Agilent Technologies

Advanced Design System 1.5

Bluetooth DesignGuide

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Bluetooth DesignGuide

Chapter 1: Bluetooth DesignGuide QuickStart

The *Bluetooth QuickStart Guide* provides an introduction to the content and use of the Bluetooth DesignGuide. It contains:

- A brief description
- Section on using the DesignGuide
- Section on displaying simulation data

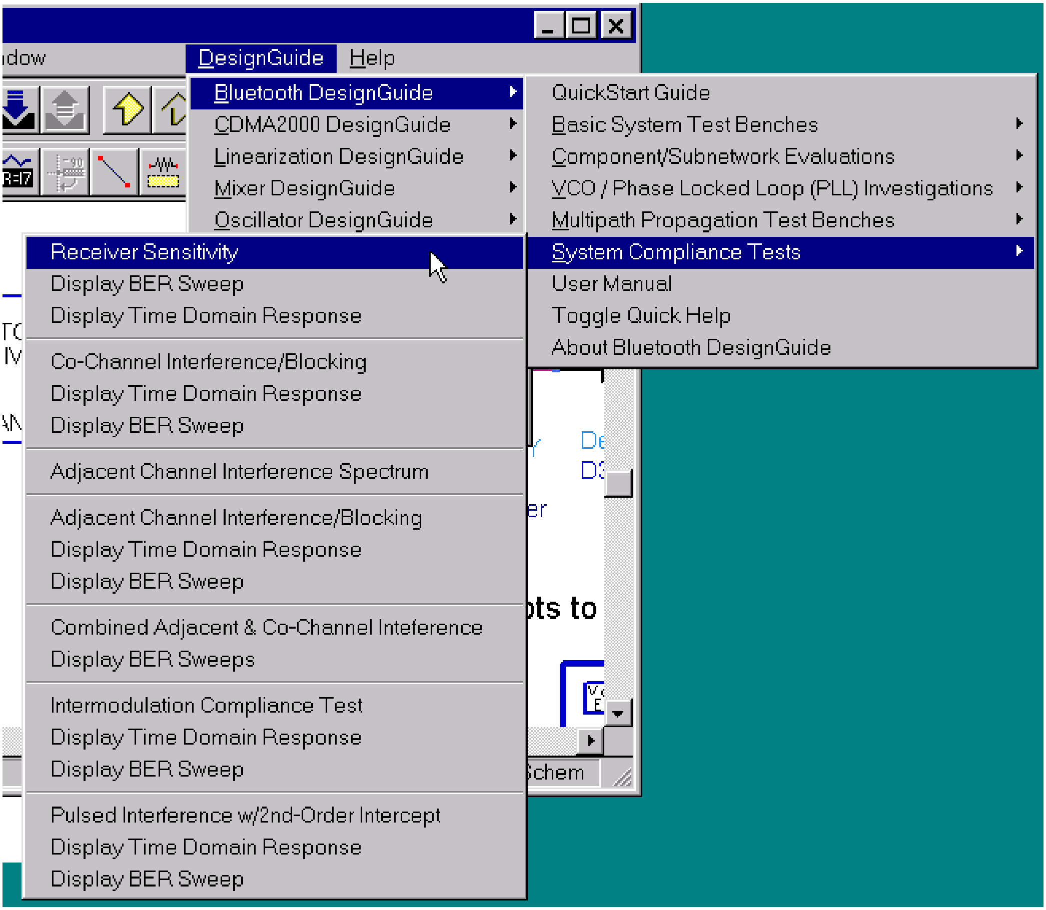
For detailed reference information, refer to Chapter 2, Bluetooth DesignGuide Reference.

