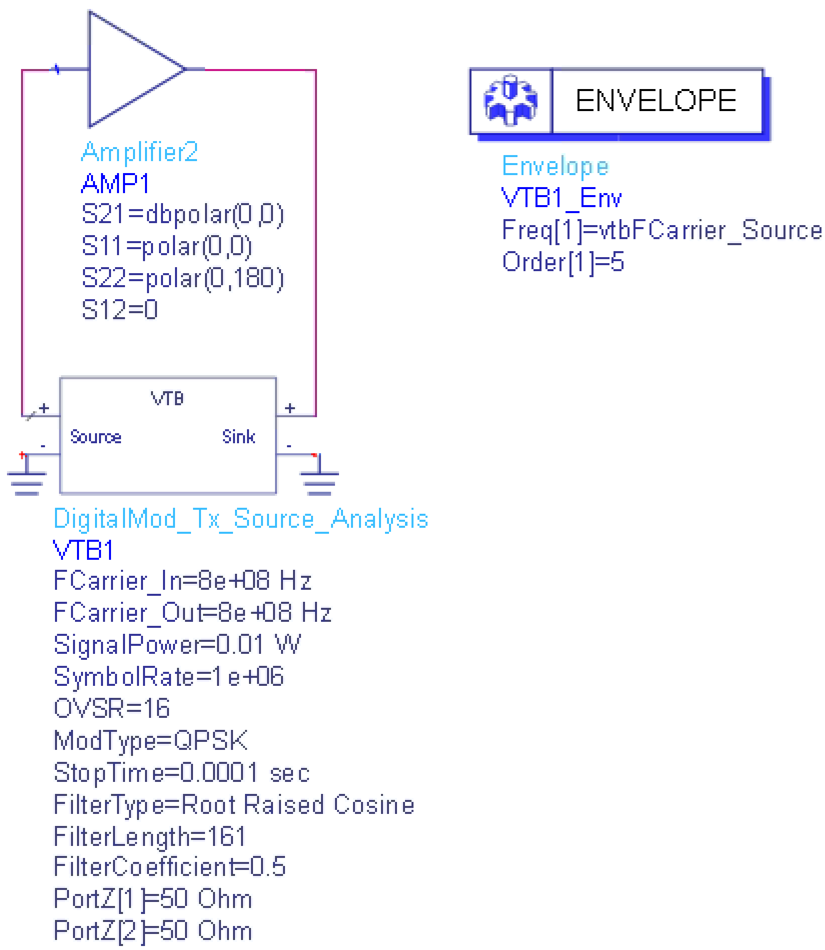
DigitalMod_Tx_Source

DigitalMod_Tx_Source_Analysis

This workspace provides a VTB test bench for generating the most common digital modulation signal.

Schematic

A simple design in ADS to use this VTB is shown below.



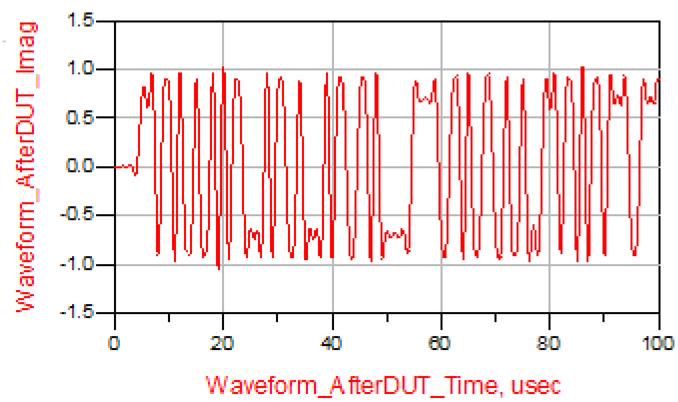
Parameter Details

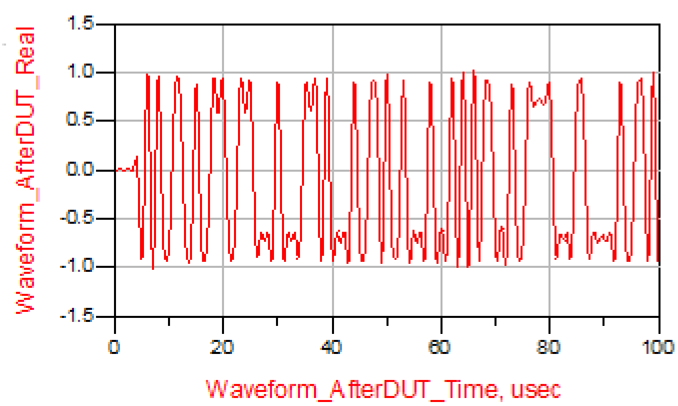
1. FCarrier_In: The frequency of the carrier of the input end, [0, inf).
2. FCarrier_Out: The frequency of the carrier of the output end, [0, inf).
3. SignalPower: The power of transmit signal power over 50ohm, (-inf, inf).
4. SymbolRate: The symbol rate of the current communication system, (0, inf).

5. OVSR: The oversampling ratio, that is the number of samples that each symbol lasts, [1, inf).
6. ModType: The digital modulation format. BPSK, QPSK, 8-PSK, 16-PSK, 16-QAM, 32-QAM, 64-QAM, 128-QAM, 256-QAM, 512-QAM, 1024-QAM, 2048-QAM, 4096-QAM, 16-APSK, 32-APSK, Star 16-QAM, Star 32-QAM, Custom APSK, DQPSK, pi/4 DQPSK, Offset QPSK, SOQPSK-MIL, SOQPSK-TG, D8PSK, EDGE-8PSK, pi/8 D8PSK, MSK, GMSK, M-ary CPM, Multi-h CPM, CQPSK, pi/4-CQPSK, IJF-OQPSK, FQPSK, EFQPSK, 2FSK, 4FSK, 8FSK, 16FSK, DBPSK, pi/2 DBPSK
7. StopTime: The stop time of data collection in seconds, [0, inf).
8. FilterType: The type of pulse shaping filter.
9. FilterLength: The length of pulse shaping filter, [1, inf).
10. FilterCoeffcient: The coefficient of the current type of pulse shaping filter, [0, 1].

Simulation Results

The waveform of I and Q are plotted separately.





LTE Advanced Workspaces

LTE Advanced Workspaces

VTB workspaces are provided to analyze LTE-Advanced transmitter characteristics for a base station according to [1].

- LTE_Advanced_BS_CA_Tx
- LTE_Advanced_BS_CA_Tx_Source

NOTE In the current implementation, there are only one input port and one output port in the SVE_Link model used in LTE Advanced workspaces, which means the DUT (design in ADS/GoldenGate environment) should only have one input and one output. In Tx examples, the DUT is connected after the modulator. Please refer to the help document of each workspace for more information. in which you can find the detailed schematic.

How to set SVE_Link properties in LTE workspaces

Users can optionally define the ***SVE_Link*** properties by setting **DefineProperties** to YES. When **DefineProperties** is set to *YES*, parameters related to ***SVE_Link*** properties, including **InFeedbackLoop**, **SampleRate**, and **InputFcs**, can be defined by values or expressions.

- InFeedbackLoop: Specify whether the SVE_Link is in a feedback loop: NO, YES. In LTE Advanced Tx examples, there is no feedback loop, hence **InFeedbackLoop** is set to *NO*.
- SampleRate: Sample rate of the signal. In LTE Advanced examples, the sample rate is set by parameter **OutputSampleRate**. Hence, **SampleRate** is directly set to **OutputSampleRate**.
- InputFcs: Array of characterization frequencies of input envelope signals. In current LTE Advanced examples, there is only one input port in **SVE_Link** model, hence, **InputFcs** is set to **[FCarrier_In]**.

Otherwise, when **DefineProperties** is set to *NO*, the VTB process will analyze the full design and provide such information to the integrating tool.

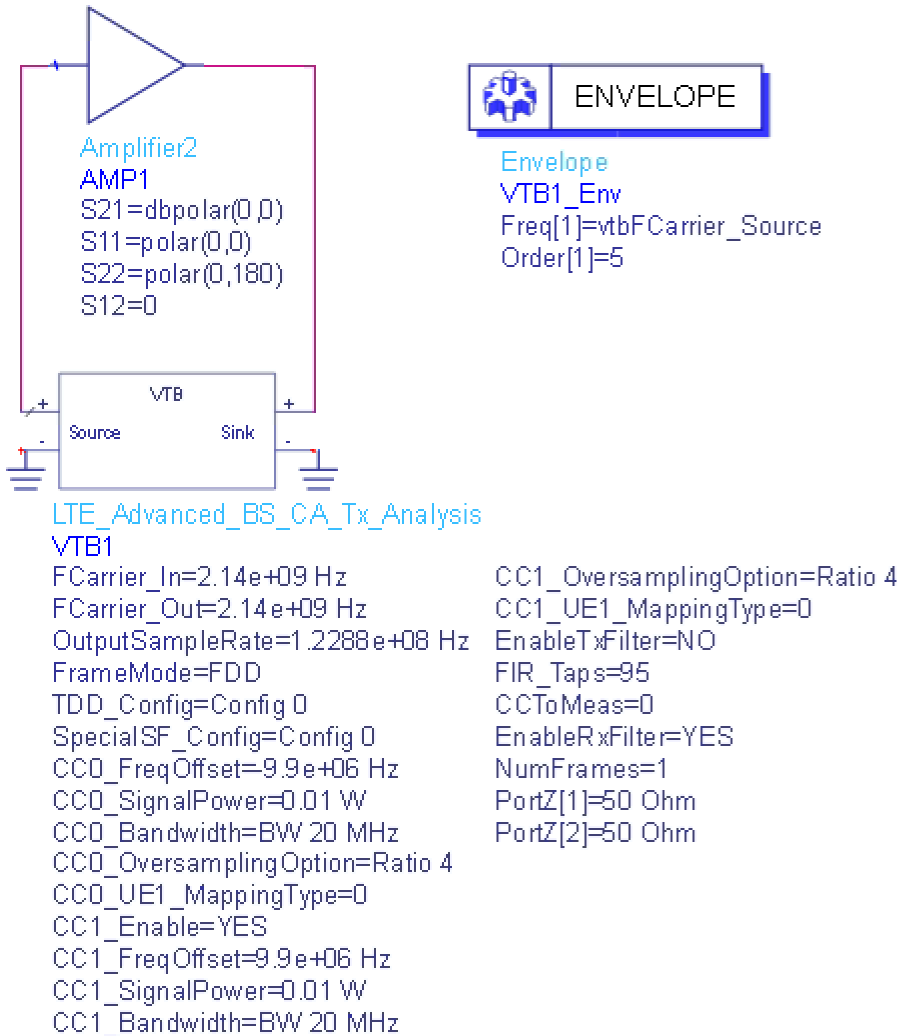
References

1. 3GPP TS 36.104 v10.0.0 "Base Station (BS) radio transmission and reception", December 2010.

LTE_Advanced_BS_CA_Tx_Analysis

This VTB design measures LTE Advanced base station transmitter characteristics with carrier aggregation, including spectrum, waveform, CCDF, EVM and ACLR according to [1].

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(***SVE_Link*** in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(***SVE_Link*** in the design) is set by **FCarrier_Out**.

The sampling rate of the aggregated signal is explicitly specified by **OutputSampleRate**. Make sure the sampling rate is sufficient to analyze the aggregated signal and can be handled by SystemVue simulation. However, large **OutputSampleRate** would significantly slow down the simulation. The transmitted signal of each component carrier would be resampled and combined in model **SSignalCombiner**. Also, make sure **OutputSampleRate** is multiple of the base sample rate of each component carrier.

By default, two component carriers are transmitted. The frequency of each component carrier (CC) is set by **CC#_FCarrier**. By setting those center frequencies, this design can generate either contiguous or noncontiguous aggregated signal either intra-band or inter-band. Again, please make sure OutputSampleRate is sufficient to analyze the aggregated signal.

Component carrier 0 would always be transmitted, while other component carriers can be turned off by set **CC#_Enable** to NO. Up to 5 component carriers are supported. Each component carrier can be configured independently. Please open the workspace in SystemVue then you can find parameters to configure each component carrier.

The ideal lowpass filter for spectrum shaping can be turned on/off by parameter **EnableTxFilter**. The number of taps can be set by **FIR_Taps**. If EnableTxFilter is set to NO, no spectrum shaping would be applied. The same spectrum shaping is implemented for each component carrier.

Users can select one component carrier for EVM measurement by setting parameter **CCToMeas**. It should be set in the range [0,4]. By default, a *ParksMcClellan* bandpass filter is used before EVM measurement. This filter can be disabled by setting **EnableRxFilter** to NO.

The number of simulated frames for EVM measurements is set by parameter NumFrames.

Parameter Details

- FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
- FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
- OutputSampleRate: User specified output sample rate of the aggregated signal. Range: (0:+∞)
- CC#_Enable: Enable transmission of component carrier#. Component carrier 0 is always transmitted
- CC#_FreqOffset: Frequency offset of component carrier# relative to **FCarrier_In**. Range: (-FCarrier_In:+∞)
- CCToMeas: Choose which component carrier to measure EVM. Range: [0,4]
- EnableRxFilter: Whether enables Rx Filter for the measured component carrier or not
  For details on other parameters, refer to 3GPP_LTE_BS_Tx.

Simulation Results

Try to change the parameters, run **LTE_Advanced_BS_CA_Tx_Analysis** and check the simulation results.

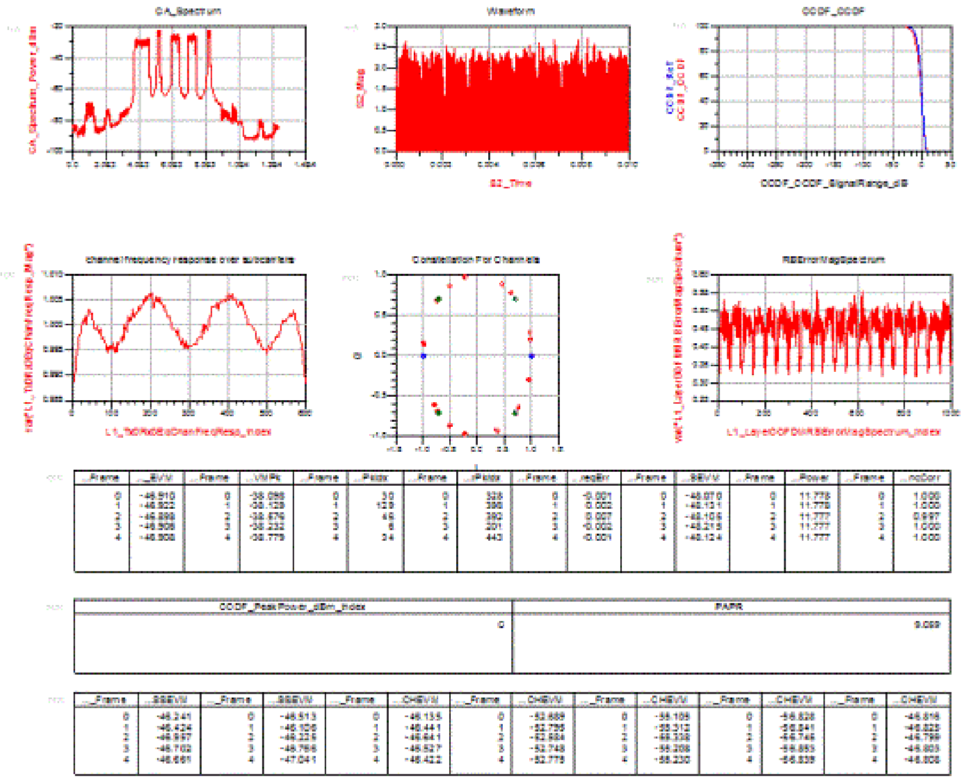
- Graph ***CCDF*** shows the Complementary Cumulative Distribution Function of the transmitted signal
- Graph ***Constellation*** shows the constellation of each physical channel and signal of component carrier 0
- Table ***ErrorSummary*** shows average EVM, peak EVM, frequency errors and other measured results of each frame of component carrier 0

- Table ***EVM*** lists EVM of each physical channel and signal of component carrier 0 according to section 6.5 of 3GPP TS 36.104
- Graph ***NormalizedEqualizerChannelFrequencyResponse*** shows the normalized equalizer channel frequency response of component carrier 0
- Graph ***RBErrorMagSpectrum*** shows the error magnitude spectrum of each RB of component carrier 0
- Graph ***Spectrum*** shows the spectrum of the aggregated signal
- Graph ***Waveform*** shows the transmitted time domain waveform

NOTE EVM is reported in % in this example, i.e. if the result is displayed as 0.187, it means EVM = 0.187%.
If EVM on PDSCH (for different modulation schemes) is better than the limits below [1], then *EVM_PassFailFlag* is set to true(1), otherwise, it is set to false(0).

Modulation scheme for PDSCH	Required EVM [%]
QPSK	17.5 %
16QAM	12.5 %
64QAM	8 %

The following graphs would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation. The DUT is shorted to get the following ideal results. The same results will be displayed in SystemVue environment if the ***SVE_Link*** model is disabled to short.



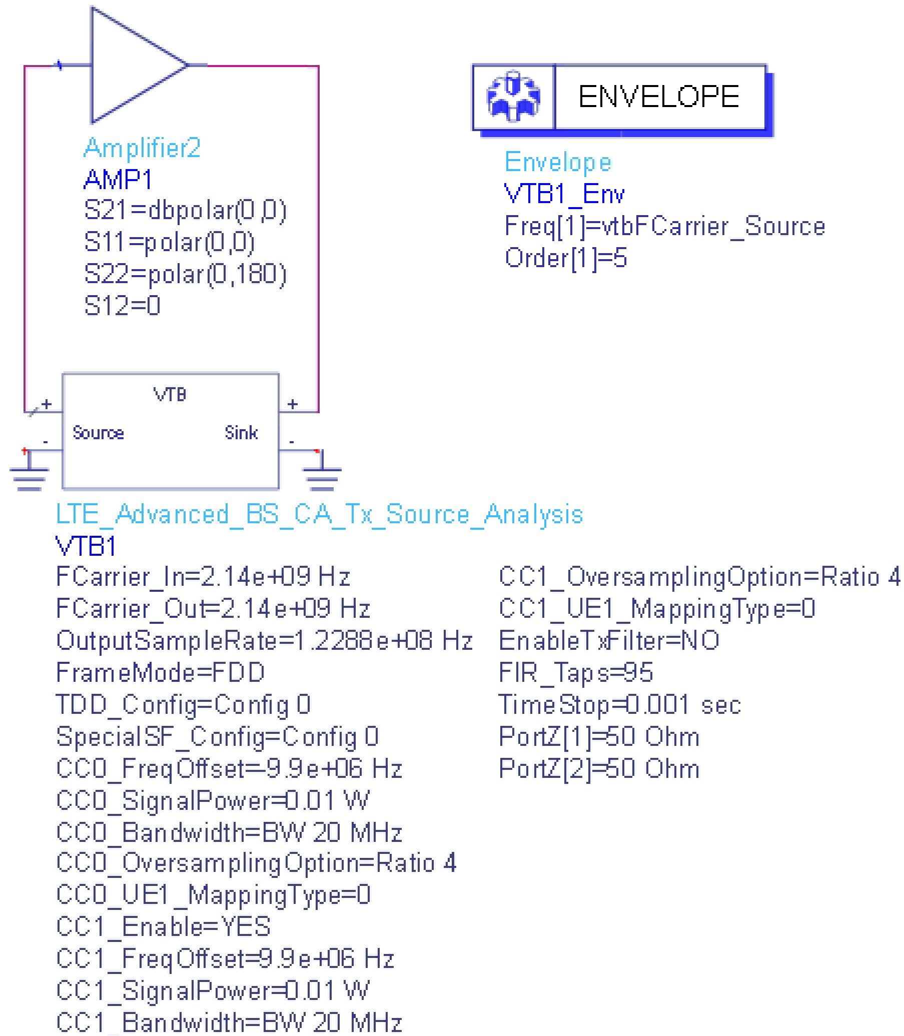
Reference

1. 3GPP TS 36.104 v10.0.0 "Base Station (BS) radio transmission and reception", December 2010.

LTE_Advanced_BS_CA_Tx_Source_Analysis

This VTB workspace is used to generate LTE-Advanced downlink carrier aggregation signal.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(***SVE_Link*** in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(***SVE_Link*** in the design) is set by **FCarrier_Out**.

The sampling rate of the aggregated signal is explicitly specified by **OutputSampleRate**. Make sure the sampling rate is sufficient to analyze the aggregated signal and can be handled by SystemVue simulation. However, large **OutputSampleRate** would significantly slow down the simulation. The transmitted signal of each component carrier would be resampled and combined in model *SignalCombiner*. Also please make sure **OutputSampleRate** is multiple of the base sample rate of each component carrier.

Up to 5 component carriers are supported. The frequency of each component carrier (CC) is set by **CC0_FCarrier**, **CC1_FCarrier**, **CC2_FCarrier**, **CC3_FCarrier** and **CC4_FCarrier** respectively. By setting those center frequencies, this design can generate either contiguous or non-contiguous aggregated signal either intra-band or inter-band. Again, please make sure OutputSampleRate is sufficient to analyze the aggregated signal.

Component carrier 0 would always be transmitted, while other component carriers can be turned off by set **CC#_Enable** to NO. Each component carrier can be configured independently.

The ideal lowpass filter for spectrum shaping can be turned on/off by parameter **EnableTxFilter**. The number of taps can be set by **FIR_Taps**. If EnableTxFilter is set to NO, no spectrum shaping would be applied. The same spectrum shaping is implemented for each component carrier.

A sink is used to save the generated signal from 0 to **TimeStop**.

Parameter Details

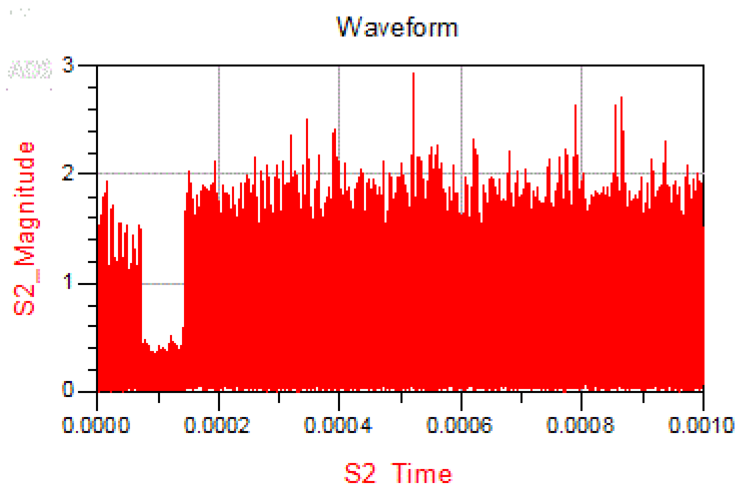
- TimeStop: Stop time of data collection. Range: (0:+∞)
  For details on other parameters, please refer to LTE_Advanced_BS_CA_Tx.

Simulation Results

Try to change the parameters, run **LTE_Advanced_BS_CA_Tx_Source_Analysis** and check the simulation results.

- Graph ***Waveform*** shows the transmitted time domain waveform

The following table would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



Reference

1. 3GPP TS 36.104 v10.0.0 "Base Station (BS) radio transmission and reception", December 2010.

LTE Workspaces

VTB workspaces are provided to analyze LTE transmitter and receiver characteristics for both user equipment and base station according to [1] and [2], respectively

UE Tx

User Equipment Transmitter characteristics according to section 6 of [1]

- 3GPP_LTE_UE_Tx
- 3GPP_LTE_UE_Tx_Source

UE Rx

User Equipment Receiver characteristics according to section 6 of [1]

- 3GPP_LTE_UE_ReferenceSensitivity
- 3GPP_LTE_UE_AdjacentChannelSelectivity

BS Tx

Base Station Transmitter characteristics according to section 6 of [2]

- 3GPP_LTE_BS_Tx
- 3GPP_LTE_BS_Tx_Source

BS Rx

Base Station Receiver characteristics according to section 7 of [2]

- 3GPP_LTE_BS_ReferenceSensitivity
- 3GPP_LTE_BS_InChannelSelectivity
- 3GPP_LTE_BS_AdjacentChannelSelectivity

NOTE In the current implementation, there are only one input port and one output port in the SVE_Link model used in LTE workspaces, which means the DUT (design in ADS/GoldenGate environment) should only have one input and one output. In Tx examples, the DUT is connected to the modulator. In Rx examples, the DUT is connected before the demodulator in the Rx chain. Refer to the help document of each workspace for more information. in which you can find the detailed schematic.

How to set SVE_Link properties in LTE workspaces

Users can optionally define the ***SVE_Link*** properties by setting **DefineProperties** to YES. When **DefineProperties** is set to *YES*, parameters related to ***SVE_Link*** properties, including **InFeedbackLoop**, **SampleRate**, and **InputFcs**, can be defined by values or expressions.

- InFeedbackLoop: Specify whether the SVE_Link is in a feedback loop: NO, YES. In LTE Tx examples, e.g. 3GPP_LTE_BS_Tx, there is no feedback loop, hence **InFeedbackLoop** is set to *NO*. In LTE Rx examples, e.g. 3GPP_LTE_UE_ReferenceSensitivity, HARQ feedback could be enabled by setting parameter **UE1_HARQ_Enable** to *YES*, hence, **InFeedbackLoop** is set to *UE1_HARQ_Enable*.
- SampleRate: Sample rate of the signal. In LTE examples, in the *Equations* tab of the design, **SamplingRate** of the LTE system is calculated from **Bandwidth** and **OversamplingOption**. Hence, **SampleRate** is directly set to **SamplingRate**. The base sample rate of 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz and 20MHz LTE systems are 1.92MHz, 3.84 MHz, 7.68 MHz, 15.36 MHz, 23.04 MHz and 30.72 MHz, respectively.
- InputFcs: Array of characterization frequencies of input envelope signals. In current LTE examples, there is only one input port in **SVE_Link** model, hence, **InputFcs** is set to **[FCarrier_In]**.

Otherwise, when **DefineProperties** is set to *NO*, the VTB process will analyze the full design and provide such information to the integrating tool.

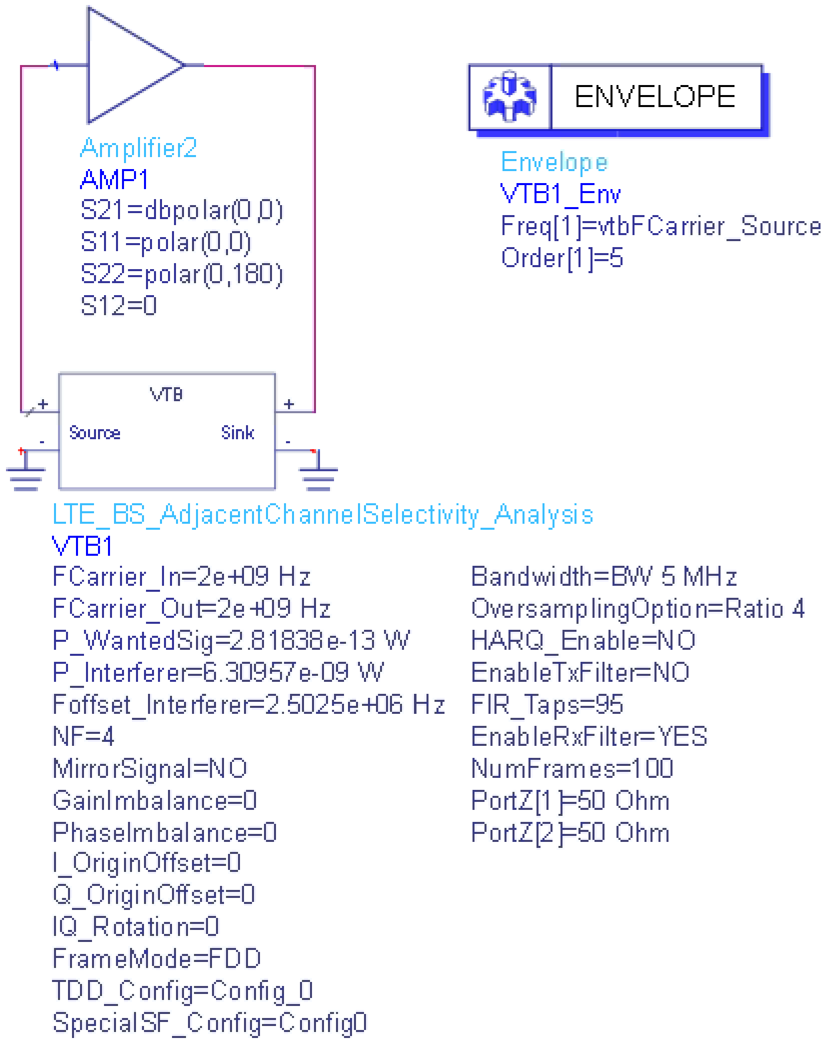
References

1. 3GPP TS 36.101 v9.3.0 "User Equipment (UE) radio transmission and reception", March 2010.
2. 3GPP TS 36.104 v9.3.0 "Base Station (BS) radio transmission and reception", March 2010.

LTE_BS_AdjacentChannelSelectivity_Analysis

This workspace provides a VTB test bench of Adjacent Channel Selectivity (ACS) of LTE BS receiver according to section 7.5 of 3GPP TS 36.104. Adjacent channel selectivity (ACS) is a measure of the receiver ability to receive a wanted signal at its assigned channel frequency in the presence of an adjacent channel signal with a specified center frequency offset of the interfering signal to the band edge of a victim system. The interfering signal shall be an E-UTRA signal as specified in Annex C of 3GPP TS 36.104.

A simple design in ADS to use this VTB is shown below.



The wanted and the interfering signal should be configured according to Table 7.5.1-3, Table 7.5.1-4 and Table 7.5.1-5 for Wide Area BS, Local Area BS and Home BS, respectively.

The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

An AddNDensity model with NDensity = -173.975dBm is used to introduce thermal noise for room temperature (T = 300K). The noise figure is set by parameter NF.

The wanted signal mean power is set by parameter **P_WantedSig**, while the interfering signal mean power is set by parameter **P_Interferer**.

The ideal low pass filter for spectrum shaping can be turned on/off by parameter **EnableTxFilter**. The number of taps can be set by **FIR_Taps**. If **EnableTxFilter** is set to NO, no spectrum shaping would be applied.

The interfering signal center frequency offset is set by parameter **Foffset_Interferer**. **Foffset_Interferer** ≤ 0 indicates the center frequency of the interferer is lower than the lower edge of the wanted signal, otherwise, the center frequency of the interferer is higher than the upper edge of the wanted signal.

The bandwidth of the interfering signal is determined by the bandwidth of the wanted signal according to Table 7.5.1-3 ~ Table 7.5.1-5, i.e. if **Bandwidth** of the wanted signal is smaller than 5MHz, the interfering signal would have the same bandwidth as the wanted signal, otherwise, the bandwidth of the interfering signal is 5MHz.

HARQ retransmission can be enabled by setting **HARQ_Enable** to YES. When HARQ retransmission is enabled, **EnableTxFilter** should be set to NO as ideal lowpass filter is not supported in HARQ retransmission in current SystemVue version. A number of HARQ processes is 8 for FDD and 7 for TDD. A maximum number of HARQ transmissions is set to 4. The redundancy version sequence is set to [0,1,2,3].

A *Parks-McClellan* bandpass filter centered at **FCarrier_Out** is used on the receiver side. The PassBandwidth is set to the transmission bandwidth of the wanted signal, and the StopBandwidth is set to the channel bandwidth. For example, if **Bandwidth** of wanted signal is 5MHz, then PassBandwidth = 4.5MHz, StopBandwidth = 5MHz. This filter could be disabled by setting parameter **EnableRxFilter** to NO.

By default, the reference measurement channels specified in Annexes A of 3GPP TS 36.104 are used. If you want to customize the test configuration, please open this workspace in SystemVue and set **UseFRC** to *NO* and set the payload configuration and RB allocation.

The number of simulated frames is set by parameter **NumFrames**.

Parameter Details

- P_WantedSig: Wanted signal mean power over 50ohm. Range: (-∞:+∞)
- P_Interferer: Interfering signal means power over 50ohm. Range: (-∞:+∞)
- FOffset_Interfer: The interfering signal center frequency offset. Foffset_Interferer<0 indicates the center frequency of the interferer is lower than the lower edge of the wanted signal, otherwise, the center frequency of the interferer is higher than the upper edge of the wanted signal. Range: (-**FCarrier_In**:+∞)
- EnableRxFilter: Whether to enable Rx bandpass filter or not
  For details on other parameters, refer to 3GPP_LTE_UE_Tx.

> **NOTE** When HARQ is turned on, the dynamic range used for fast circuit envelope extraction (in ADS and GoldenGate) might not be exactly the same as the actual dynamic range during VTB simulation

Simulation Results

Try to change the parameters, run LTE_BS_AdjacentChannelSelectivity_Analysis and check the simulation results in table ***ThroughputFraction*** to see whether the throughput meets the requirements. The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels.

NOTE If ***ThroughputFraction*** > 95%, ***PassFailFlag*** is set to true(1), otherwise, it is set to false(0).

The following table would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

L1_ThroughputFraction_Index	L1_ThroughputFraction
0	99.800

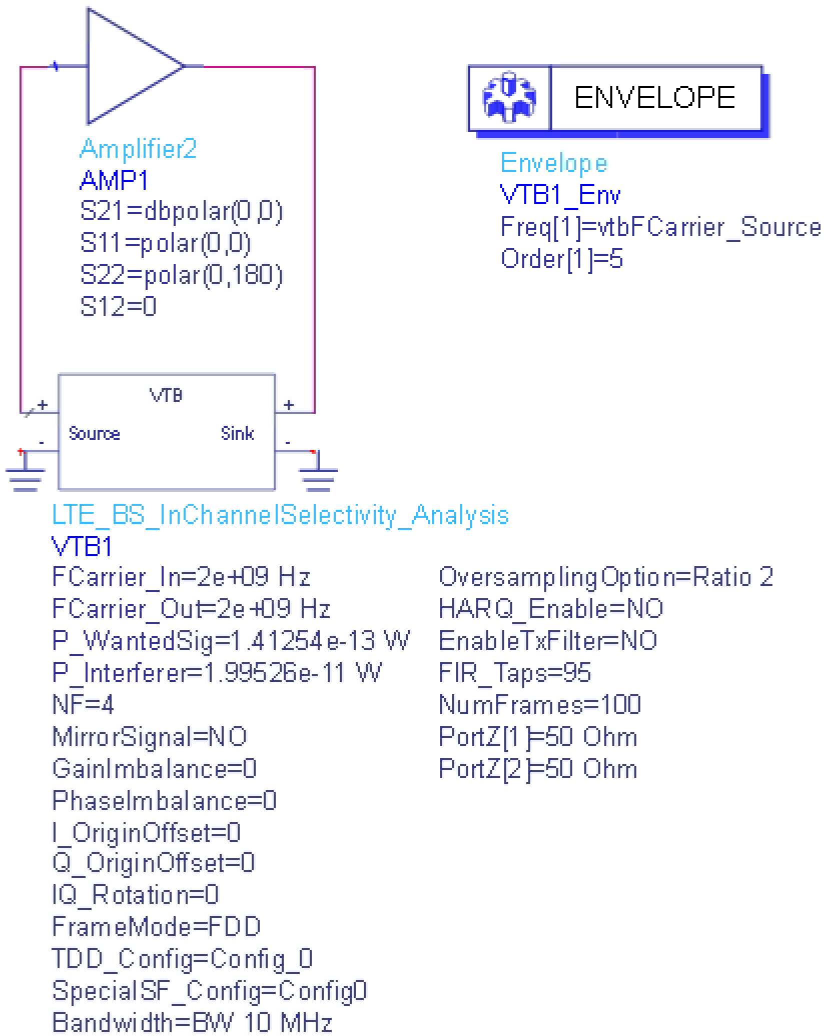
Reference

1. 3GPP TS 36.104 v9.3.0 "Base Station (BS) radio transmission and reception", March 2010.

LTE_BS_InChannelSelectivity_Analysis

This workspace provides a VTB test bench of In-Channel Selectivity (ICS) of LTE BS receiver according to section 7.4 of 3GPP TS 36.104. In-channel selectivity (ICS) is a measure of the receiver ability to receive a wanted signal at its assigned resource block locations in the presence of an interfering signal received at a larger power spectral density. In this condition, a throughput requirement shall be met for a specified reference measurement channel. The interfering signal shall be an E-UTRA signal as specified in Annex C and shall be time aligned with the wanted signal.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

An AddNDensity model with NDensity = -173.975dBm is used to introduce thermal noise for room temperature (T = 300K). The noise figure is set by parameter NF.

The wanted signal mean power is set by parameter **P_WantedSig**, while the interfering signal mean power is set by parameter **P_Interferer**.

Wanted and interfering signal is placed adjacently around Fc. The type of the interfering signal is determined by the bandwidth of the wanted signal according to Table 7.4.1-1 ~ Table 7.4.1-3. The RB allocation of wanted signal and interfering signal are set as follows.

Wanted Signal Bandwidth (MHz)	Wanted Signal RB Allocation [Start RB, NumRBs]	Interfering Signal Bandwidth (MHz)	Interfering Signal RB Allocation [Start RB, NumRBs]
1.4	[0,3]	1.4	[3,3]
3	[0,9]	3	[9,6]
5	[0,15]	5	[15,10]
10	[0,25]	10	[25,25]
15	[23,25]	15	[38,25]
20	[25,25]	20	[50,25]

The ideal low pass filter for spectrum shaping can be turned on/off by parameter **EnableTxFilter**. The number of taps can be set by **FIR_Taps**. If **EnableTxFilter** is set to NO, no spectrum shaping would be applied.

HARQ retransmission can be enabled by setting **HARQ_Enable** to YES. When HARQ retransmission is enabled, **EnableTxFilter** should be set to NO as ideal lowpass filter is not supported in HARQ retransmission in current SystemVue version. A number of HARQ processes is 8 for FDD and 7 for TDD. A maximum number of HARQ transmissions is set to 4. The redundancy version sequence is set to [0,1,2,3].

By default, the reference measurement channels specified in Annexes A of 3GPP TS 36.104 are used. If you want to customize the test configuration, please open this workspace in SystemVue and set **UseFRC** to *NO* and set the payload configuration and RB allocation.

The number of simulated frames is set by parameter **NumFrames**.

Parameter Details

1. RF Parameters
   - P_WantedSig: Wanted signal mean power over 50ohm. Range: (-∞:+∞)
   - P_Interferer: Interfering signal mean power over 50ohm. Range: (-∞:+∞)
2. Advanced Parameters

NOTE The following parameters are not exposed in ADS/GoldenGate environment. The default values of these parameters will be used in the simulation. To change them, please open the workspace in SystemVue, go to the Parameters tab of the design and change the Default Value there. To expose them to ADS/GoldenGate environment, please also open the workspace in SystemVue, go to Parameters tab and change the Hide Condition to false or simply delete the Hide Condition.

- WantedSig_StartRB: First RB of the wanted signal
- WantedSig_NumRBs: Number of RBs allocated to wanted signal
- Interferer_StartRB: First RB of the interfering signal
- Interferer_NumRBs: Number of RBs allocated in interfering signal
  For details on other parameters, please refer to 3GPP_LTE_UE_Tx and 3GPP_LTE_BS_ReferenceSensitivity.

NOTE When HARQ is turned on, the dynamic range used for fast circuit envelope extraction (in ADS and GoldenGate) might not be exactly the same as the actual dynamic range during VTB simulation

Simulation Results

Try to change the parameters, run LTE_BS_InChannelSelectivity_Analysis and check the simulation results in table *ThroughputFraction* to see whether the throughput meets the requirements. The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels.

NOTE If *ThroughputFraction* > 95%, *PassFailFlag* is set to true(1), otherwise, it is set to false(0).

The following table would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

L1_ThroughputFraction_Index	L1_ThroughputFraction
0	100.000

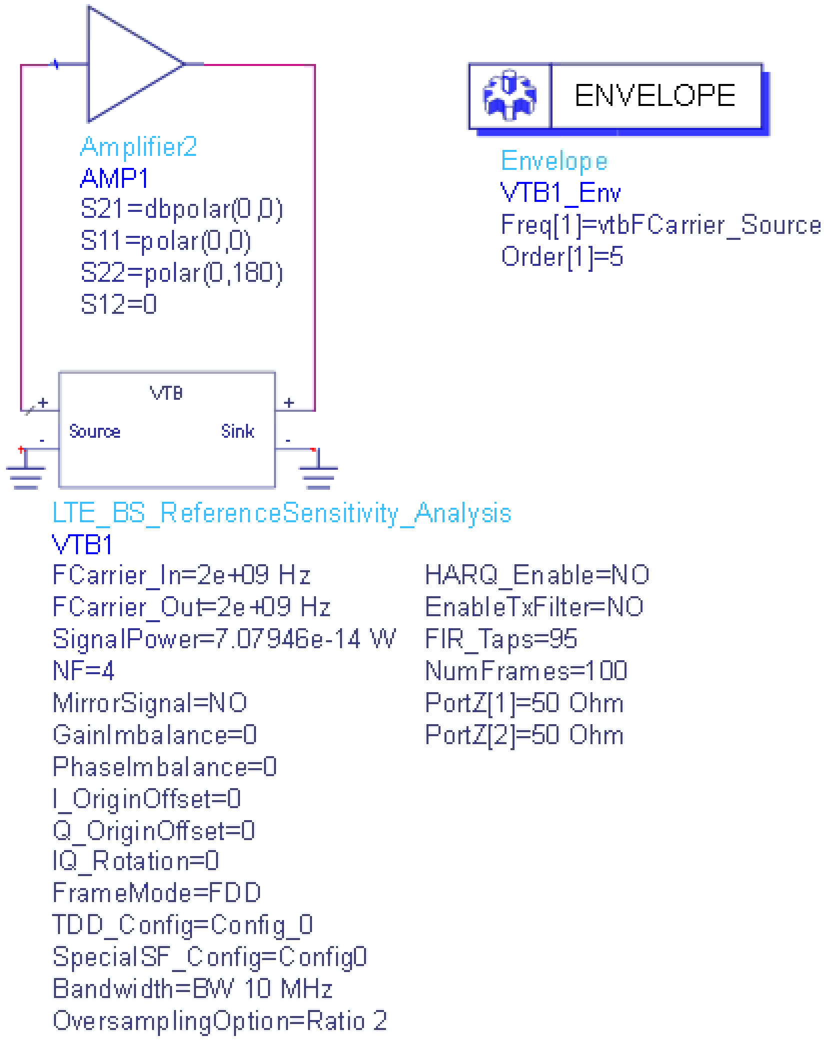
Reference

1. 3GPP TS 36.104 v9.3.0 "Base Station (BS) radio transmission and reception", March 2010.