The Bluetooth DesignGuide is an application package for the Agilent Advanced Design System (ADS), which contains various *system test benches* and reference designs (for example, an optimal low-IF receiver) for the RF portion of the Bluetooth physical layer. Briefly, it allows for the investigation of system performance (from simple EYE diagrams to BER, the ultimate test) when there are present impairments such as AWGN (Gaussian noise), VCO phase noise, multipath, and/or co-channel / adjacent-channel / intermodulation / pulsed-RF interference. In many cases, the receiver's EYE diagram may be observed in *real time* during the simulation, while the level of the signal or interferer is adjusted via an interactive slider.

In addition, the DesignGuide addresses some PLL/VCO design issues and helps you select the best demodulator for your receiver. All of these applications are easily accessed via a menu-type user-interface that is integrated with ADS when the DesignGuide is installed.

Using the DesignGuide

The Bluetooth DesignGuide adds a menu selection to each ADS Schematic window under DesignGuides, which provides convenient access to test benches, subnetworks and data displays. It may be installed by itself, or may be installed along with other DesignGuides.



The DesignGuide Menu

All of the DesignGuide contents are accessed using the Bluetooth DesignGuide menu found under the DesignGuide pull-down on any schematic window. The contents have been divided into several categories:

- **Basic System Test Benches.** Tutorial simulations to help you understand the Bluetooth RF segment and to evaluate some filtering options for the transmitter
- **Component/Subnetwork Evaluations**. Simulations to help you understand and validate many of the built-in subnetworks used in the system test benches
- **VCO/Phase-Locked-Loop(PLL) Investigations.** Simulations of PLL topologies which address timing and noise issues
- **Multipath Propagation Test Benches.** Simulations that include multipath models for investigating system performance under non-ideal indoor propagation conditions
- **System Compliance Tests.** System test benches for sensitivity and blocking performance

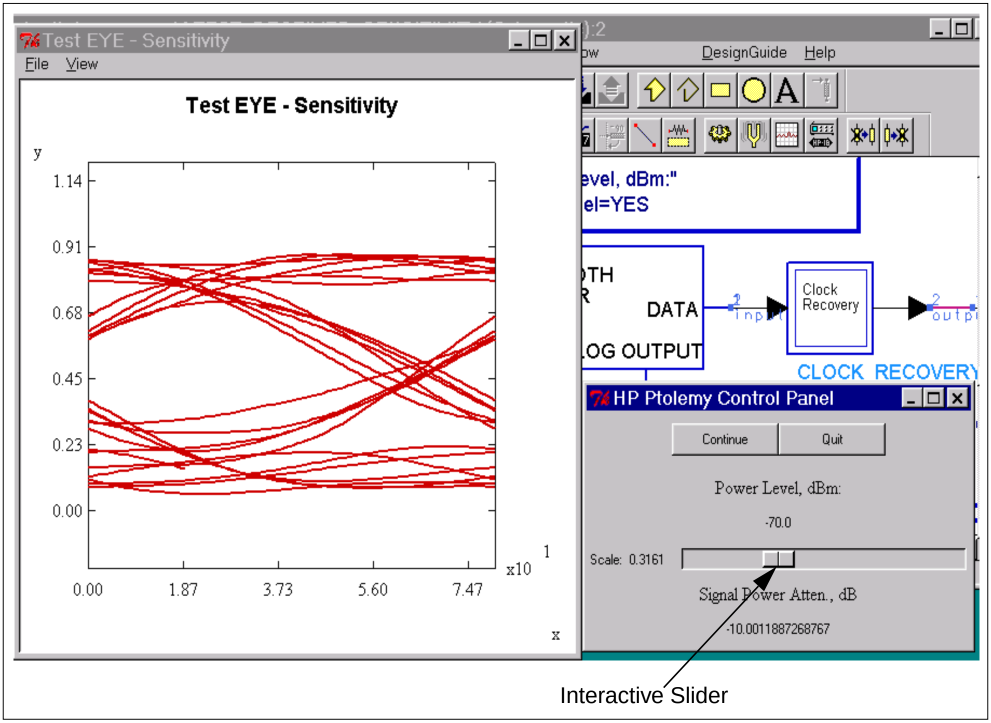
From each category, move the cursor to the right to open the menu that displays the available items. Each selection (except those named *Display....* will open a top-level test bench schematic and in many cases, a data display will also open.The *Display....* selections will open *additional* data displays, but only after the test bench listed above it has been opened. There are also menu selections to open this QuickStart help, a User Manual and an *About...* box.

Displaying Simulation Data

Some test benches have *real-time* Tk displays that open by themselves each time a simulation is performed. Other test benches will automatically open a Data Display window when selected. In several instances, for example a test bench that is capable of BER (Bit Error Rate) calculations, additional Data Displays are available. Access them by selecting the *Display.....* options listed under the test bench item on the menu, after the test bench has been opened.

Interactive Simulations

Some of the simulations that use Tk displays also have interactive *sliders* that allow a parameter to be adjusted during the simulation so the results can be immediately observed. When you want to run a non-interactive simulation so that output data are only collected by sinks, such as time-domain or spectrum measurements, all Tk items should be de-activated. The subnetwork *TkPowerControl* should also be de-activated and bypassed with a wire because it contains an interactive slider.



Chapter 2: Bluetooth DesignGuide Reference

The Bluetooth DesignGuide User Manual contains application guidelines for using the test benches provided with the Bluetooth DesignGuide, including:

- Basic System Test Benches
- Component/Subnetwork Evaluations
- VCO/PLL (Phase Locked Loop) Investigations
- Multipath Propagation Test Benches
- System Compliance Tests

.For a useful reference list, refer to the section “Catalog of Test Benches and Subnetworks” on page 2-18.

Note This manual assumes that you are familiar with all of the basic ADS program operations. For additional information, refer to the ADS User’s Guide. For access to the complete set of ADS online documents, select *Help* > *Topics and Index* from an ADS program window.

Where Do I Start?

Your first steps depend on whether you are creating or integrating a design:

- **Designing a Bluetooth solution**: This DesignGuide provides a reference receiver design that can be evaluated against measurements of your RF hardware and simulations of an ADS model of that RF hardware. There are also other tools that target specific components of the Bluetooth physical layer. It is suggested that you review the Basic System Test Benches first, followed by the Component/Subnetwork Evaluations (emphasizing filter selection). The VCO/PLL segment may be useful if you are either designing a synthesized source or need to optimize an existing design for good time-domain performance and phase noise characteristics. Finally, the System Compliance Tests focus on evaluating performance in the presence of interferers.
- **Integrating a Bluetooth solution**: For integrating into a product, such as another wireless device, handset or any environment with other RF emitters, the DesignGuide provides simulation-based tools for understanding system performance under various conditions. It is suggested that you review the Basic System Test Benches first, followed by the System Compliance Tests. The Multipath Propagation Test Benches add the ability to model certain indoor propagation conditions and observe the effect on the system's performance.

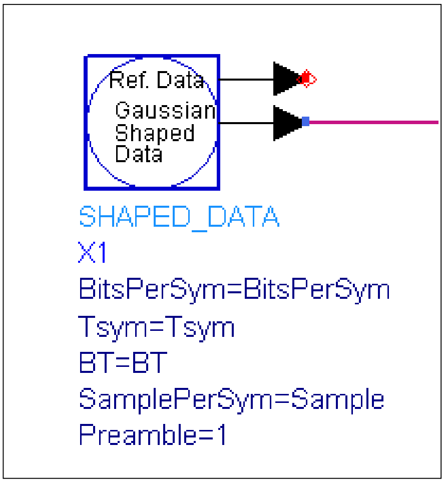
In the following sections, some important Test Benches are discussed in detail.

Basic System Test Benches

The basic system test benches provide an introduction to the Bluetooth RF interface. Here, we will use them to discuss in detail some of the main components and subnetworks used in the DesignGuide.