LTE_BS_ReferenceSensitivity_Analysis

This workspace provides a VTB test bench of reference sensitivity power level of LTE base station receiver according to section 7.2 of [1]. The reference sensitivity power level PREFSENS is the minimum mean power received at the antenna connector at which a throughput requirement shall be met for a specified reference measurement channel.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

An AddNDensity model with NDensity = -173.975dBm is used to introduce thermal noise for room temperature (T = 300K). The noise figure is set by parameter NF.

The transmitted signal mean power is set by **SignalPower**.

The ideal low pass filter for spectrum shaping can be turned on/off by parameter **EnableTxFilter**. The number of taps can be set by **FIR_Taps**. If **EnableTxFilter** is set to NO, no spectrum shaping would be applied.

HARQ retransmission can be enabled by setting **UE1_HARQ_Enable** to YES. When HARQ retransmission is enabled, **EnableTxFilter** should be set to NO as ideal lowpass filter is not supported in HARQ retransmission in current SystemVue version. A number of HARQ processes is 8 for FDD and 7 for TDD. A maximum number of HARQ transmissions is set to 4. The redundancy version sequence is set to [0,1,2,3].

By default, the reference measurement channels specified in Annexes A of 3GPP TS 36.104 are used. If you want to customize the test configuration, please open this workspace in SystemVue and set **UseFRC** to *NO* and set the payload configuration and RB allocation.

The number of simulated frames is set by parameter **NumFrames**.

Parameter Details

- UseFRC: Whether use FRC (fixed reference measurement channels) as defined in the specification or not. The default value is set to *YES*.
- Payload_Config: Payload configuration type. It indicates the meaning of **Payload** as 0 for MCS index, 1 for Transport block size, 2 for Code rate. The default value is set to *Code rate*. Active only when **UseFRC** is set to *NO*
- Payload: Specify the payload of each frame according to the selection of **Payload_Config**. The default value is set to *1/3* (code rate). Active only when **UseFRC** is set to *NO*
  For details on other parameters, please refer to LTE Parameters.

NOTE When HARQ is turned on, the dynamic range used for fast circuit envelope extraction (in ADS and GoldenGate) might not be exactly the same as the actual dynamic range during VTB simulation

Simulation Results

Try to change the parameters, run LTE_BS_ReferenceSensitivity_Analysis and check the simulation results in table ***ThroughputFraction*** to see whether the throughput meets the requirements. The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in Annexes A of 3GPP TS 36.104.

NOTE If ***ThroughputFraction*** > 95%, ***PassFailFlag*** is set to true(1), otherwise, it is set to false(0).

The following table would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

ADS

L1_ThroughputFraction_Index	L1_ThroughputFraction
0	97.400

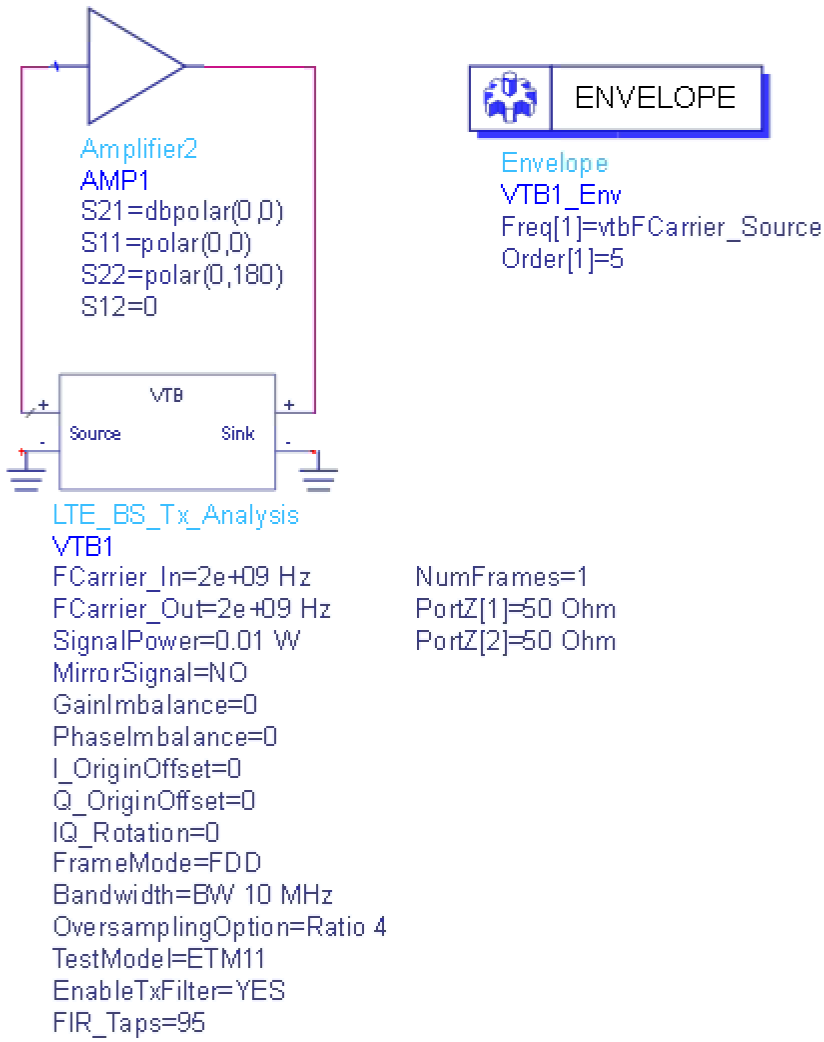
Reference

1. 3GPP TS 36.104 v9.3.0 "Base Station (BS) radio transmission and reception", March 2010.

LTE_BS_Tx_Analysis

This workspace provides a VTB test bench for measuring base station transmitter characteristics including spectrum, waveform, CCDF, EVM and ACLR according to [1].

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

E-UTRA Test Models are provided in this workspace according to [2] for both FDD and TDD. You can select **TestModel** and **Bandwidth** to configure different ETMs.

The transmitted signal mean power is set by **SignalPower**. **SignalPower** specifies the mean power of the transmitted signal when all RBs (resource blocks) are allocated.

The ideal low pass filter for spectrum shaping can be turned on/off by parameter **EnableTxFilter**. The number of taps can be set by **FIR_Taps**. If **EnableTxFilter** is set to NO, no spectrum shaping would be applied.

The number of simulated frames for EVM measurements is set by parameter **NumFrames**.

Parameter Details

1. RF Parameters
   - FCarrier_In: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+∞)
   - FCarrier_Out: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+∞)
   - SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
   - MirrorSignal: Mirror signal about carrier
   - GainImbalance: Gain imbalance in dB. Range: (-∞:+∞)
   - PhaseImbalance: Phase imbalance. Range: (-∞:+∞)
   - I_OriginOffset: I origin offset. Range: (-∞:+∞)
   - Q_OriginOffset: Q origin offset. Range: (-∞:+∞)
   - IQ_Rotation: IQ rotation. Range: (-∞:+∞)
2. LTE Parameters
   - FrameMode: frame mode of LTE, the type is enum and it can be selected as FDD and TDD. FDD supports frame structure typ1 and TDD supports frame structure type 2
   - Bandwidth: bandwidth of LTE, the type is enum and it can be selected as BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz and BW 20 MHz
   - OversamplingOption: Over-sampling ratio option. Oversampling ratio 1, ratio 2, ratio 4 and ratio 8 are supported in this downlink source
   - TestModel: E-UTRA test model type, can be selected from ETM 1.1, ETM 1.2, ETM2, ETM 3.1, ETM 3.2 and ETM 3.3
   - EnableTxFilter: Whether enable the Tx spectrum shaping filter (an ideal low pass FIR filter) or not
   - FIR_Taps: Number of taps of the ideal low pass filter. Range: [1:1000]

- NumFrames: Number of frames for EVM measurement. Range: [1:+∞)

3. Advanced Parameters

> **NOTE** The following parameters are not exposed in ADS/GoldenGate environment. The default values of these parameters will be used in the simulation. To change them, please open the workspace in SystemVue, go to the *Parameters* tab of the design and change the *Default Value* there. To expose them to ADS/GoldenGate environment, please also open the workspace in SystemVue, go to *Parameters* tab and change the *Hide Condition* to *false* or simply delete the *Hide Condition*.

- UseTestModel: Whether user E-TM or not. The default value is set to *YES*. If you want to customize the generated signal other than using the pre-defined test models, please set this parameter to *NO*. The following parameters are only active when **UseTestModel** is set to *NO*
- TDD_Config: Downlink and uplink allocations for TDD. The default value is set to *Config 0*. Active, only when **FrameMode** is set to TDD and UseTestModel, is set to *NO*
- SpecialSF_Config: Special subframe configurations for TDD. The default value is set to *Config 4*. Active, only when **FrameMode** is set to TDD and UseTestModel, is set to *NO*
- FullRB_Alloc: Whether allocates all RBs or not. The default value is set to *YES*, i.e. all RBs will be occupied no matter which **Bandwidth** is selected. If it is set to *NO*, the RB allocation will be determined by **StartRB** and **NumRBs**. RB allocation will be kept the same in all downlink subframes. Active only when **UseTestModel** is set to *NO*
- StartRB: The first RB to be allocated. The default value is set to *0*. Active only when **FullRB_Alloc** is set to *NO* and **UseTestModel** is set to *NO*. Range: [0:*NumTotalRBs*], where *NumTotalRBs* is the total number of RBs and is different for each **Bandwidth**.
- NumRBs: Number of RBs to be allocated. The default value is set to *25* . Active only when **FullRB_Alloc** is set to *NO* and **UseTestModel** is set to *NO*. Range: [0:*NumTotalRBs*]. In addition, the RB allocation specified by **StartRB** and **NumRBs** should not be out of the range determined by **Bandwidth**.
- UE1_MappingType: The modulation orders, for which 0 for QPSK, 1 for 16QAM, 2 for 64QAM. The default value is set to *0*. Active only when **UseTestModel** is set to *NO*. Range: [0:2]
- PDCCH_SymsPerSF: Number of OFDM symbols for PDCCH. The default value is set to *0*. Active only when **UseTestModel** is set to *NO*. Range: [0:4]

Simulation Results

Try to change the parameters, run LTE_BS_Tx_Analysis and check the simulation results.

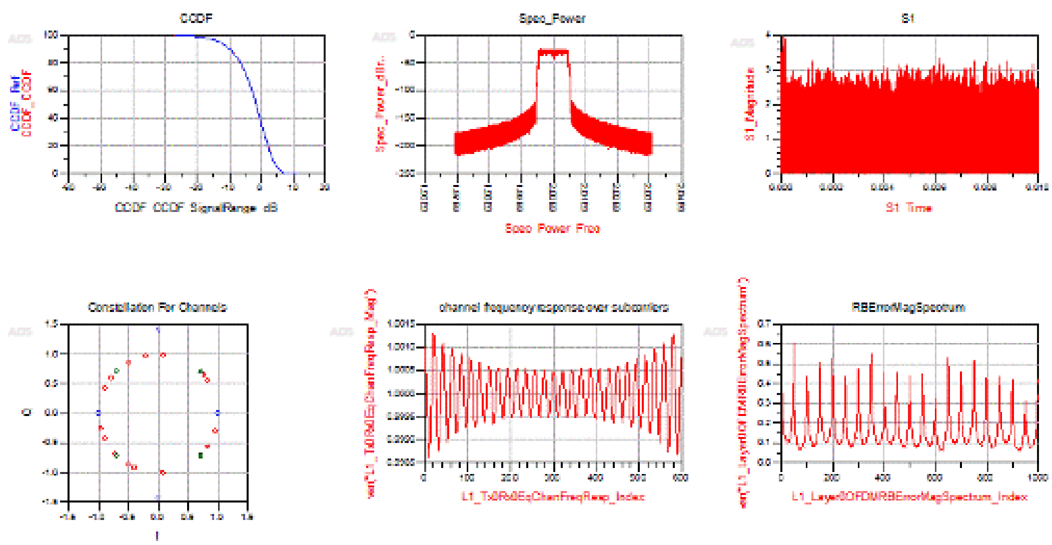
- Table *ACLR* shows Adjacent Channel Leakage power Ratio as defined in section 6.6.2 of 3GPP TS 36.104
- Graph *CCDF* shows the Complementary Cumulative Distribution Function of the transmitted signal
- Graph *Constellation* shows the constellation of each physical channel and signal
- Table *ErrorSummary* shows average EVM, peak EVM, frequency errors and other measured results of each frame got from EVM model
- Table *EVM* lists EVM of each physical channel and signal according to section 6.5 of 3GPP TS 36.104
- Graph *NormalizedEqualizerChannelFrequencyResponse* shows the normalized equalizer channel frequency response got from EVM model
- Graph *RBErrorMagSpectrum* shows the error magnitude spectrum of each RB got from EVM model
- Graph *Spectrum* shows the spectrum of the transmitted signal
- Graph *Waveform* shows the transmitted time domain waveform

NOTE EVM is reported in % in this example, i.e. if the result is displayed as 0.187, it means EVM = 0.187%.
If EVM on PDSCH (for different modulation schemes) is better than the limits below [1], then *EVM_PassFailFlag* is set to true(1), otherwise, it is set to false(0).

Modulation scheme for PDSCH	Required EVM [%]
QPSK	17.5 %
16QAM	12.5 %
64QAM	8 %

If ACLR > 45dB, then *ACLR_PassFailFlag* is set to true(1), otherwise, it is set to false(0).

The following graphs would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation. The DUT is shorted to get the following ideal results. The same results will be displayed in SystemVue environment if the **SVE_Link** model is disabled to short.



..Frame	L1_EVM	..Frame	..VMPk	..Frame	..PkIdx	..Frame	..rPkIdx	..Frame	..reqErr	..Frame	..SEVM	..Frame	..Power	..Frame	..ncCorr
0	-54.542	0	-38.288	0	2	0	0	0	4.566...	0	-55.150	0	-17.779	0	1.000
1	-54.517	1	-38.283	1	2	1	0	1	4.583...	1	-55.128	1	-17.779	1	1.000
2	-54.517	2	-38.288	2	2	2	0	2	2.880...	2	-55.152	2	-17.779	2	1.000
3	-54.506	3	-38.282	3	2	3	0	3	3.583...	3	-55.132	3	-17.779	3	1.000
4	-54.542	4	-38.288	4	2	4	0	4	4.566...	4	-55.150	4	-17.779	4	1.000

..._Frame	..SSEVM	..._Frame	..SSEVM	..._Frame	..CHEVM	..._Frame	..ICHEVM	..._Frame	..ICHEVM	..._Frame	..CHEVM	..._Frame	..CHEVM
0	-62.103	0	-60.028	0	-62.272	0	-52.704	0	-53.066	0	-55.506	0	-54.443
1	-62.117	1	-60.029	1	-62.262	1	-52.703	1	-53.066	1	-55.506	1	-54.416
2	-62.484	2	-60.028	2	-62.316	2	-52.704	2	-53.066	2	-55.506	2	-54.416
3	-61.947	3	-60.029	3	-62.146	3	-52.703	3	-53.066	3	-55.506	3	-54.405
4	-62.103	4	-60.028	4	-62.272	4	-52.704	4	-53.066	4	-55.506	4	-54.443

ACLR_Lower1	ACLR_Lower2	ACLR_Upper1	ACLR_Upper2
105.464	138.180	105.092	138.051

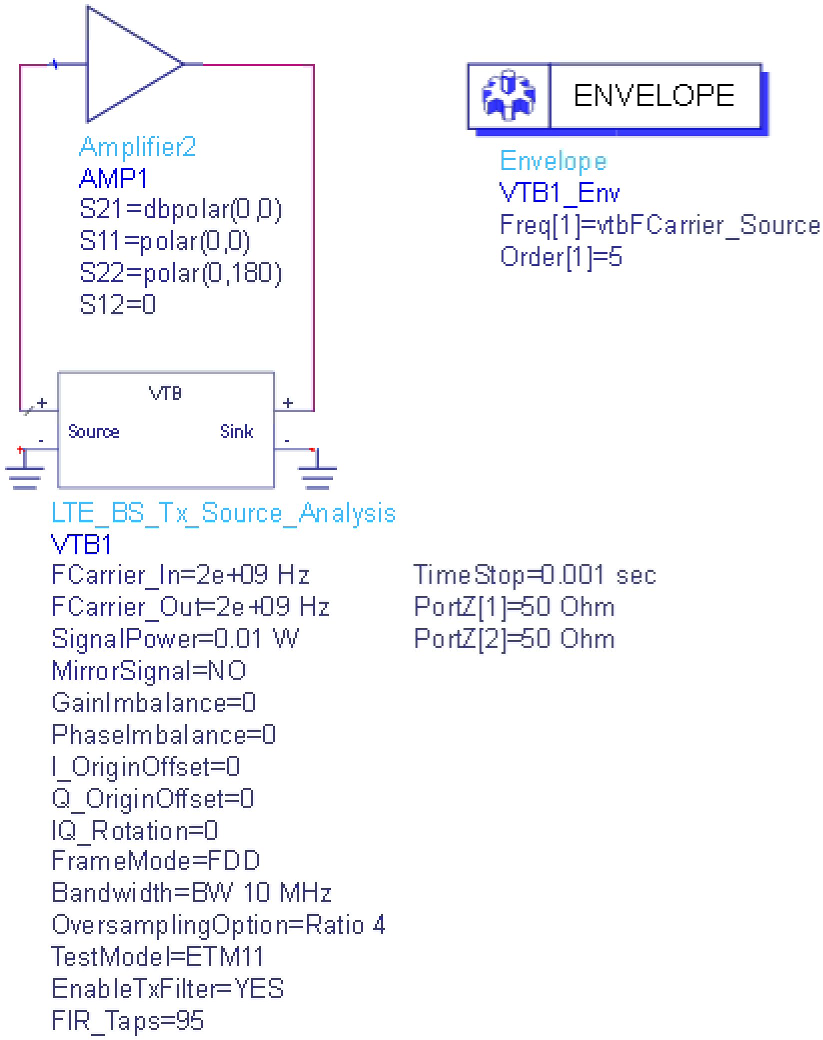
Reference

1. 3GPP TS 36.104 v9.3.0 "Base Station (BS) radio transmission and reception", March 2010.
2. 3GPP TS 36.141 v8.5.0 "Base Station (BS) conformance testing", December 2009.
3. 3GPP TS 36.211 v9.1.0, "Physical Channels and Modulation", March 2010.
4. 3GPP TS 36.213 v8.8.0, "Physical Layer Procedures", September 2009.

LTE_BS_Tx_Source_Analysis

This workspace provides a VTB test bench to generate the LTE downlink signal.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

E-UTRA Test Models are provided in this workspace according to [2] for both FDD and TDD. You can select **TestModel** and **Bandwidth** to configure different ETMs.

The transmitted signal mean power is set by **SignalPower**. **SignalPower** specifies the mean power of the transmitted signal when all RBs (resource blocks) are allocated.

The ideal low pass filter for spectrum shaping can be turned on/off by parameter **EnableTxFilter**. The number of taps can be set by **FIR_Taps**. If **EnableTxFilter** is set to NO, no spectrum shaping would be applied.

A sink is used to save the generate signal from 0 to **TimeStop**.

Parameter Details

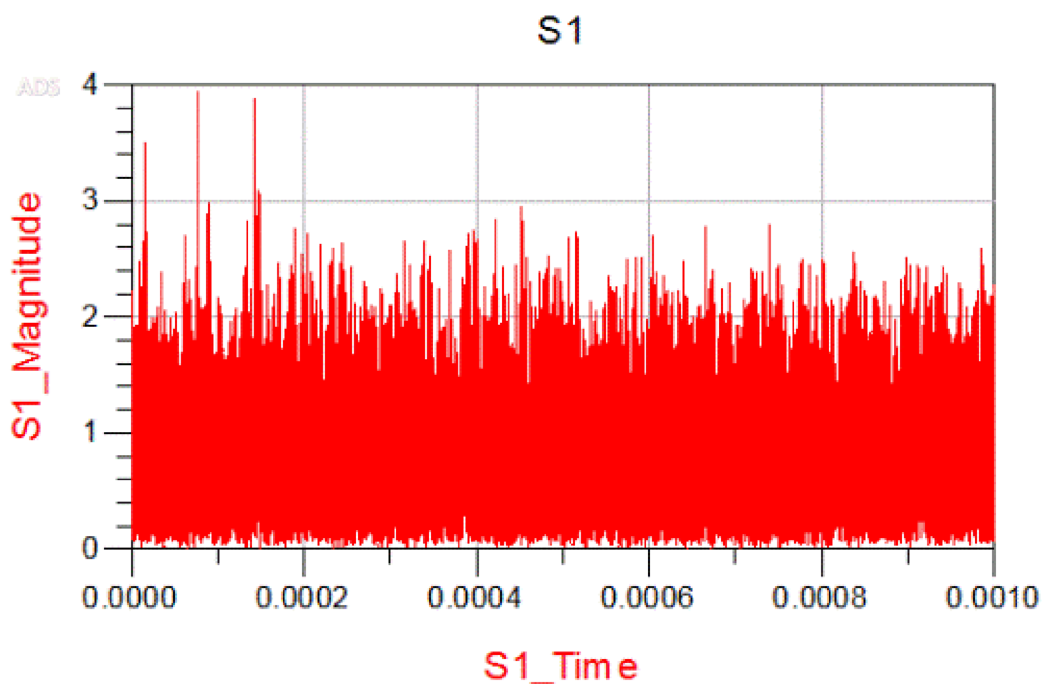
- TimeStop: Stop time of data collection. Range: (0:+∞)
  For details on other parameters, please refer to 3GPP_LTE_BS_Tx.

Simulation Results

Try to change the parameters, run *LTE_BS_Tx_Source_Analysis* and check the simulation results.

- Graph ***Waveform*** shows the transmitted time domain waveform

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



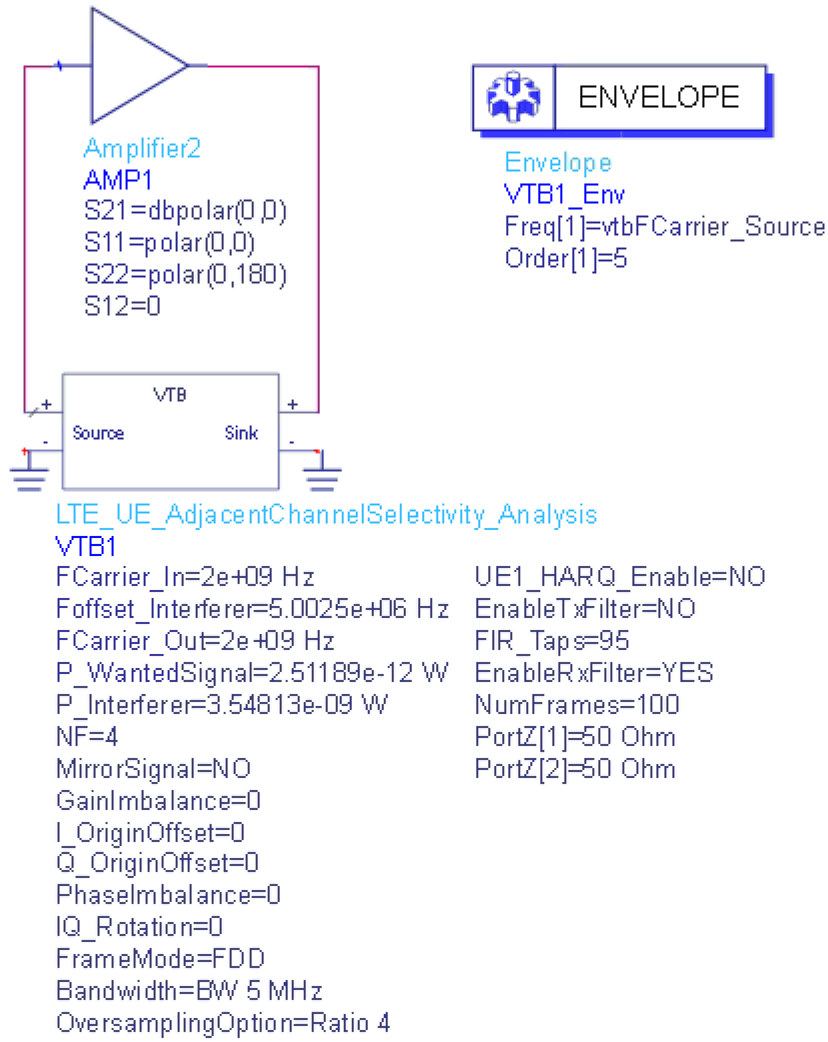
Reference

1. 3GPP TS 36.104 v9.3.0 "Base Station (BS) radio transmission and reception", March 2010.
2. 3GPP TS 36.141 v8.5.0 "Base Station (BS) conformance testing", December 2009.
3. 3GPP TS 36.211 v9.1.0, "Physical Channels and Modulation", March 2010.
4. 3GPP TS 36.213 v8.8.0, "Physical Layer Procedures", September 2009.

LTE_UE_AdjacentChannelSelectivity_Analysis

This workspace provides a VTB test bench of Adjacent Channel Selectivity (ACS) of LTE user equipment receiver according to section 7.5 of [1]. Adjacent Channel Selectivity (ACS) is a measure of a receiver's ability to receive a E-UTRA signal at its assigned channel frequency in the presence of an adjacent channel signal at a given frequency offset from the centre frequency of the assigned channel. ACS is the ratio of the receive filter attenuation on the assigned channel frequency to the receive filter attenuation on the adjacent channel(s).

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

An AddNDensity model with NDensity = -173.975dBm is used to introduce thermal noise for room temperature (T = 300K). The noise figure is set by parameter NF.

The wanted signal mean power is set by parameter **P_WantedSig**, while the interfering signal mean power is set by parameter **P_Interferer**. **P_WantedSig** and **P_Interferer** specify the mean power of the wanted signal and interfering signal when all RBs (resource blocks) are allocated.

The ideal low pass filter for spectrum shaping can be turned on/off by parameter **EnableTxFilter**. The number of taps can be set by **FIR_Taps**. If **EnableTxFilter** is set to NO, no spectrum shaping would be applied.

The interfering signal center frequency offset is set by parameter **Foffset_Interferer**. **Foffset_Interferer** ≤ 0 indicates the center frequency of the interferer is lower than center frequency of the wanted signal by **Foffset_Interferer**, otherwise, the center frequency of the interferer is higher than the center frequency of the wanted signal by Foffset_Interferer. **FCarrier_Interferer** = **FCarrier_Tx** + **Foffset_Interferer**.

The bandwidth of the interfering signal is determined by the bandwidth of the wanted signal according to Table 7.5.1-2 ~ Table 7.5.1-3 of [1], i.e. if **Bandwidth** of the wanted signal is smaller than 5MHz, the interfering signal would have same bandwidth as the wanted signal, otherwise, the bandwidth of the interfering signal is 5MHz.

HARQ retransmission can be enabled by setting **UE1_HARQ_Enable** to YES. When HARQ retransmission is enabled, **EnableTxFilter** should be set to NO as ideal lowpass filter is not supported in HARQ retransmission in current SystemVue version. Number of HARQ processes is 8 for FDD and 7 for TDD. Maximum number of HARQ transmissions is set to 4. The redundancy version sequence is set to [0,1,2,3].

A *Parks-McClellan* bandpass filter centered at **FCarrier_Out** is used in the receiver side. The PassBandwidth is set to the transmission bandwidth of the wanted signal, and the StopBandwidth is set to the channel bandwidth. For example, if **Bandwidth** of wanted signal is 5MHz, then PassBandwidth = 4.5MHz, StopBandwidth = 5MHz. This filter could be disabled by setting parameter **EnableRxFilter** to NO.

By default, the reference measurement channels specified in Annexes A of 3GPP TS 36.104 are used. If you want to customized the test configuration, please open this workspace in SystemVue and set **UseFRC** to *NO* and set the payload configuration and RB allocation.

The number of simulated frames is set by parameter **NumFrames**.

Parameter Details

- P_WantedSig: Wanted signal mean power over 50 ohm. Range: (-∞:+∞)
- P_Interferer: Interfering signal mean power over 50 ohm. Range: (-∞:+∞)
- FOffset_Interfer: The interfering signal center frequency offset. Range: (-**FCarrier_In**:+∞)
- EnableRxFilter: Whether enable Rx bandpass filter or not
  For details on other parameters, please refer to 3GPP_LTE_BS_Tx and 3GPP_LTE_UE_ReferenceSensitivity.

NOTE

When HARQ is turned on, the dynamic range used for fast circuit envelope extraction (in ADS and GoldenGate) might not be exactly the same as the actual dynamic range during VTB simulation

Simulation Results

Try to change the parameters, run *LTE_UE_AdjacentChannelSelectivity_Analysis* and check the simulation results in table ***ThroughputFraction*** to see whether the throughput meets the requirements. The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in Annexes A.2.2, A.2.3 and A.3.2 of [1].

NOTE If ***ThroughputFraction*** > 95%, ***PassFailFlag*** is set to true(1), otherwise, it is set to false(0).

The following table would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

L1_ThroughputFraction_Index	L1_ThroughputFraction
0	100.000

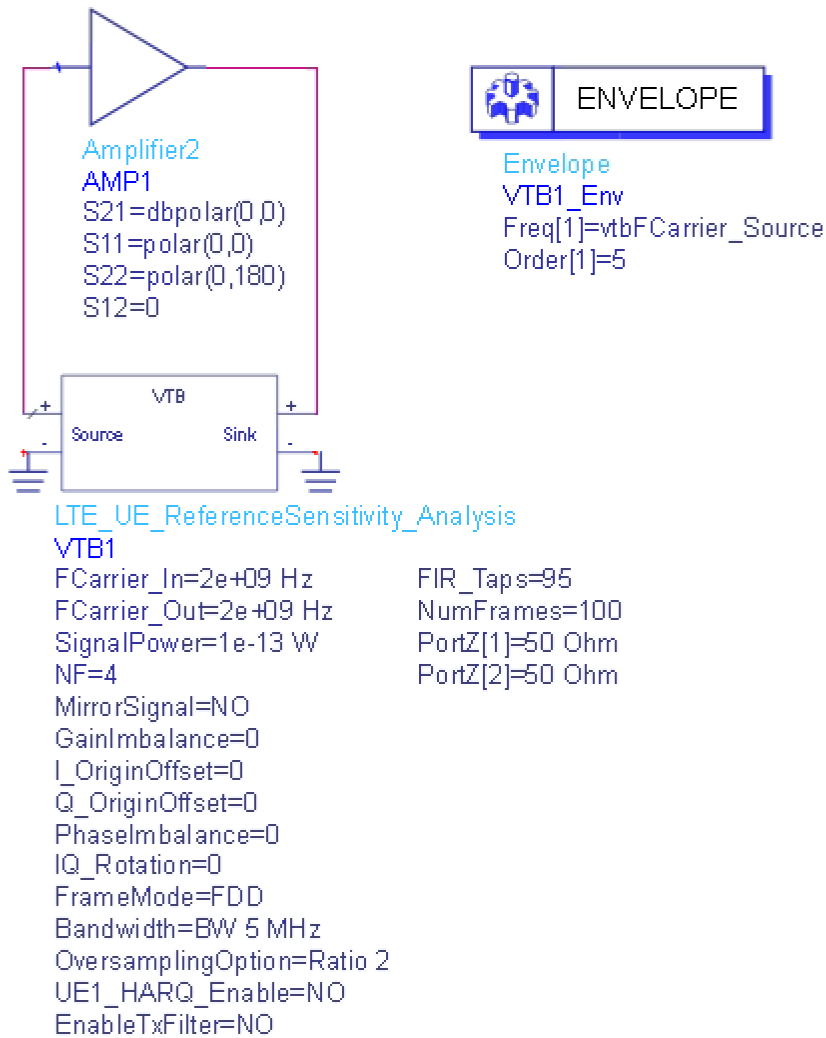
Reference

1. 3GPP TS 36.101 v9.3.0 "User Equipment (UE) radio transmission and reception", March 2010.

LTE_UE_ReferenceSensitivity_Analysis

This workspace provides a VTB test bench of reference sensitivity power level of LTE UE receiver according to section 7.3 of 3GPP TS 36.101. The reference sensitivity power level REFSENS is the minimum mean power applied to both the UE antenna ports at which the throughput shall meet or exceed the requirements for the specified reference measurement channel.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

An AddNDensity model with NDensity = -173.975dBm is used to introduce thermal noise for room temperature (T = 300K). The noise figure is set by parameter NF.

The transmitted signal mean power is set by **SignalPower**. **SignalPower** specifies the mean power of the transmitted signal when all RBs (resource blocks) are allocated.

The ideal low pass filter for spectrum shaping can be turned on/off by parameter **EnableTxFilter**. The number of taps can be set by **FIR_Taps**. If **EnableTxFilter** is set to NO, no spectrum shaping would be applied.

HARQ retransmission can be enabled by setting **UE1_HARQ_Enable** to YES. When HARQ retransmission is enabled, **EnableTxFilter** should be set to NO as ideal lowpass filter is not supported in HARQ retransmission in current SystemVue version. Number of HARQ processes is 8 for FDD and 7 for TDD. Maximum number of HARQ transmissions is set to 4. The redundancy version sequence is set to [0,1,2,3].

By default, the reference measurement channels specified in Annexes A.3.2 of 3GPP TS 36.101 are used. If you want to customized the test configuration, please open this workspace in SystemVue and set **UseFRC** to *NO* and set the payload configuration and RB allocation.

The number of simulated frames is set by parameter **NumFrames**.

Parameter Details

1. RF Parameters
   - NF: Noise figure in receiver. Range: [0:+∞)
     For details on other parameters, please refer to RF Parameters.
2. LTE Parameters
   - HARQ_Enable: specify whether closed-loop HARQ transmission is enabled.

     NOTE When HARQ is turned on, the dynamic range used for fast circuit envelope extraction (in ADS and GoldenGate) might not be exactly the same as the actual dynamic range during VTB simulation

     For details on other parameters, please refer to LTE Parameters.
3. Advanced Parameters
   - UseFRC: Whether use FRC (fixed reference measurement channels) as defined in the specification or not. The default value is set to *YES*.
   - UE1_Config: Payload configuration type. It indicates the meaning of **Payload** as 0 for MCS index, 1 for Transport block size, 2 for Code rate. The default value is set to *Code rate*. Active only when **UseFRC** is set to *NO*
   - UE1_Payload: Specify the payload of each frame according to the selection of **Payload_Config**. The default value is set to *1/3* (code rate). Active only when **UseFRC** is set to *NO*
     For details on other parameters, please refer to Advanced Parameters.

Simulation Results

Try to change the parameters, run *3GPP_LTE_UE_ReferenceSensitivity_Analysis* and check the simulation results in table ***ThroughputFraction*** to see whether the throughput meets the requirements. The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in Annexes A.2.2, A.2.3 and A.3.2 of [1].

NOTE If ***ThroughputFraction*** > 95%, ***PassFailFlag*** is set to true(1), otherwise, it is set to false(0).

The following table would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

L1_ThroughputFraction_Index	L1_ThroughputFraction
0	100.000

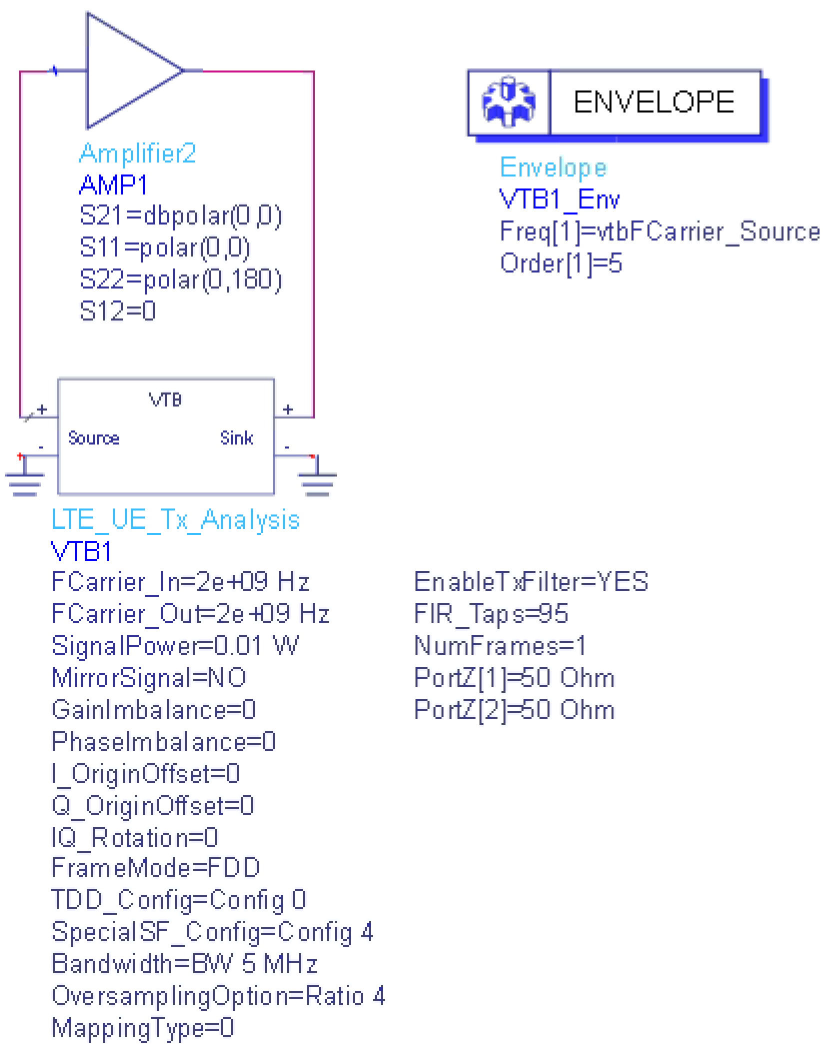
Reference

1. 3GPP TS 36.101 v9.3.0 "User Equipment (UE) radio transmission and reception", March 2010.

LTE_UE_Tx_Analysis

This workspace provides a VTB test bench to measure user equipment transmitter characteristics including spectrum, waveform, CCDF, EVM and ACLR according to [1].

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

The transmitted signal mean power is set by **SignalPower**.

The ideal low pass filter for spectrum shaping can be turned on/off by parameter **EnableTxFilter**. The number of taps can be set by **FIR_Taps**. If **EnableTxFilter** is set to NO, no spectrum shaping would be applied.

The number of simulated frames for EVM measurements is set by parameter **NumFrames**.

Parameter Details

- MappingType: The modulation orders, for which 0 for QPSK, 1 for 16QAM, 2 for 64QAM. Range: [0:2].
  For details on other parameters, please refer to 3GPP_LTE_BS_Tx.

Simulation Results

Try to change the parameters, run LTE_UE_Tx_Analysis and check the simulation results.

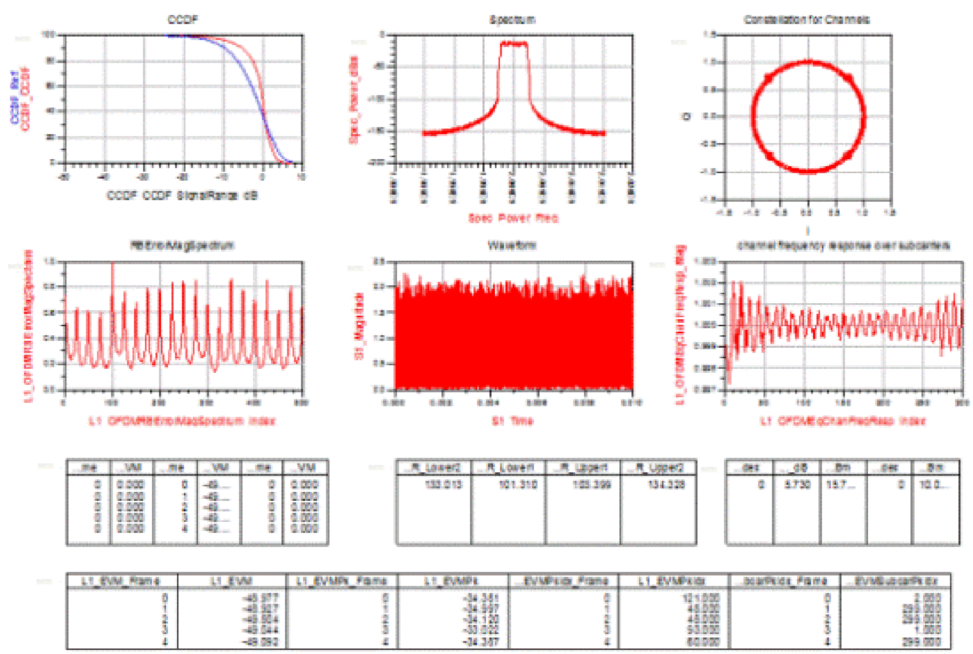
- Table ***ACLR*** shows Adjacent Channel Leakage power Ratio
- Graph ***CCDF*** shows the Complementary Cumulative Distribution Function of the transmitted signal
- Graph ***Constellation*** shows the constellation of each physical channel and signal
- Table ***ErrorSummary*** shows average EVM, peak EVM, frequency errors and other measured results of each frame
- Table ***EVM*** lists EVM of each physical channel and signal
- Graph ***NormalizedEqualizerChannelFrequencyResponse*** shows the normalized equalizer channel frequency response
- Graph ***RBErrorMagSpectrum*** shows the error magnitude spectrum of each RB got from EVM model
- Graph ***Spectrum*** shows the spectrum of the transmitted signal
- Graph ***Waveform*** shows the transmitted time domain waveform

> **NOTE** EVM is reported in % in this example, i.e. if the result is displayed as 0.187, it means EVM = 0.187%.
> If EVM (for different modulation schemes) is better than the limits below [1], then *EVM_PassFailFlag* is set to true(1), otherwise, it is set to false(0).