Ideal Transmit-Receive EYE Diagram (TEST_EYE.dsn)

This is a quick simulation to observe the eye diagram due to the combined effects of the transmitter and the complete receiver. This system is built from only the most basic components, starting with SHAPED_DATA. This component produces Gaussian-filtered MSK data according to the Bluetooth specification. An optional Preamble, which consists of the 10101010.....sequence may be included by setting Preamble > 1.



The output of SHAPED_DATA is input to an ideal ADS FM modulator component. The TkPowerControl follows, which allows the signal level to be adjusted using an interactive slider. The AWGN_CHANNEL adds thermal noise equal to -174 dBm/Hz to the signal

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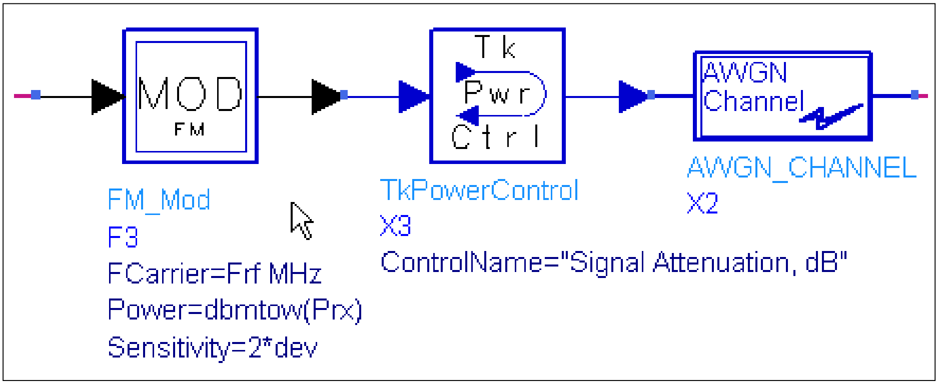
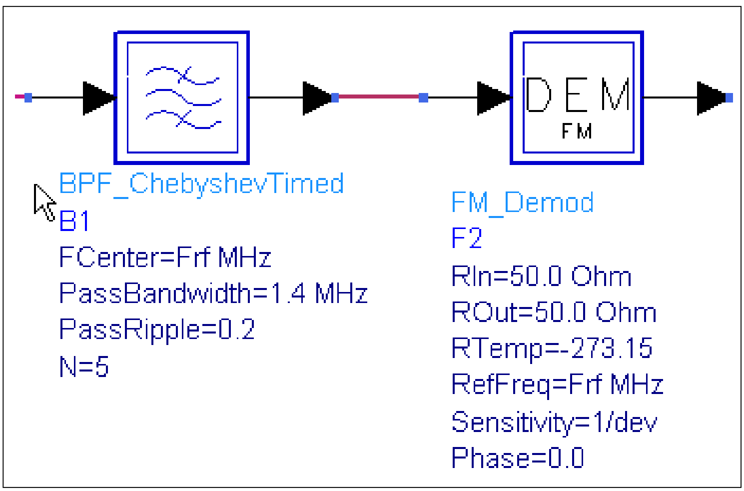
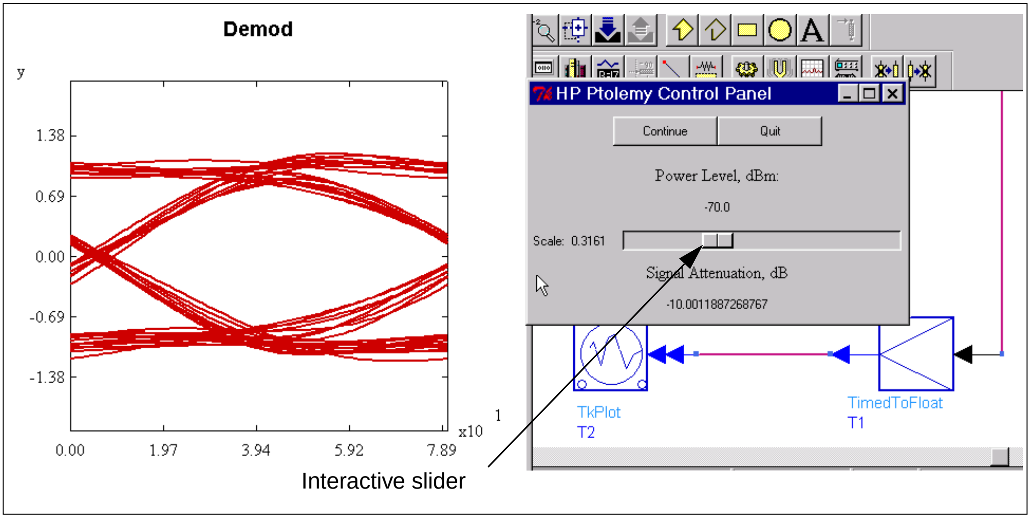