Modulation scheme for PDSCH	Required EVM [%]
QPSK	17.5 %
16QAM	12.5 %
64QAM	8 %

If ACLR > 45dB, then *ACLR_PassFailFlag* is set to true(1), otherwise, it is set to false(0).

The following graphs would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation. The DUT is shorted to get the following ideal results. The same results will be displayed in SystemVue environment if the **SVE_Link** model is disabled to short.



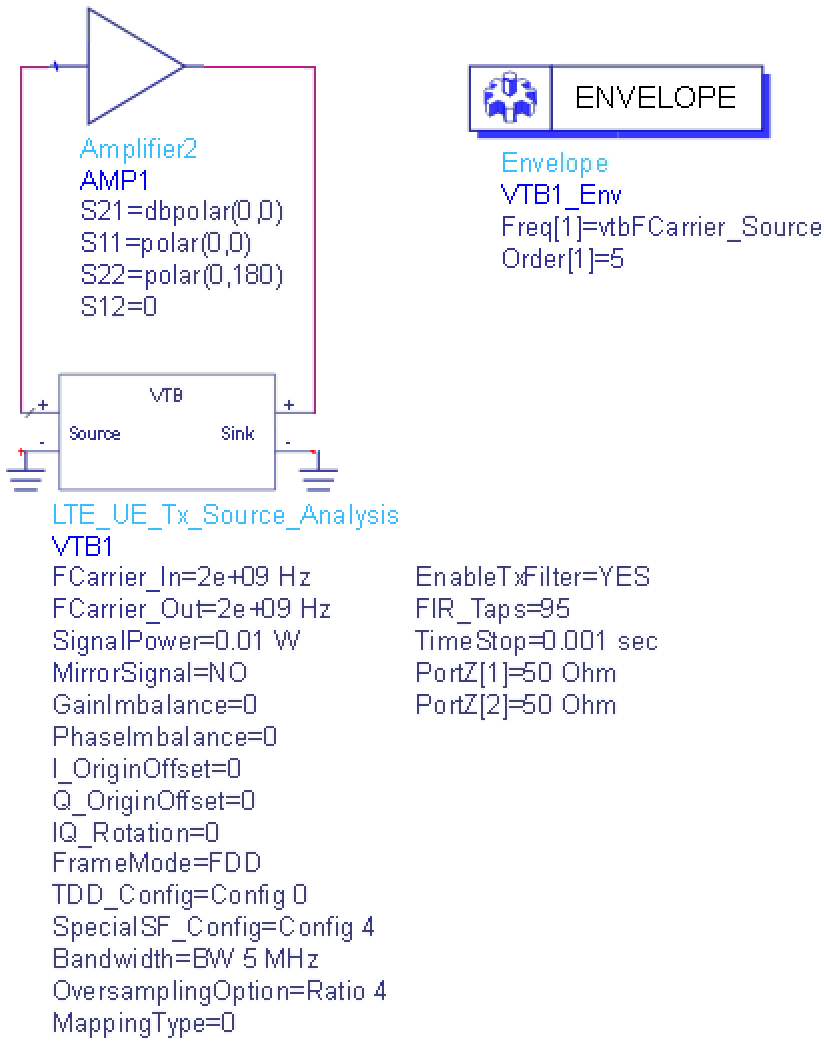
Reference

1. 3GPP TS 36.104 v9.3.0 "Base Station (BS) radio transmission and reception", March 2010.

LTE_UE_Tx_Source_Analysis

This workspace provides a VTB test bench to generate LTE uplink signal.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

The transmitted signal mean power is set by **SignalPower**.

The ideal low pass filter for spectrum shaping can be turned on/off by parameter **EnableTxFilter**. The number of taps can be set by **FIR_Taps**. If **EnableTxFilter** is set to NO, no spectrum shaping would be applied.

A sink is used to save the generated signal from 0 to **TimeStop**.

Parameter Details

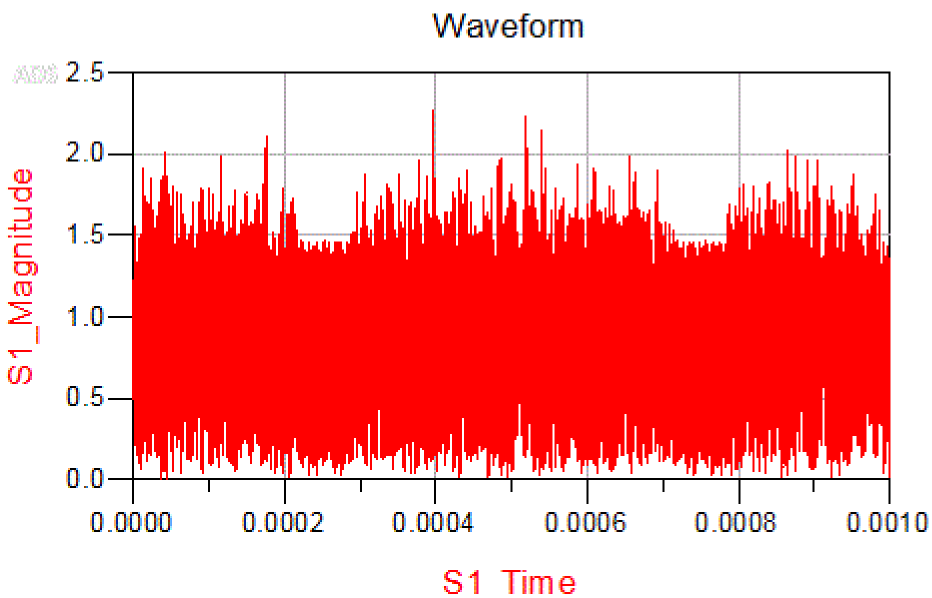
- TimeStop: Stop time of data collection. Range: (0:+∞)
  For details on other parameters, please refer to 3GPP_LTE_UE_Tx.

Simulation Results

Try to change the parameters, run *LTE_UE_Tx_Source_Analysis* and check the simulation results.

- Graph ***Waveform*** shows the transmitted time domain waveform

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



Reference

1. 3GPP TS 36.104 v9.3.0 "Base Station (BS) radio transmission and reception", March 2010.

NB IoT Workspaces

VTB workspaces are provided to analyze NB IoT transmitter characteristics for both user equipment and base station, respectively

UE Tx

- LTE_Advanced_NBIoT_DL_Tx

BS Tx

- LTE_Advanced_NBIoT_UL_Tx

NOTE In the current implementation, there are only one input port and one output port in the SVE_Link model used in NB IoT workspaces, which means the DUT (design in ADS/GoldenGate environment) should only have one input and one output. In the examples, the DUT is connected to the modulator.

How to set SVE_Link properties in NB IoT workspaces

Users can optionally define the ***SVE_Link*** properties by setting **DefineProperties** to YES. When **DefineProperties** is set to *YES*, parameters related to ***SVE_Link*** properties, including **InFeedbackLoop**, **SampleRate**, and **InputFcs**, can be defined by values or expressions.

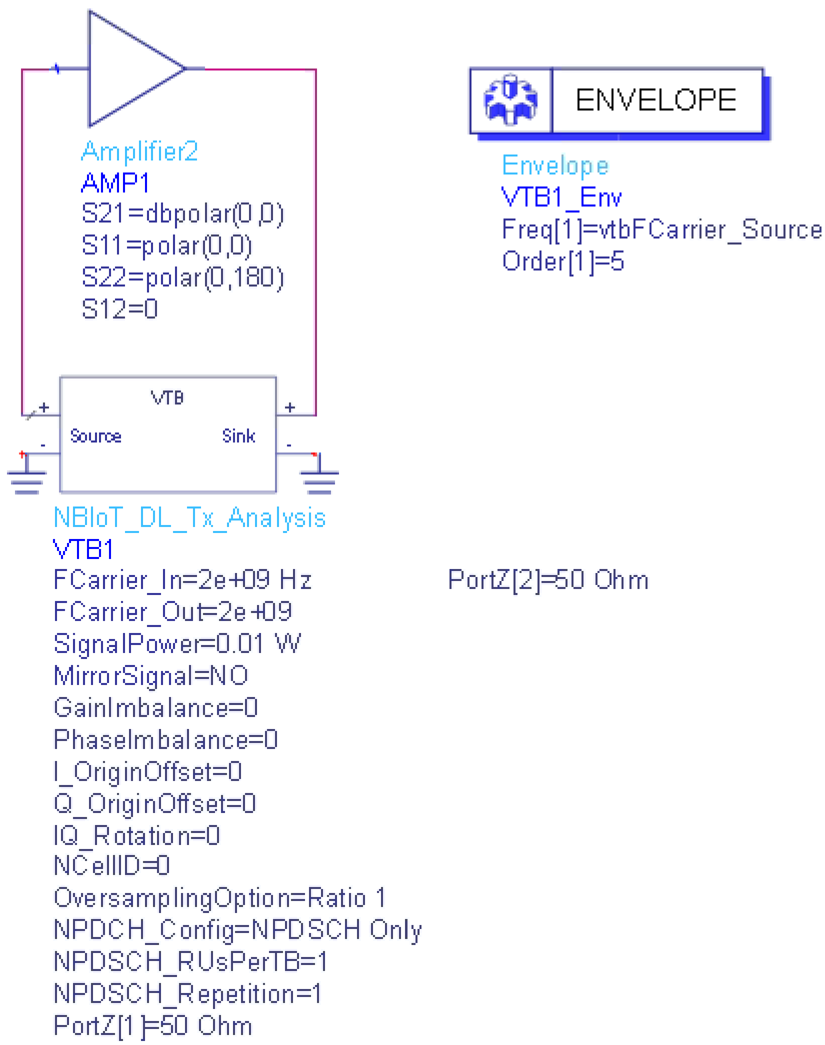
- InFeedbackLoop: Specify whether the SVE_Link is in a feedback loop: NO, YES. In NBIoT examples, there is no feedback loop, hence **InFeedbackLoop** is set to *NO*.
- SampleRate: Sample rate of the signal. In NB IoT examples, in the *Equations* tab of the design, **SamplingRate** of the NBIoT system is calculated from **BaseSampleRate** and **OversamplingOption**. Hence, **SampleRate** is directly set to **SamplingRate**. The base sample rate for downlink is 1.92MHz. For uplink, it's 1.92MHz for 15kHz subcarrier spacing and it's 240kHz for 3.75 kHz subcarrier spacing.
- InputFcs: Array of characterization frequencies of input envelope signals. In current NB IoT examples, there is only one input port in **SVE_Link** model, hence, **InputFcs** is set to **[FCarrier_In]**.

Otherwise, when **DefineProperties** is set to *NO*, the VTB process will analyze the full design and provide such information to the integrating tool.

References

NBIoT_DL_Tx_Analysis

This example workspace provides a VTB test bench to measure spectrum, CCDF and EVM of an LTE Advanced NBIoT downlink transmitter.



The center frequency of the input signal to DUT (***SVE_Link*** in the design***)*** is set by **FCarrier_In**, while center frequency of the output signal from DUT (***SVE_Link*** in the design***)*** is set by **FCarrier_Out**.

RF distortions in the modulator can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

The transmitted signal mean power is set by **SignalPower**.

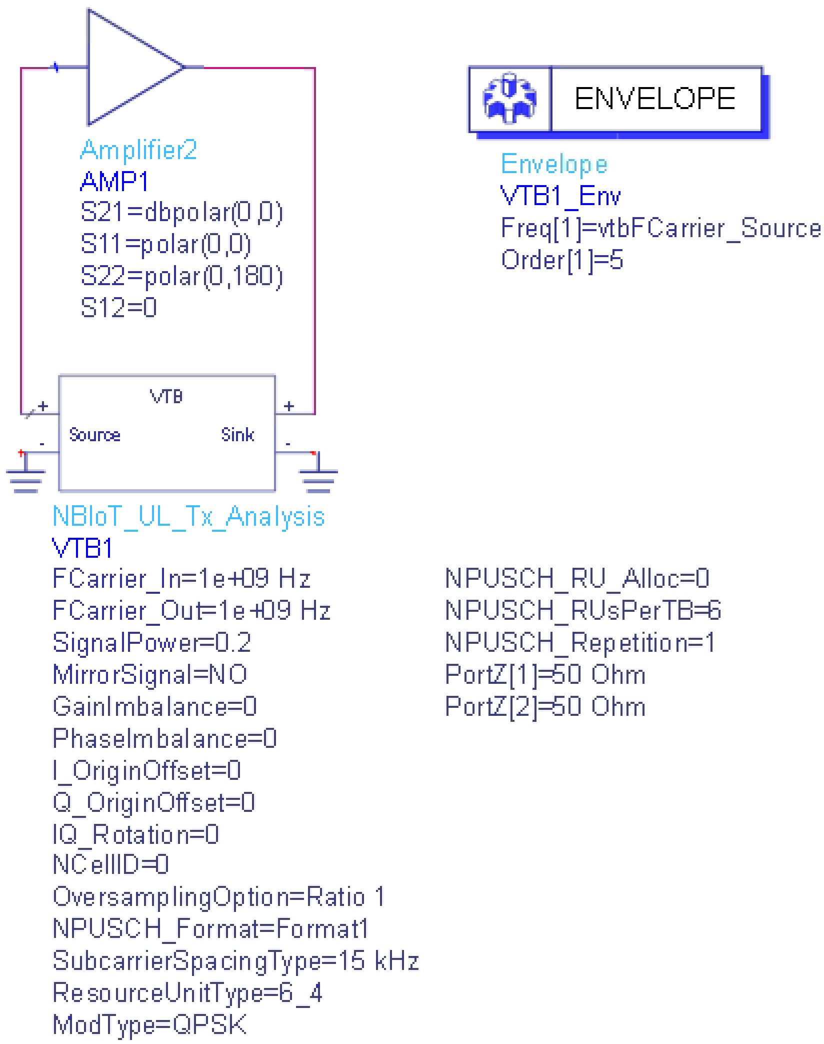
Please note that those parameters with *hide condition* set to **true** will not be shown in ADS/GoldenGate environment.

Try to change the parameters, run ***NBIoT_DL_Tx_Analysis*** and check the simulation results.

- Graph ***CCDF*** shows the Complementary Cumulative Distribution Function of the transmitted signal
- Graph ***Spectrum*** shows the spectrum of the transmitted signal
- Graph ***Waveform*** shows the transmitted time domain waveform

NBIoT_UL_Tx_Analysis

This example workspace provides a VTB test bench to measure spectrum, CCDF and EVM of an LTE Advanced NBIoT uplink transmitter.



The center frequency of the input signal to DUT (***SVE_Link*** in the design***)*** is set by **FCarrier_In**, while center frequency of the output signal from DUT (***SVE_Link*** in the design***)*** is set by **FCarrier_Out**.

RF distortions in the modulator can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

The transmitted signal mean power is set by **SignalPower**.

Please note that those parameters with *hide condition* set to **true** will not be shown in ADS/GoldenGate environment.

Try to change the parameters, run ***NBIoT_UL_Tx_Analysis*** and check the simulation results.

- Graph ***CCDF*** shows the Complementary Cumulative Distribution Function of the transmitted signal
- Graph ***Spectrum*** shows the spectrum of the transmitted signal
- Graph ***Waveform*** shows the transmitted time domain waveform

RADAR Workspaces

VTB workspaces are provided to analyze the Radar signal transmitter.

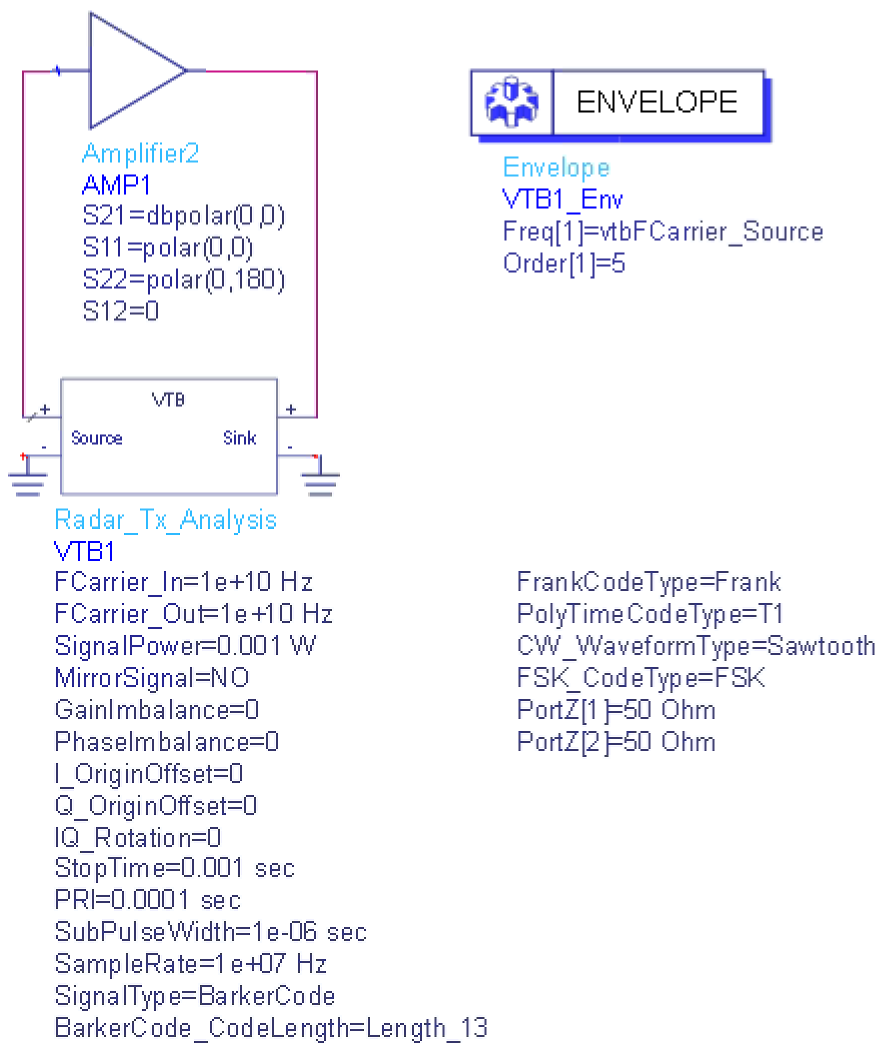
Tx

- Radar_Tx
- Radar_Tx_Source

Radar_Tx_Analysis

This workspace provides a VTB test bench to measure Radar transmitter characteristics including spectrum, waveform, and ACF.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

Several Radar signal Models are provided in this workspace. You can select **SignalType** to configure different Radar signals including BarkerCode, FrankCode, CW, PloyTimeCode, FSK, LFM and PULSE signals. When the Radar signal type is selected, corresponding parameters are valid.

The transmitted signal mean power is set by **SignalPower**. **SignalPower** specifies the mean power of the transmitted.

Parameter Details

1. RF Parameters
    - **FCarrier_In**: Carrier frequency of the input signal to DUT(*SVE_Link*). Range: (0:+Inf)
    - **FCarrier_Out**: Carrier frequency of the output signal from DUT(*SVE_Link*). Range: (0:+Inf)
    - **SignalPower**: Transmitted signal mean power over 50 ohm. Range: (-Inf:+Inf))
    - **MirrorSignal**: Mirror signal about carrier
    - **GainImbalance**: Gain imbalance in dB. Range: (-Inf:+Inf))
    - **PhaseImbalance**: Phase imbalance. Range: (-Inf:+Inf))
    - **I_OriginOffset**: I origin offset. Range: (-Inf:+Inf))
    - **Q_OriginOffset**: Q origin offset. Range: (-Inf:+Inf))
    - **IQ_Rotation**: IQ rotation. Range: (-Inf:+Inf))
2. Measurement Parameters
    - **StopTime**: Stop time of data collection. Range: (0:+Inf)
3. Radar Parameters
    - **PRI** is used to specify the pulse repetition interval. Range: (0:+Inf)
    - **SubPulseWidth** is used to specify the width of each sub-pulse(code). Range: (0:+Inf)
    - **SamplingRate** is used to specify the baseband sampling rate. Range: (0:+Inf)
    - **SignalType** is used to specify the active radar signal source type.

- **BarkerCode_CodeLength** is used to specify the length of Barker code and the final Barker code is constructed by CodeLength number of sub-pulses with a pulse width of CodeLength x SubPulseWidth; valid when **SignalType**=BarkerCode;
- **FrankCodeType** is used to specify the Frank and P code type; valid when **SignalType**=FrankCode;
- **PolyTimeCodeType** is used to specify the PolyTimeCode type; valid when **SignalType**=PolyTimeCode;
- **CW_WaveformType** is used to specify the CW waveform type; valid when **SignalType**=CW;
- **FSK_CodeType** is used to specify the FSK type; valid when **SignalType** =FSK;
- **CostasType** is used to specify the Costas code type; valid when **SignalType**=FSK; Note that this parameter is applicable only for the Radar_Tx_Source_Analysis VTB.

4. Advanced Parameters

NOTE The following parameters are not exposed in ADS/GoldenGate environment. The default values of these parameters will be used in the simulation. To change them, please open the workspace in SystemVue, go to the *Parameters* tab of the design and change the *Default Value* there. To expose them in ADS/GoldenGate environment, please also open the workspace in SystemVue, go to *Parameters* tab and change the *Hide Condition* to *false* or simply delete the *Hide Condition*.

- **FrankCode_M** is used to specify the number of step frequency and the number of samples per frequency; valid when **SignalType**=FrankCode; Range: (0, +Inf). The default value is set to *2*.
- **PolyTimeCode_NumberOfSegment** is the number of step frequency segment; valid when **SignalType**=PolyTimeCode. The default value is set to *4*.
- **PolyTimeCode_DeltaF** is the modulation bandwidth; valid when **SignalType**=PolyTimeCode; Range Range: (0:+Inf). The default value is set to *1e3*.
- **PolyTimeCode_OverallCodePeriod** is the subpulse width; valid when **SignalType**=PolyTimeCode; Range: (0:+Inf). The default value is set to *1e-6s*.
- **PolyTimeCode_NumberOfPhase** is the number of phase state; valid when **SignalType**=PolyTimeCode; Range: (0:+Inf). The default value is set to *2*.
- **CW_Amplitude** is used to specify the radar Transmit waveform Magnitude; valid when **SignalType**=CW; Range: (0:+Inf). The default value is set to *1*.

- **CW_Period** is used to specify Waveform period; valid when **SignalType** =CW; Range: (0:+Inf). The default value is set to *1e-4*.
- **CW_LowerFreq** is used to specify Start Frequence; valid when **SignalType**=CW; Range: (0:+Inf). The default value is set to *10e3*.
- **CW_DeltaFreq** is used to specify the delta frequency; valid when **SignalType**=CW; Range: (0:+Inf). The default value is set to *50e3*.
- **CostasSequenceDeltaFreq** is used to specify the delta frequency of Costas Sequence; valid when **SignalType**=FSK and **FSKType**=Costas; Range: (0:+Inf). The default value is set to *1e6*.
- **LFM_Bandwidth** is an array parameter to specify different pulse bandwidth for each staggering PRI group; valid when **SignalType** =LFM; Range: (0:+Inf). The default value is set to *5e6*.
- **FM_Offset** is an array parameter to specify different frequency domain offset for each staggering PRI group; valid when **SignalType**=LFM; Range: (0:+Inf). The default value is set to *0*.
- **FSK_CodeLength** is used to specify the number of phases; valid when **SignalType**=FSK. The default value is set to *Length13*.
- **ACF_NumSamples**: Number of samples used to calculate the ACF (auto-correlation function). The default value is set to *130*.

NOTE The following parameters cannot be exposed in ADS /GoldenGate environment. The default values of these parameters will be used in the simulation. To change them, please open the workspace in SystemVue, go to the *Equation* tab of the design and change the *Default Value* there.

- **PRI_Combination** is an array parameter to specify pulse numbers for each staggering PRI group; for each element, Range: (0:+Inf). The default value is set to **PRI_Combination** = 1.
- **FSK_FHSequence** is an array parameter used to specify frequence hopping sequence. For each element, Range: (0: +Inf). The default value is set to **FSK_FHSequence** = [1e6, 2e6, 3e6];
- **FSK_TimeIntervals** is an array parameter used to specify Frequence Hopping Time Intervals Sequence. For each element, Range: (0: +Inf). The default value is set to **FSK_TimeIntervals** = [1e-5, 1e-5, 1e-5];
- **CostasSequence** is an array parameter used to specify Frequence Hopping Sequence. For each element, Range: (0: +Inf). The default value is set to **CostasSequence** = [2,4, 8, 5, 10, 9, 7, 3, 6, 1];
- **CostasTimePeriod** is used to specify Subpulse duration period. Range: (0:+Inf). The default value is set to **CostasTimePeriod** = 1e-5;

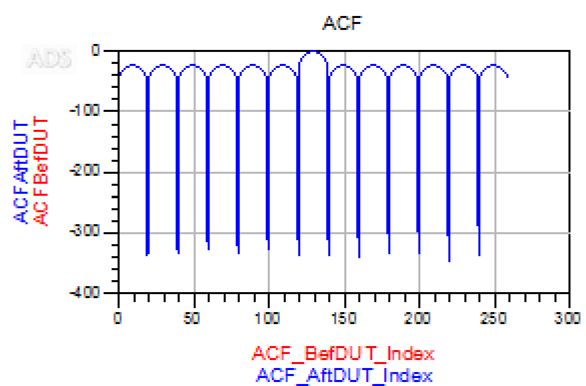
- **FSK_FSKPSKSequence** is an array parameter used to specify specify FSK/PSK Sequence. For each element, Range: (0: +Inf). The default value is set to **FSK_FSKPSKSequence** = [2,4, 8, 5, 10, 9, 7, 3, 6, 1] *1e5;
- **FSK_FSKPSKSubTimePeriod** is used to specify FSK/PSK Subpulse duration period. Range: (0: +Inf). The default value is set to **FSK_FSKPSKSubTimePeriod** = 1e-5;

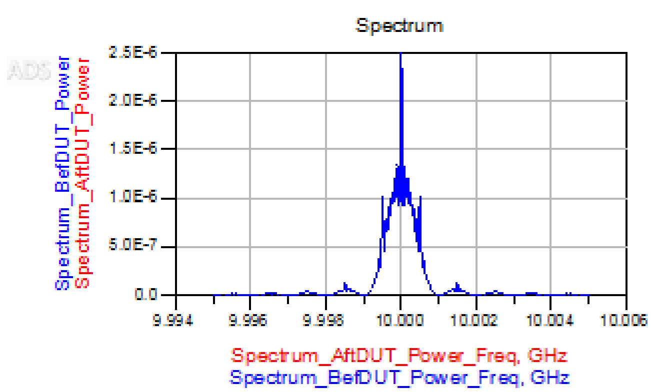
Simulation Results

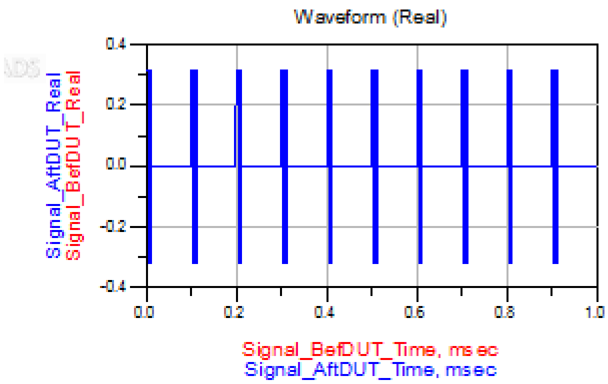
Try to change the parameters, run Radar_Tx_Analysis and check the simulation results.

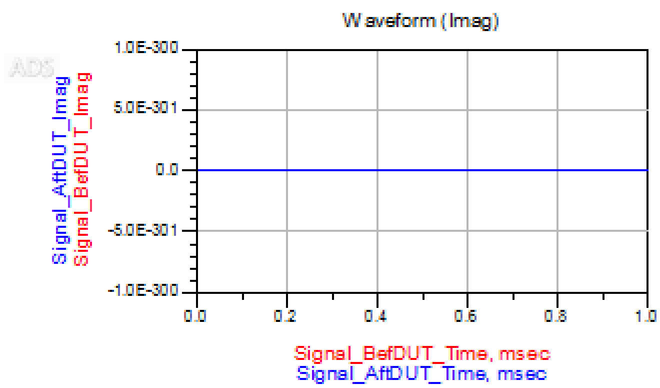
- Graph ***ACF*** shows ACF(auto-correlation function) of the Radar signal.
- Graph ***Spectrum*** shows the spectrum of the transmitted signal.
- Graph ***WaveformReal*** shows the real part of transmitted time domain waveform.
- Graph ***WaveformImag*** shows the image part of transmitted time domain waveform.

The following graphs would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation. The DUT is shorted to get the following ideal results. The same results will be displayed in SystemVue environment if the **SVE_Link** model is disabled to short.









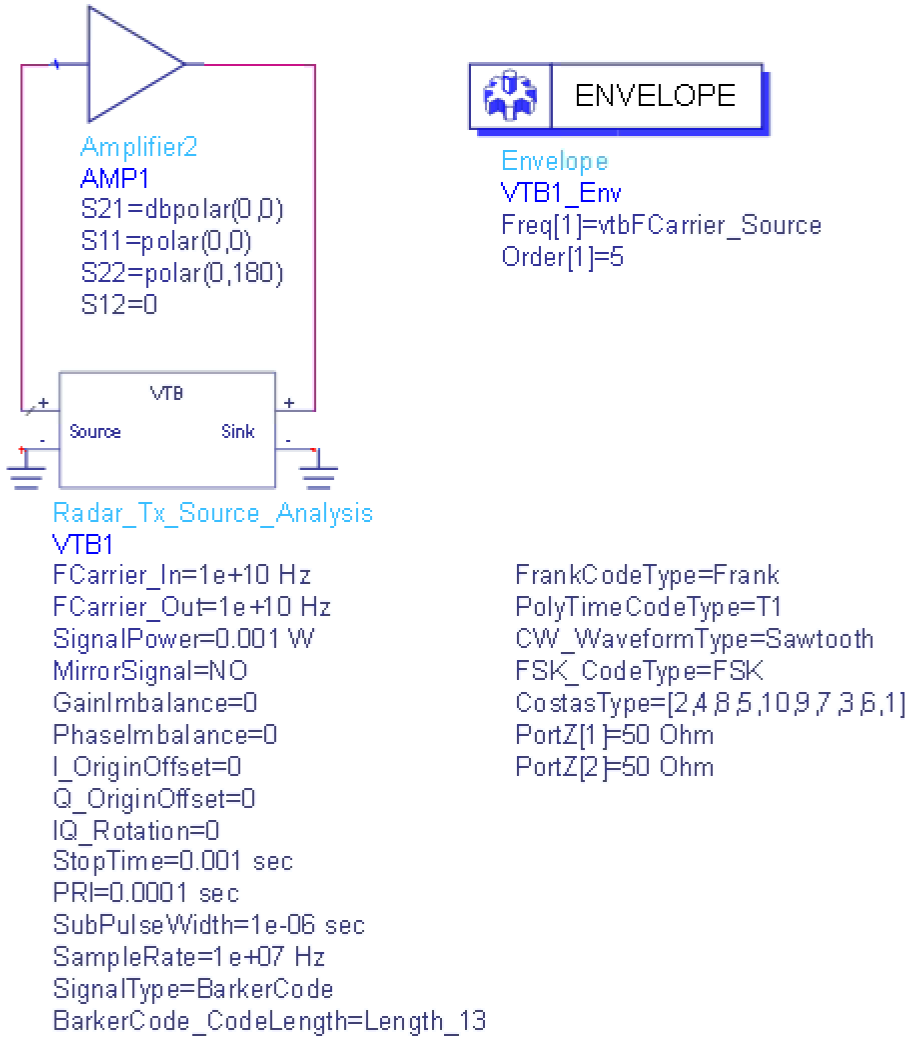
Reference

1. Nadav Levanon and Eli Mozeson, Radar Signals, Wiley, New York, 2004.
2. Phillip E. Pace, Detecting and Classifying Low Probability of Intercept Radar, ARTECH HOUSE, MA ,2009
3. Mark Richards, Fundamentals of Radar Signal Processing, Mcgraw-Hill, New York, 2005
4. Merrill I. Skolnik, Introduction to Radar Systems, Third Edition, Mcgraw-Hill, New York, 2001.

Radar_Tx_Source_Analysis

This workspace provides a VTB test bench to generate the Radar signals.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

Several Radar signal Models are provided in this workspace. You can select **SignalType** to configure different Radar signals. The supported Radar signal type include BarkerCode, FrankCode, CW, PolyTimeCode, FSK, LFM and PULSE signals.

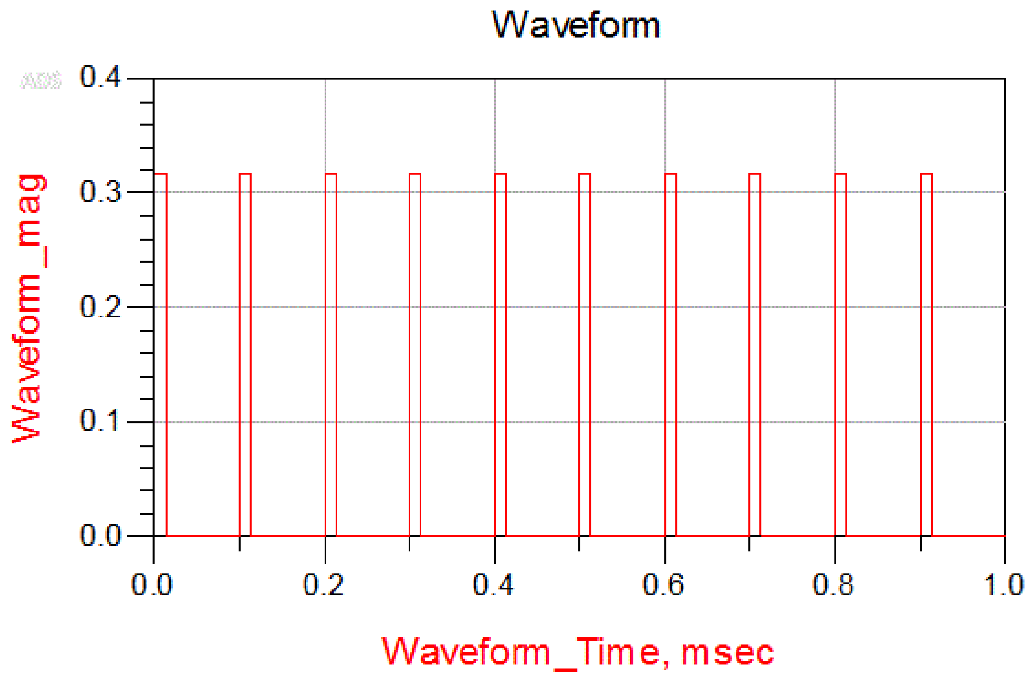
The transmitted signal mean power is set by **SignalPower**. **SignalPower** specifies the mean power of the transmitted signal.

Parameter Details

For details on other parameters, please refer to Radar_Tx.

Simulation Results

Try to change the parameters, run Radar_Tx_Source_Analysis and check the simulation results.
The following graphs would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation. The DUT is shorted to get the following ideal results. The same results will be displayed in SystemVue environment if the **SVE_Link** model is disabled to short.



Reference

1. Nadav Levanon and Eli Mozeson, Radar Signals, Wiley, New York, 2004.
2. Phillip E. Pace, Detecting and Classifying Low Probability of Intercept Radar, ARTECH HOUSE, MA ,2009
3. Mark Richards, Fundamentals of Radar Signal Processing, Mcgraw-Hill, New York, 2005
4. Merrill I. Skolnik, Introduction to Radar Systems, Third Edition, Mcgraw-Hill, New York, 2001.

- Graph ***Waveform*** shows the transmitted time domain waveform

WLAN 11ac Workspaces

VTB workspaces are provided to analyze WLAN 802.11ac transmitter and receiver characteristics according to [1].

Tx

- WLAN_802.11ac_Tx
- WLAN_802.11ac_Tx_Source

Rx

- WLAN_802.11ac_ReferenceSensitivity
- WLAN_802.11ac_AdjacentChannelRejection
- WLAN_802.11ac_NonadjacentChannelRejection

NOTE In current implementation, there are only one input port and one output port in the SVE_Link model used in WLAN 802.11ac workspaces, which means the DUT (design in ADS/GoldenGate environment) should only have one input and one output. In Tx examples, the DUT is connected after the modulator. In Rx examples, the DUT is connected before the demodulator in the Rx chain. Please refer to the help document of each workspace for more information. in which you can find the detailed schematic.

CAUTION In current SystemVue implementation, Bandwidth 80+80 MHz is not supported in the WLAN 802.11ac receiver and EVM model. So there is no option of BW 80+80 MHz in RX VTBs for analyzing WLAN 802.11ac receiver characteristics.

How to set SVE_Link properties in LTE workspaces

Users can optionally define the ***SVE_Link*** properties by setting **DefineProperties** to YES. When **DefineProperties** is set to *YES*, parameters related to ***SVE_Link*** properties, including **InFeedbackLoop**, **SampleRate**, and **InputFcs**, can be defined by values or expressions.

- InFeedbackLoop: Specify whether the SVE_Link is in a feedback loop: NO, YES. In WLAN 802.11ac examples, there is no feedback loop, hence **InFeedbackLoop** is set to *NO*.
- SampleRate: Sample rate of the signal. In WLAN 802.11ac examples, in the *Equations* tab of the design, **SampleRate** is calculated from **Bandwidth** and **OversampleRation**.
- InputFcs: Array of characterization frequencies of input envelope signals. In WLAN 802.11ac examples, there is only one input port in **SVE_Link** model, hence **InputFcs** is set to **[FCarrier_In]**.

Otherwise when **DefineProperties** is set to *NO*, the VTB process will analyze the full design and provide such information to the integrating tool.

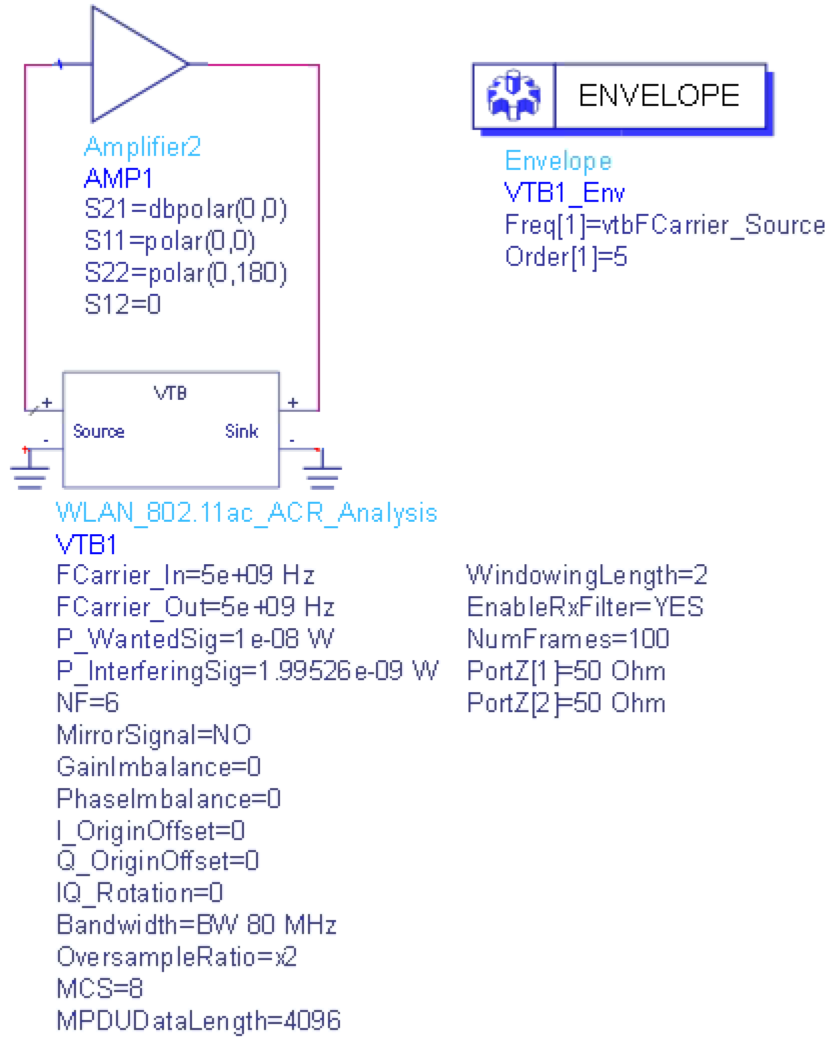
Reference

1. IEEE P802.11ac/D1.0, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications", May 2011.

WLAN_802.11ac_ACR_Analysis

This workspace provides a VTB test bench to analyze Rx adjacent channel rejection of the 802.11ac one antenna receiver. Adjacent channel rejection for W MHz channels (where W is 20, 40, 80 or 160) shall be measured by setting the desired signal's strength 3 dB above the rate dependent sensitivity specified in Table 22-21 (Receiver minimum input level sensitivity) of [1] and raising the power of the interfering signal of W MHz bandwidth until 10% PER is caused for a PSDU length of 4096 octets. The power difference between the interfering and desired channel is the corresponding adjacent channel rejection. The center frequency of the adjacent channel shall be placed W MHz away from the center frequency of the desired signal.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

The wanted signal mean power is set by parameter **P_WantedSig**, while the interfering signal mean power is set by parameter **P_InterferingSig**.

A *Butterworth* IIR bandpass filter centered at **FCarrier_Out** is used in the receiver side. The PassBandwidth is set to the bandwidth of the wanted signal, the PassAtten is set to 3 and Order is set to 5. This filter could be disabled by setting parameter **EnableRxFilter** to NO.

An ***AddNDensity*** model with NDensity = -173.975dBm is used to introduce thermal noise for room temperature (T = 300K). The noise figure is set by parameter **NF**.

RF distortions can be introduced by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

An ***AddNDensity*** model with NDensity = -173.975dBm is used to introduce thermal noise for room temperature (T = 300K). The noise figure is set by parameter **NF**.

The number of frames to be simulated is specified by **NumFrames**.

Parameter Details

- P_WantedSig: Wanted signal mean power over 50 ohm. Range: (-∞:+∞)
- P_InterferingSig: Interfering signal mean power over 50 ohm. Range: (-∞:+∞)
- EnableRxFilter: Whether enable Rx band pass filter or not
  For details on other parameters, please refer to WLAN_802.11ac_Tx.