The signal is bandpass-filtered and ideally demodulated.



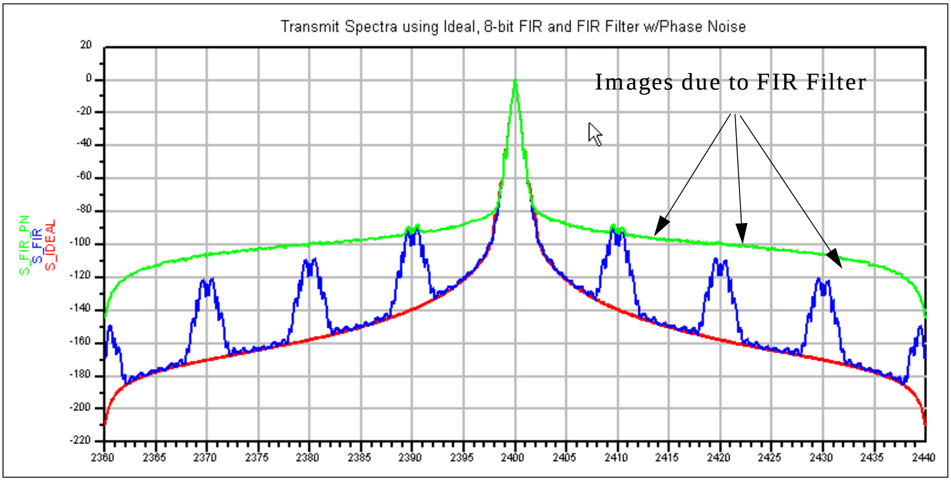


After scaling and conversion to floating-point, the EYE diagram is displayed on a TkPlot. In this simulation, SHAPED_DATA, TkPowerControl and AWGN_Channel are subnetworks created for the Bluetooth DesignGuide.

Transmit Spectrum (TEST_TX_SPECTRUM.dsn)

Summary This test bench is intended to illustrate some of the filtering options for the Bluetooth transmitter. When the 8-bit FIR filter is used, images of the spectrum are seen at intervals related to the sampling rate. However, these images are below the phase noise sidebands and are hence adequately filtered out.

Additional analysis of the FIR filter may be found by selecting *Component/Subnetwork Evaluations > Transmit Filter (Gaussian FIR).*



VCO/PLL (Phase Locked Loop) Investigations

In this category of Test Benches, a set of tools are provided to assist in the design and optimization of signal sources for a Bluetooth implementation. These are intended as basic tools that address some key performance requirements. For help with the full PLL design flow, the PLL DesignGuide for ADS is available.

VCO Response to Frequency Step (TEST_PLL_TR)

This test bench demonstrates Bluetooth Fractional-N Synthesizer transient response to an 80-MHz step. The VCO frequency is 2.4 GHz and the Reference frequency is 1 MHz. The output frequency is Fvco+N or 2.48 GHz. The loop bandwidth, fn, is 5 kHz.

This design, which is simulated under the Transient controller, uses the VCO_DivideByN and PhaseFreqDet components. The PFD output is coupled to the RC loop filter using the Voltage Controlled Current Source (VCCS). The frequency of the source must settle to within +/- 20PPM in 200 usec. To understand how to *optimize* the loop filter, select *VCO Parameter Optimization*.

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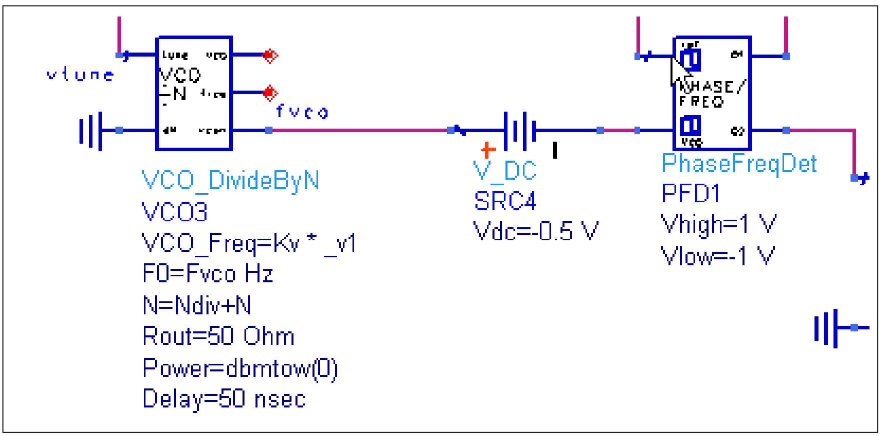
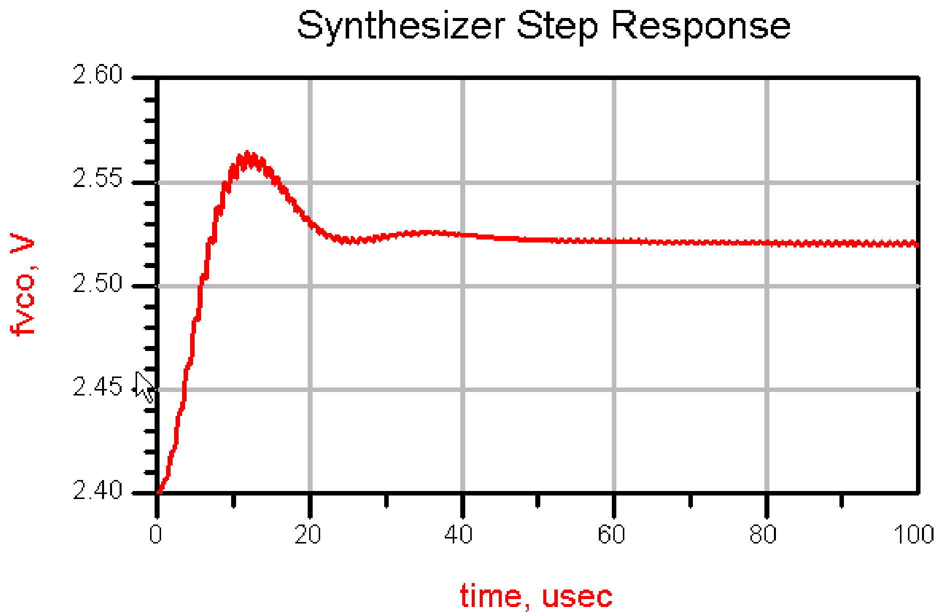



Synthesizer Step Response
2.60
2.55
2.50
2.45
2.40
fvco, V
0
20
40
60
80
100
time, usec

Component/Subnetwork Evaluations

Following are details on designs demonstrating component/subnetwork evaluations.