Simulation Results

Try to change the parameters, run **WLAN_802.11ac_ACR_Analysis** and check the simulation results in table ***FER*** to see whether the FER meets the requirements. The FER shall be ≤ 10%.

NOTE If FER < 10%, then *PassFailFlag* is set to true(1), otherwise, it is set to false(0).

The following table would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

B2_FER_Index	B2_FER
0	0.000

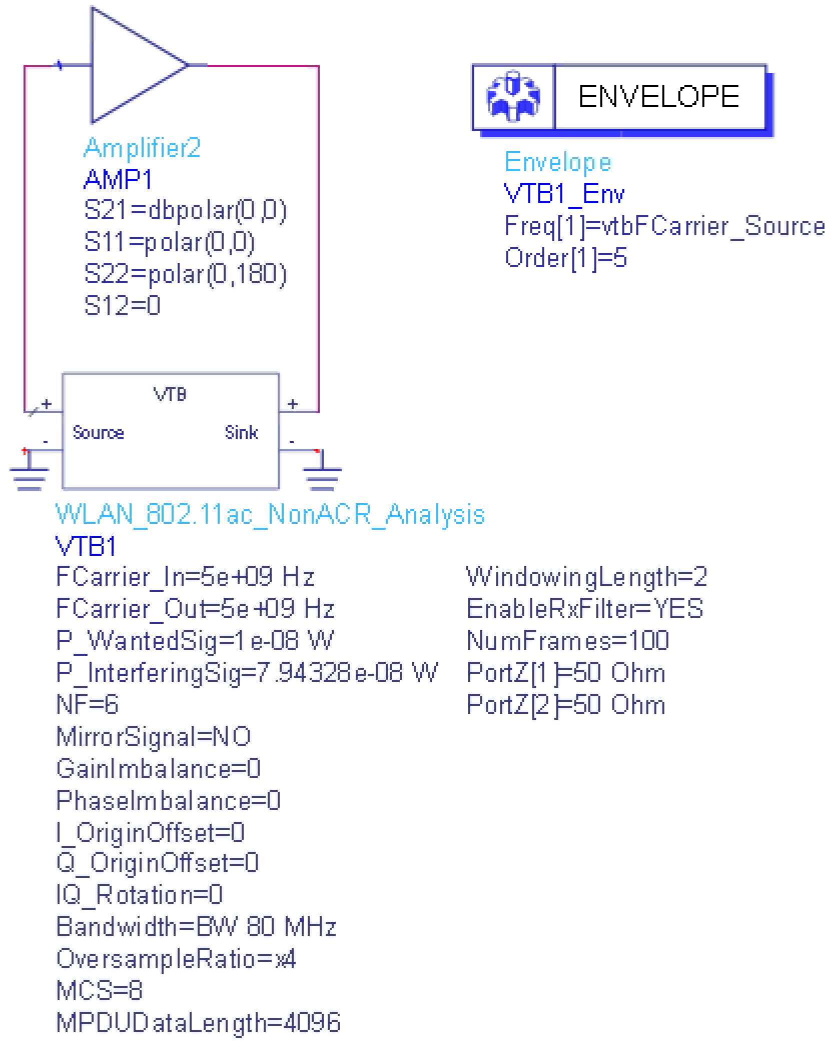
Reference

1. IEEE P802.11ac/D1.0, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", May 2011.

WLAN_802.11ac_NonACR_Analysis

This workspace provides a VTB test bench to analyze Rx nonadjacent channel rejection of the 802.11ac one antenna receiver. Nonadjacent channel rejection for W MHz channels (where W is 20, 40, 80 or 160) shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 22-21 (Receiver minimum input level sensitivity) of [1]\, and raising the power of the interfering signal of W MHz bandwidth until a 10% PER occurs for a PSDU length of 4096 octets. The power difference between the interfering and desired channel is the corresponding nonadjacent channel rejection. The center frequency of the nonadjacent channel shall be placed 2×W MHz or more away from the center frequency of the desired signal.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

The wanted signal mean power is set by parameter **P_WantedSig**, while the interfering signal mean power is set by parameter **P_InterferingSig**.

A *Butterworth* IIR bandpass filter centered at **FCarrier_Out** is used in the receiver side. The PassBandwidth is set to the bandwidth of the wanted signal, the PassAtten is set to 3 and Order is set to 5. This filter could be disabled by setting parameter **EnableRxFilter** to NO.

An ***AddNDensity*** model with NDensity = -173.975dBm is used to introduce thermal noise for room temperature (T = 300K). The noise figure is set by parameter **NF**.

RF distortions can be introduced by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

The number of frames to be simulated is specified by **NumFrames**.

Parameter Details

For details on parameters, please refer to WLAN_802.11ac_AdjacentChannelRejection.

Simulation Results

Try to change the parameters, run *WLAN_802.11ac_NonACR_Analysis* and check the simulation results in table ***FER*** to see whether the FER meets the requirements. The FER shall be ≤ 10%.

NOTE If FER < 10%, then *PassFailFlag* is set to true(1), otherwise, it is set to false(0).

The following table would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

B2_FER_Index	B2_FER
0	0.000

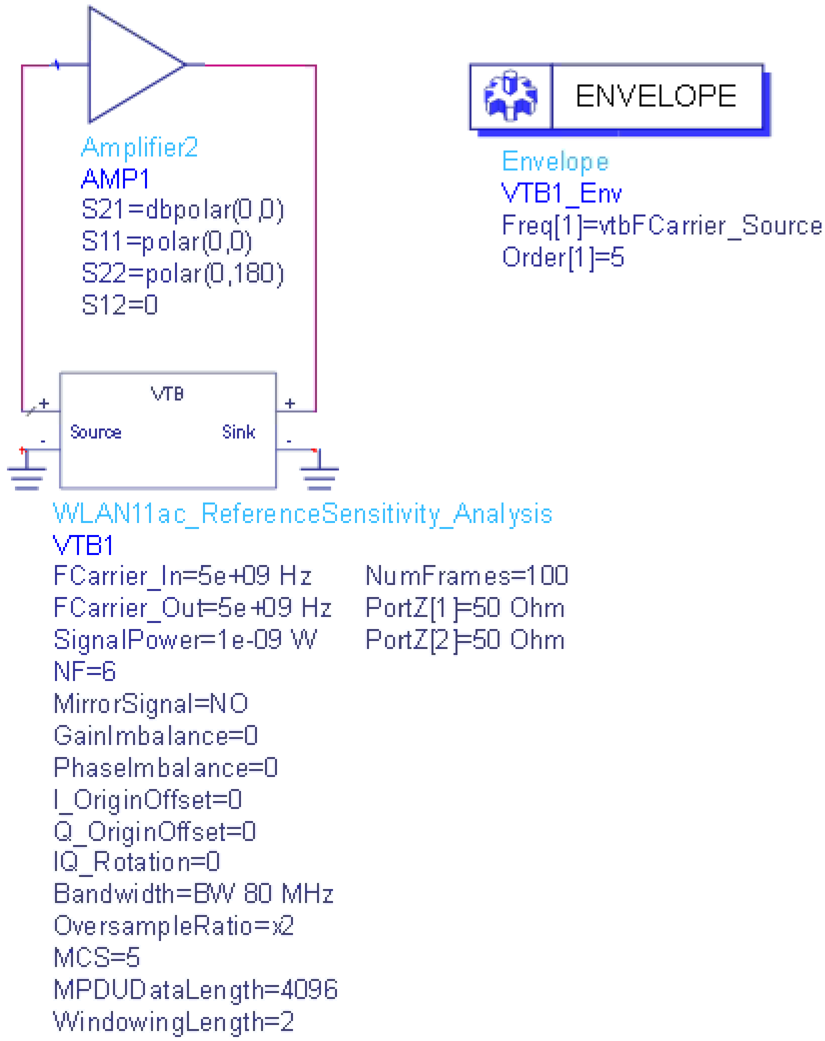
Reference

1. IEEE P802.11ac/D1.0, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", May 2011.

WLAN11ac_ReferenceSensitivity_Analysis

This workspace provides test bench to analyze receiver minimum input sensitivity of the 802.11ac signals. The packet error rate (PER) shall be less than 10% for a PSDU length of 4096 octets with the rate-dependent input levels listed in Table 22-21 (Receiver minimum input level sensitivity) of [1]. The test applies to non-STBC modes, 800 ns GI and BCC.
For example, for 80MHz, 64QAM, Rate 2/3, the minimum sensitivity is -60 dBm.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

The transmitted signal mean power is set by **SignalPower**.

An ***AddNDensity*** model with NDensity = -173.975dBm is used to introduce thermal noise for room temperature (T = 300K). The noise figure is set by parameter **NF**.

The number of frames to be simulated is specified by **NumFrames**.

Parameter Details

- NF: Noise figure in receiver. Range: [0:+∞)
- NumFrames: number of frames to be simulated. Range: [1:+∞)
  For details on other parameters, please refer to WLAN_802.11ac_Tx.

Simulation Results

Try to change the parameters, run **WLAN11ac_ReferenceSensitivity_Analysis** and check the simulation results in table ***FER*** to see whether the FER meets the requirements.

NOTE If FER < 10%, then *PassFailFlag* is set to true(1), otherwise, it is set to false(0).

The following table would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

B2_FER_Index	B2_FER
0	0.000

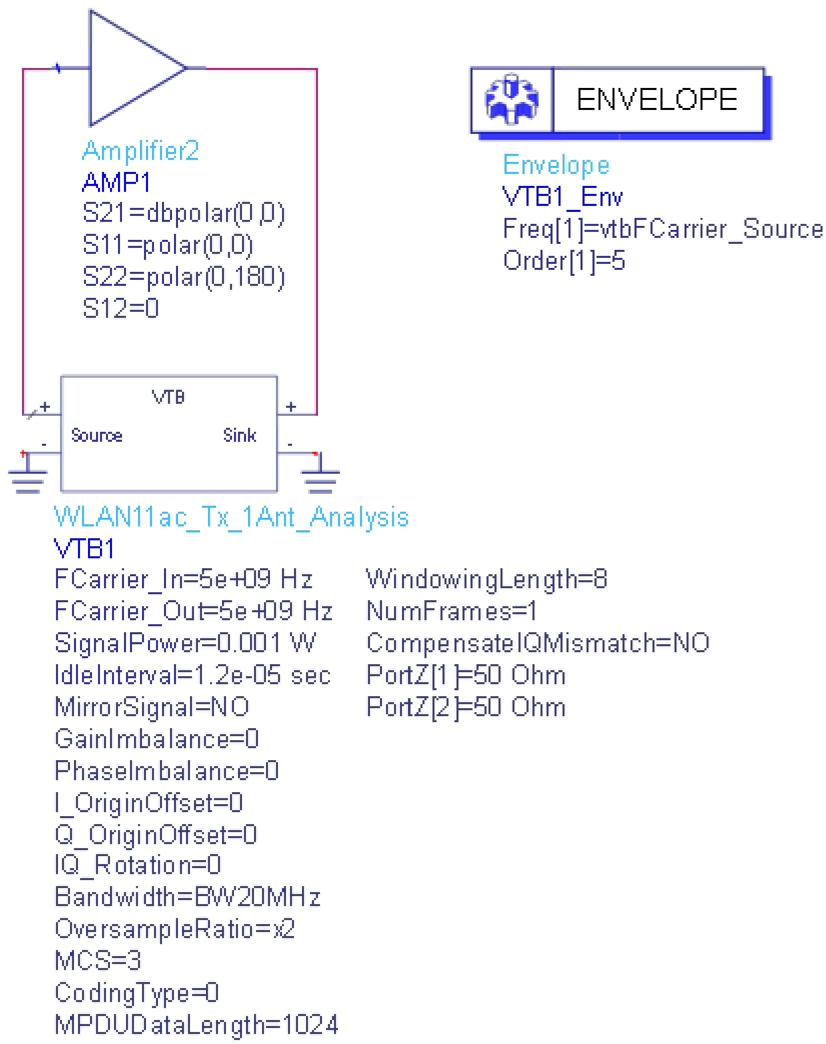
Reference

1. IEEE P802.11ac/D1.0, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", May 2011.

WLAN11ac_1Ant_Analysis

This workspace provides a VTB test bench to analyze the CCDF, EVM, PAPR, spectrum and waveform of the signal generated by WLAN 802.11ac single antenna transmitter.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

The transmitted signal mean power is set by **SignalPower**.

The number of OFDM data symbols in each frame is dertermined by **CodingType** and **MPDUDataLength**. The other parameters related to the determination of number of OFDM symbols in a frame include AggregatedMPDU, NumMPDUPerUser, MPDUMACHeader and ShortGI. These parameters are set to use default values: AggregatedMPDU = 1, NumMPDUPerUser = 1, MPDUMACHeader = 0 and ShortGI = 0. To change those parameters, please open this workspace in SystemVue, go to the *Equations* tab of the design and change the formulas.

The number of frames for EVM measurements is specified by **FrameToAverage**.

Parameter Details

1. RF Parameters
   - SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞:+∞)
     For details, please refer to RF Parameters.
2. WLAN 802.11ac Parameters
   - **IdleInterval**: idle interval between two frame packets. Range: [0:+∞)
   - **Bandwidth**: bandwidth of WLAN 11 ac, the type is enum and it can be selected as BW 20 MHz, BW 40 MHz, BW 80 MHz, BW 160 MHz and BW 80+80 MHz for Source. The receiver and EVM model does not support BW 80+80 MHz at present.
   - **OversampleRatio**: Over-sampling ratio option, the type is enum and it can be selected as x1 , x2, x4 and x8 in the Source and Receiver.
   - **MCS**: Modulation coding scheme for the user.The supported MCSs for different **Bandwidth** and number of spatial streams are defined according to Section 22.5 [1]. Range [0:9].
   - **CodingType**: coding type for all users for which 0 means binary convolutional code (BCC) and 1 means low density parity check (LDPC) code.
   - **MPDUDataLength**: Data length of MPDU. Range [0:11426].
   - **NumFrames**: Number of frames for EVM measurements. Range: [1:+∞)
   - **CompensateIQMismatch**: If set YES, the demodulation tries to compensate for IQ Gain Imbalance, IQ Quadrature Error, and IQ Timing Skew found in the input signal. This allows for EVM computations which exclude any IQ impairments: NO, YES

Simulation Results

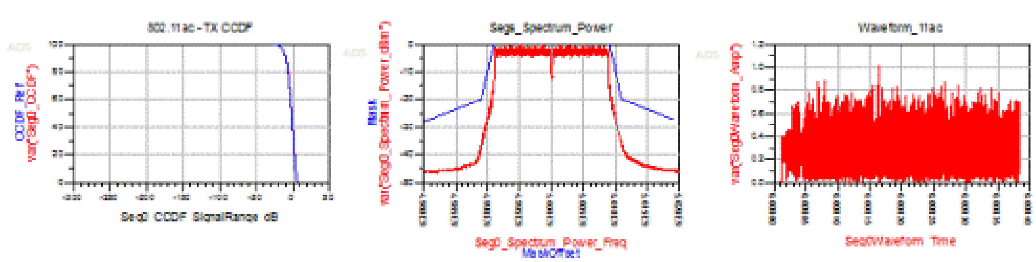
Try to change the parameters, run **WLAN11ac_1Ant_Analysis** and check the simulation results.

Graph ***Tx_CCDF*** shows the Complementary Cumulative Distribution Function of the transmitted signal
Table ***Tx_EVM*** lists average EVM and EVM for each frame
Table ***Tx_PAPR*** shows the Peak to Average Power Ratio
Graph ***Tx_Spectrum*** shows spectrum of the transmitted signal
Graph ***Tx_SpectrumMask*** shows whether the spectrum mask is met
Graph ***Tx_Waveform*** shows the transmitted time domain waveform

NOTE RCE is reported in dB in this example.
If data RCE is better than the limits below [1], then *RCE_PassFailFlag* is set to true(1), otherwise, it is set to false(0).

MCS	Modulation	Coding rate	Relative constellation error (dB)
0	BPSK	1/2	-5
1	QPSK	1/2	-10
2	QPSK	3/4	-13
3	16-QAM	1/2	-16
4	16-QAM	3/4	-19
5	64-QAM	2/3	-22
6	64-QAM	3/4	-25
7	64-QAM	5/6	-27
8	256-QAM	3/4	-30
9	256-QAM	5/6	-32

The following graphs would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation. The DUT is shorted to get the following ideal results. The same results will be displayed in SystemVue environment if the **SVE_Link** model is disabled to short.



...Power_dBm_index	PAPR
0	8.323

W1_Avg_RCE_dB_index	W1_Avg_RCE_dB	W1_RCE_dB_Frame	W1_RCE_dB
0	-34.609	1 2	-36.794 -33.449

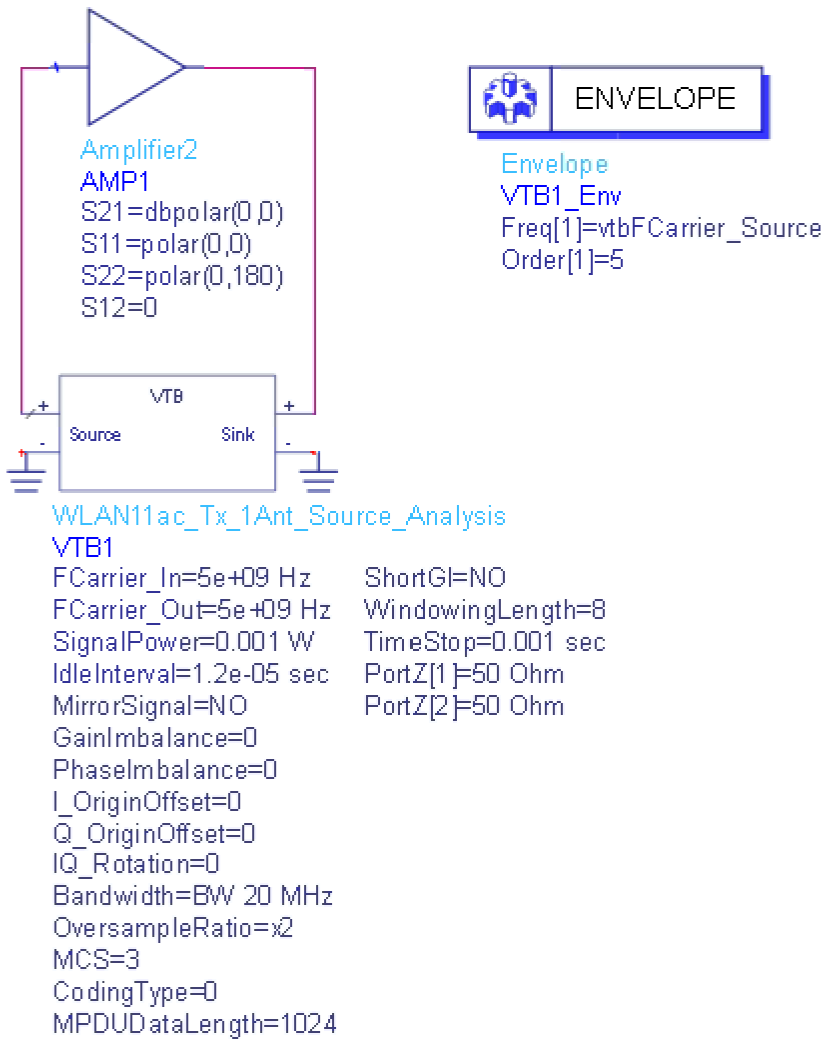
Reference

1. IEEE P802.11ac/D1.0, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", May 2011.

WLAN11ac_Tx_1Ant_Source_Analysis

This workspace provides a VTB test bench to generate WLAN 802.11ac signal.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

The transmitted signal mean power is set by **SignalPower**.

The number of OFDM data symbols in each frame is dertermined by **CodingType** and **MPDUDataLength**. The other parameters related to the determination of number of OFDM symbols in a frame include AggregatedMPDU, NumMPDUPerUser, MPDUMACHeader and ShortGI. These parameters are set to use default values: AggregatedMPDU = 1, NumMPDUPerUser = 1, MPDUMACHeader = 0 and ShortGI = 0. To change those parameters, please open this workspace in SystemVue, go to the *Equations* tab of the design and change the formulas.

A sink is used to save the generated signal from 0 to **TimeStop**.

Parameter Details

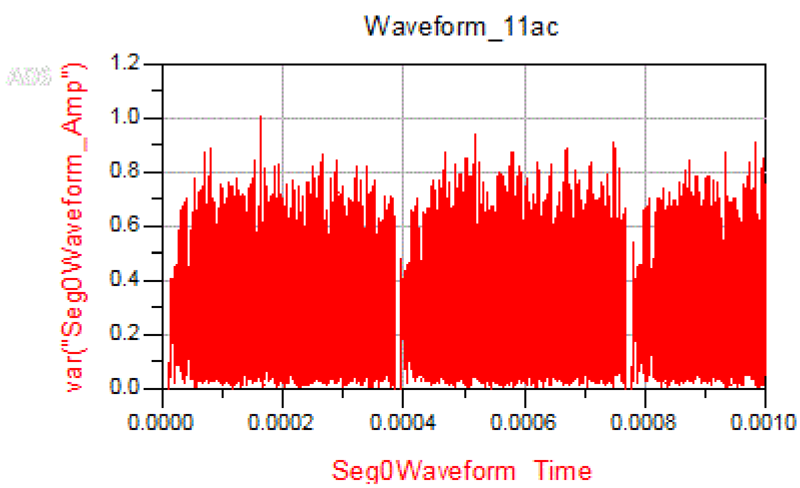
- TimeStop: Stop time of data collection. Range: (0:+∞)
  For details on other parameters, please refer to WLAN_802.11ac_Tx.