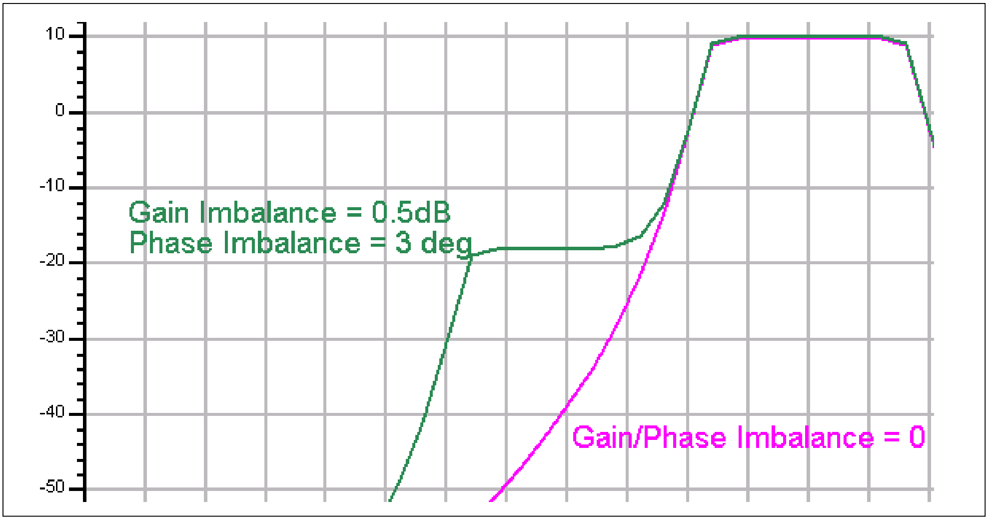
Channel Filter Impulse Response (TEST_FILTER_IMPULSE.dsn)

Summary This test bench evaluates the impulse response of the Bessel filter used for pulse shaping in the Bluetooth Receiver.

ADS has two main simulation modes: Analog/RF and DSP. This Test Bench compares the impulse responses of the circuit (A/RF) and timed (DSP) models, which can be very similar. The A/RF model has an advantage in that its group delay at the edge of the passband may be controlled. However, using it in a DSP design requires Transient cosimulation, which may be slower.

Channel Filter Swept Response (TEST_FILTER_COMPLEX.dsn)

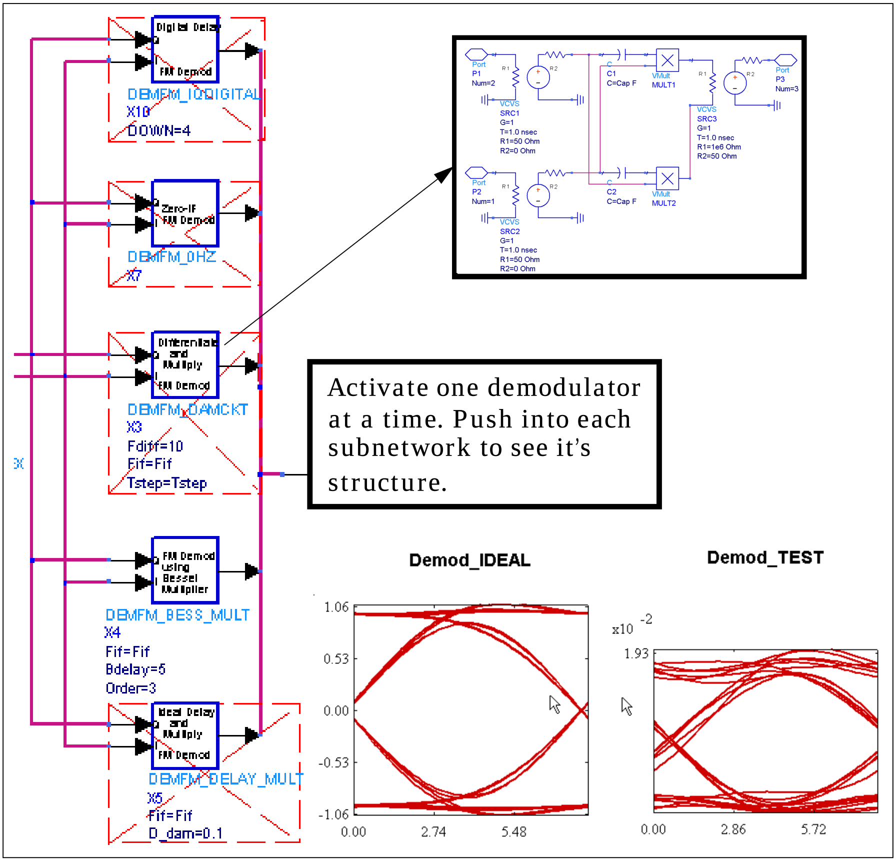
Summary This test bench sweeps the complex receive filter model used in the Design Guide (FILTER_CHEB_COMPLEX). Open Data Display TEST_FILTER_COMPLEX. Note that the QAM_Demod is set for a Gain Imbalance of 0.5 dB and a Phase Imbalance of 3 degrees. The data display compares the swept RF response to the balanced condition.