Simulation Results

Try to change the parameters, run **WLAN11ac_1Ant_Source_Analysis** and check the simulation results.

- Graph ***Tx_Waveform*** shows the transmitted time domain waveform

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



Reference

1. IEEE P802.11ac/D1.0, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", May 2011.

WLAN 11ad Workspaces

WLAN 11ad Workspaces

VTB workspaces are provided to analyze WLAN 11ad transmitter and receiver characteristics according to [1].

Tx

WLAN 11ad transmitter characteristics according to section 21 of [1]

- WLAN_11ad_Tx
- WLAN_11ad_Tx_Source

Rx

WLAN 11ad receiver characteristics according to section 21 of [1]

- WLAN_11ad_RxSensitivity

NOTE In current implementation, there is only one input port and one output port in the SVE_Link model used in WLAN 11ad workspaces, which means the DUT (design in ADS/GoldenGate environment) should only have one input and one output. In Tx examples, the DUT is connected after the modulator. In Rx examples, the DUT is connected before the demodulator in the Rx chain. Please refer to the help document of each workspace for more information in which you can find the detailed schematic.

How to set SVE_Link properties in LTE workspaces

Users can optionally define the ***SVE_Link*** properties by setting **DefineProperties** to YES. When **DefineProperties** is set to *YES*, parameters related to ***SVE_Link*** properties, including **InFeedbackLoop**, **SampleRate**, and **InputFcs**, can be defined by values or expressions.

- InFeedbackLoop: Specify whether the SVE_Link is in a feedback loop: NO, YES. In WLAN 802.11ad examples, there is no feedback loop, hence **InFeedbackLoop** is set to *NO*.
- SampleRate: Sample rate of the signal. In WLAN 802.11ad examples, in the *Equations* tab of the design, **SampleRate** is calculated from **MCS** and **OversampleRation**.
- InputFcs: Array of characterization frequencies of input envelope signals. In WLAN 802.11ad examples, there is only one input port in **SVE_Link** model, hence **InputFcs** is set to **[FCarrier_In]**.

Otherwise when **DefineProperties** is set to *NO*, the VTB process will analyze the full design and provide such information to the integrating tool.

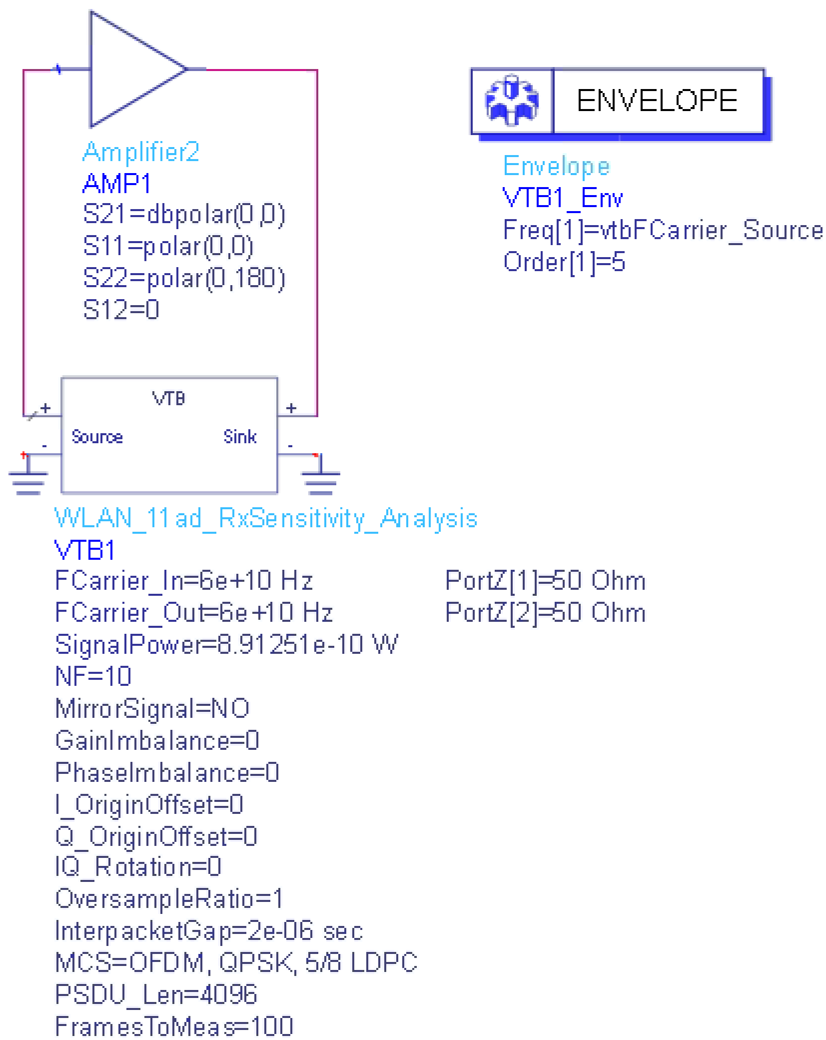
References

1. IEEE P802.11ad/D4.0, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", July 2011.

WLAN_11ad_RxSensitivity_Analysis

This workspace provides a test bench of reference sensitivity power level of WLAN 11ad receiver according to section 21.3.3 of [1]. The reference sensitivity power level is the minimum mean power received at the antenna connector at which a PER requirement shall be met for a specified MCS.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.
In our implementation, the output signal from WLAN_11ad_Source is the 1x-sampled complex baseband signals. Then the signal is oversampled in the filter models with the oversample ratio specified in the **OversampleOption** parameter. With the default, the pre-configured filter types for both SC and OFDM modulation are as follows:

- SC: RaisedCosine filter with SymbolRate = 1.76e9 Hz, RollOff (Alpha) = 0.5
- OFDM: Flat Top filter with PassFreq = 2.5e9 Hz, Order = 96

For MCS 13 to 24, the OFDM modulation is used and for other case, SC modulation is used.

The received signal mean power is set by **SignalPower**. Please refer to the last table to set this parameter for all MCS

An ***AddNDensity*** model with NDensity = -173.975dBm is used to introduce thermal noise for room temperature (T = 300K). The noise figure is set to 10.

The number of frames to be simulated is specified by **NumTestFrames**.

Parameter Details

- FramesToMeas: number of frames to be simulated. Range: [1:+∞)
  For details on other parameters, please refer to WLAN_11ad_Tx.

Simulation Results

For MCS0, the PER shall be less than 5% for a PSDU length of 256 octets specified by parameter **PSDU_Len**. For the other MCSs, the PER shall be less than 1% for a PSDU length of 4096 octets specified by parameter **PSDU_Len**.
Try to change the parameters, run **WLAN_11ad_RxSensitivity_Analysis** and check the simulation results in table ***FER*** to see whether the FER meets the requirements. The following table would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.

B3_FER_Index	B3_FER
0	0.000

Table 21-3 of the section 21.3.3.9 of [1] listed the MCS dependent input levels. It assumes 5 dB implementation loss and 10 dB noise factor (Noise Figure). But in the current implementation, for some MCS cases (MCS 13 ~ 24), the implementation loss of the receiver is more than 5 dB and for other cases, the implementation is less than 5 dB. Here we listed the actual input level for all MCS in the implementation.

MCS Index	Receive Sensitivity (dBm)	Actual Input Level (dBm)
0	-78	-79
1	-68	-70
2	-67	-69
3	-65	-67
4	-64	-66
5	-62	-64
6	-63	-65
7	-62	-64
8	-61	-63
9	-59	-61
10	-55	-57
11	-54	-56
12	-53	-55
13	-66	-62.5
14	-64	-61.5
15	-63	-60.5
16	-62	-60.5
17	-60	-59

18	-58	-57
19	-56	-55
20	-54	-53
21	-53	-52
22	-51	-50
23	-49	-48
24	-47	-46
25	-64	-66
26	-60	-62
27	-57	-59
28	-57	-59
29	-57	-59
30	-57	-59
31	-57	-59

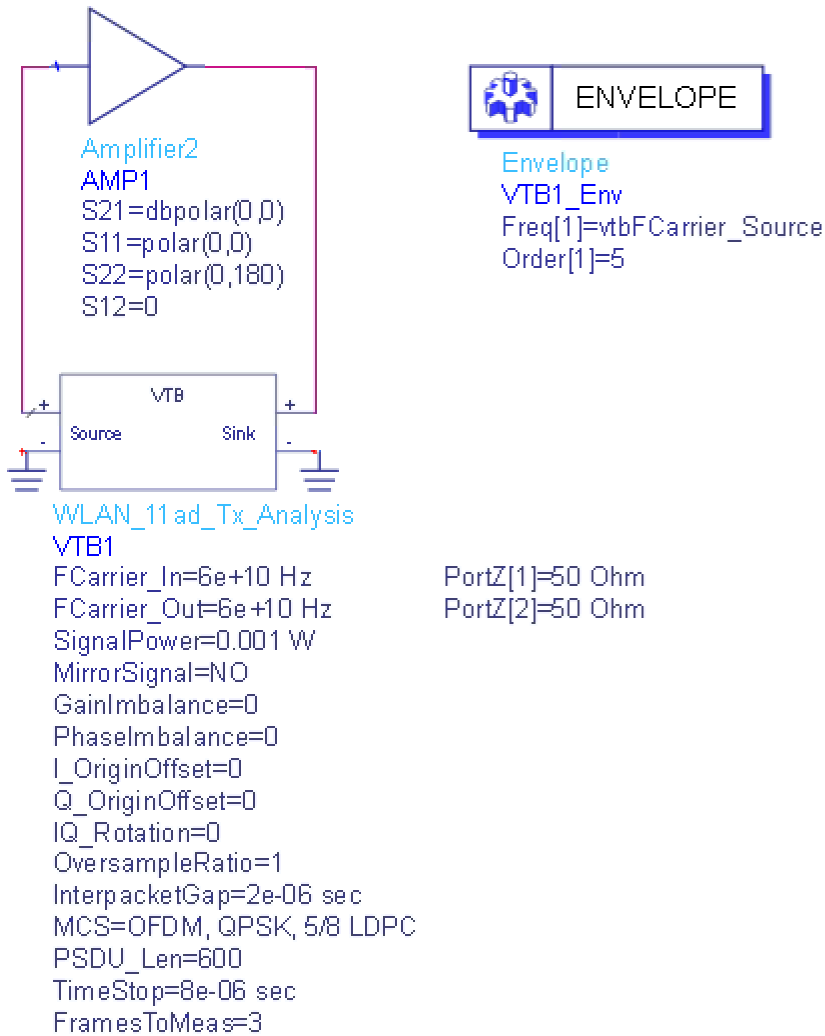
Reference

1. IEEE P802.11ad/D4.0, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", July 2011.

WLAN_11ad_Tx_Analysis

This workspace provides a VTB test bench to analyze the CCDF, EVM, spectrum and waveform of the signal generated by WLAN 802.11ad transmitter.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

The transmitted signal mean power is set by **SignalPower**.

In our implementation, the output signal from WLAN_11ad_Source is the 1x-sampled complex baseband signals. Then the signal is oversampled in the filter models with the oversample ratio specified in the **OversampleOption** parameter. With the default, the pre-configured filter types for both SC and OFDM modulation are as follows:

- SC: RaisedCosine filter with SymbolRate = 1.76e9 Hz, RollOff (Alpha) = 0.5
- OFDM: Flat Top filter with PassFreq = 2.5e9 Hz, Order = 96
  For MCS 13 to 24, the OFDM modulation is used and for other case, SC modulation is used.

The number of frames for EVM measurements is specified by **FrameToMeas**.

Parameter Details

1. RF Parameters
    - SignalPower: Transmitted signal mean power over 50 ohm. Range: (-∞: +∞)
      For details, please refer to RF Parameters.
2. WLAN 11ad Parameters
    - **OversampleRatio**: Over-sampling ratio option, the type is integer and it can be set to 0 ~ 3 which means x1 , x2, x4 and x8 in the Source and Receiver
    - **InterpacketGap**: idle interval between two packets. Zeros will be inserted during this interval.
      Range: [0:+∞).
    - **PSDU_Len**: the PHY PSDU length in octets. For non-Control PHY modes it is limited to the range [0:262143]. For Control PHY modes (MCS 0), it is limited to the range[4:1023]
    - **MCS**: modulation and coding scheme. For MCS 0~12 and MCS 25~31, it is single carrier modulation and the output sample rate is 1.76GHz. For MCS 13~24, it is OFDM modulation and the output sample rate is 2.64GHz.
    - **FramesToMeas**: Number of frames for EVM measurements. Range: [1: +∞)

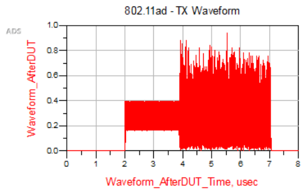
Simulation Results

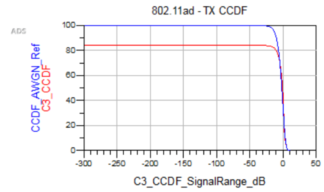
Try to change the parameters, run **WLAN_11ad_Tx_Analysis** and check the simulation results.

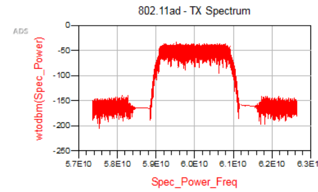
Graph ***Tx_Waveform*** shows the transmitted time domain waveform
Graph ***Tx_CCDF*** shows the Complementary Cumulative Distribution Function of the transmitted signal
Table ***Tx_EVM*** lists average EVM and EVM for each frame
Graph ***Tx_Spectrum*** shows spectrum of the transmitted signal

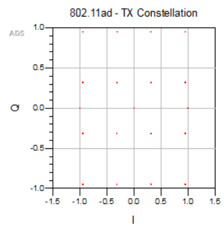
Graph ***Tx_Constellation*** shows constellation symbols of the transmitted data symbols

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.









EVM_Average_EVM_Percent_Index	EVM_Average_EVM_Percent	EVM_EVM_Percent_Frame	EVM_EVM_Percent
0	0.005	0 1 2	0.005 0.005 0.005

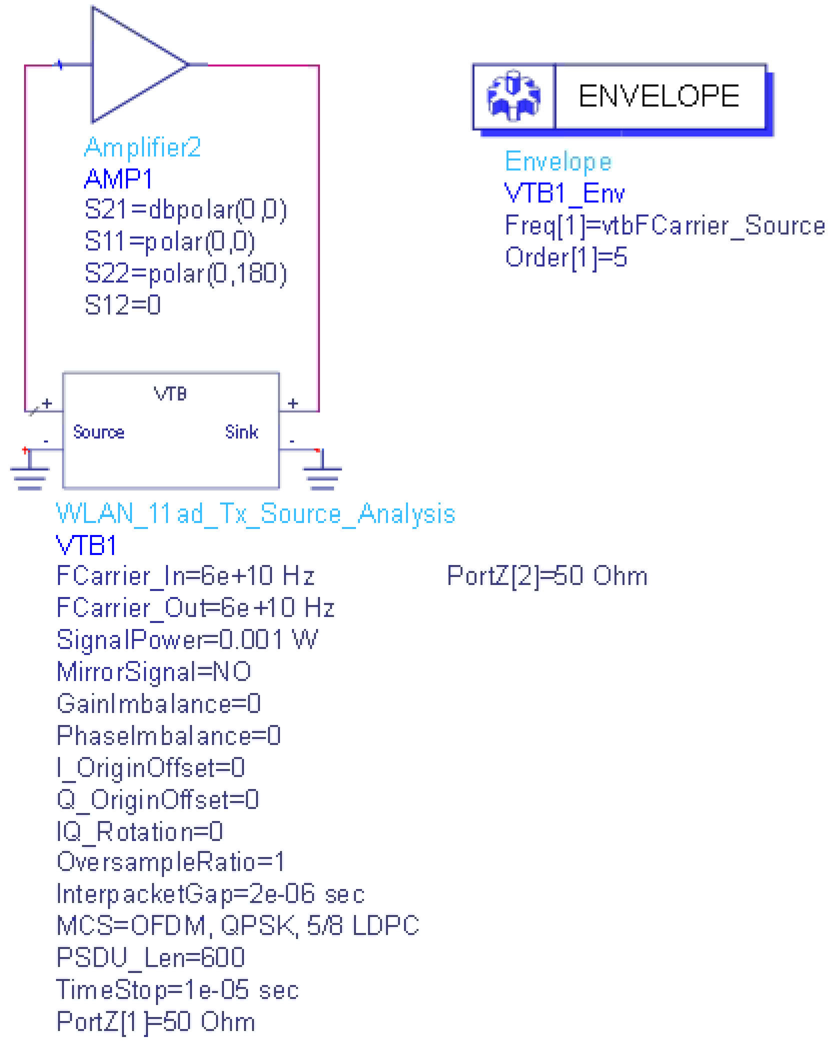
Reference

1. IEEE P802.11ad/D4.0, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", July 2011.

WLAN_11ad_Tx_Source_Analysis

This workspace provides a VTB test bench to generate WLAN 802.11ad signal following the TGad Draft Amendment (P802.11ad/D4.0) July. 2011.

A simple design in ADS to use this VTB is shown below.



The center frequency of the input signal to DUT(*SVE_Link* in the design) is set by **FCarrier_In**, while center frequency of the output signal from DUT(*SVE_Link* in the design) is set by **FCarrier_Out**.

RF distortions can be simulated by setting parameters **GainImbalance**, **PhaseImbalance**, etc.

The transmitted signal mean power is set by **SignalPower**.

In our implementation, the output signal from WLAN_11ad_Source is the 1x-sampled complex baseband signals. Then the signal is oversampled in the filter models with the oversample ratio specified in the **OversampleOption** parameter. With the default, the pre-configured filter types for both SC and OFDM modulation are as follows:

- SC: RaisedCosine filter with SymbolRate = 1.76e9 Hz, RollOff (Alpha) = 0.5
- OFDM: Flat Top filter with PassFreq = 2.5e9 Hz, Order = 96

For MCS 13 to 24, the OFDM modulation is used and for other case, SC modulation is used.
A sink is used to save the generated signal from 0 to **TimeStop**.

Parameter Details

- TimeStop: Stop time of data collection. Range: (0:+∞)

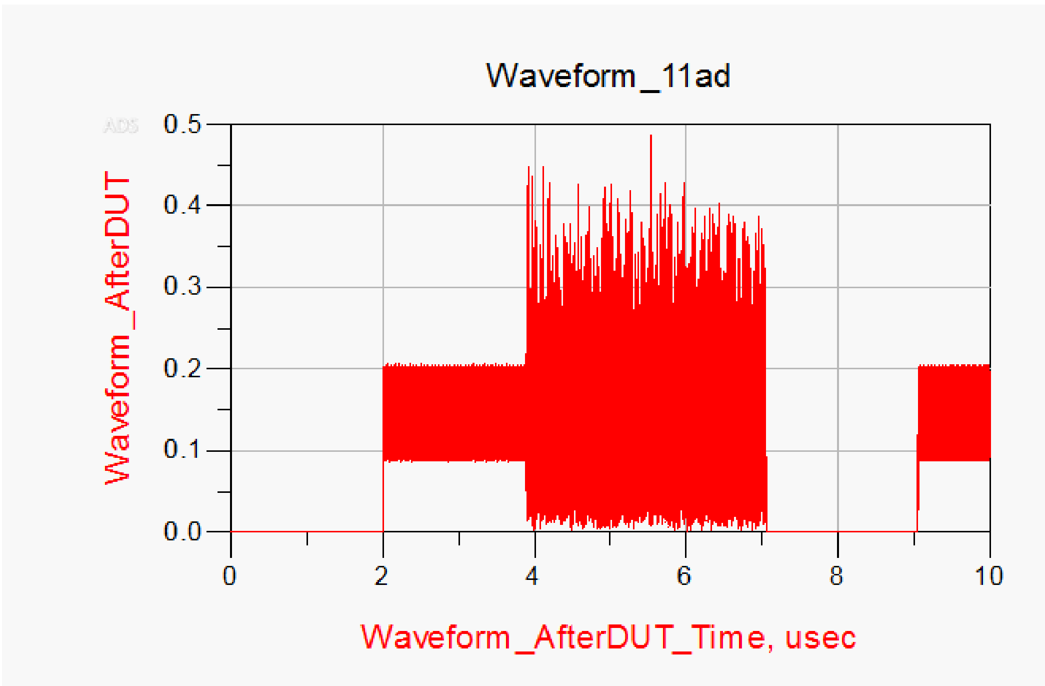
For details on other parameters, please refer to WLAN_11ad_Tx.

Simulation Results

Try to change the parameters, run **WLAN_11ad_Tx_Source_Analysis** and check the simulation results.

- Graph ***Tx_Waveform*** shows the transmitted time domain waveform

The following graph would be shown in ADS/GoldenGate DDS tool automatically when the adx file is imported after simulation.



Reference

1. IEEE P802.11ad/D4.0, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", July 2011.