FM Demodulator Selection (TEST_LOWIF_FMDEMOD)

Summary An EYE diagram display allows for the relative performance of various demodulators to be observed. Due to the different output levels and the amount of residual DC for each demodulator, select *View* > *View ALL* on the Demod_TEST TkPlot to see the EYE diagram.

Demodulator selection is important when designing a Bluetooth solution because receiver performance is often largely dependent upon the demodulator's performance. The DesignGuide provides a choice of several demodulators.



Descriptions of each demodulator are available in the *Catalog* of subnetworks. The DEMFM_BESS_MULT is notable for excellent performance. An additional test bench, available under *FM Demod Selection w/Channel Filter* uses just a single complex Chebyshev channel filter in the receiver, instead of the high-pass/Chebyshev/limiter/Bessel signal path used in *TEST_LOWIF_FMDEMOD*. This puts additional requirements on the demodulator in exchange for a simpler signal path.

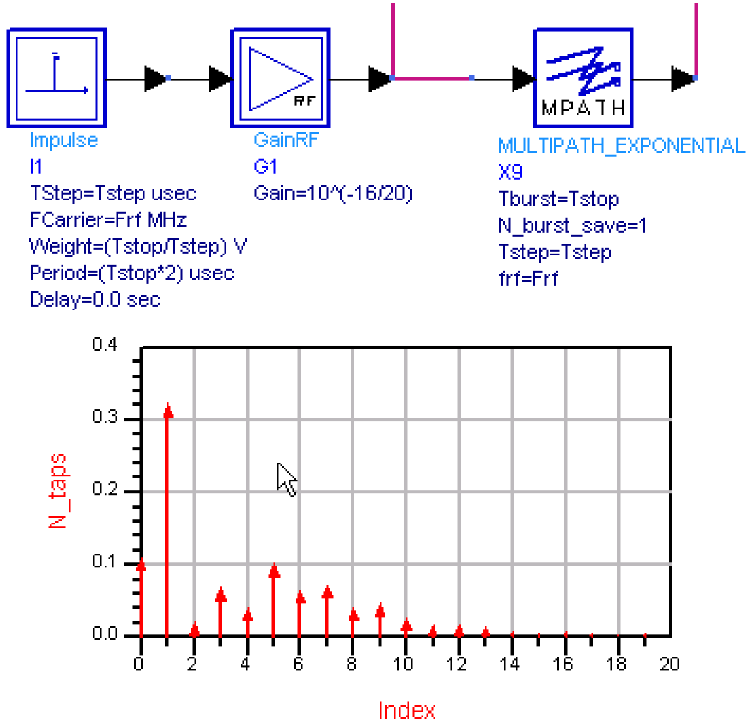
Multipath Propagation Test Benches

Following are summaries of test benches used for multipath propogation.

Multipath Impulse Response (TEST_MULTIPATH_IMPULSE)

Summary This test bench evaluates the MULTIPATH_EXPONENTIAL model using an impulse input. The delay spread profile is shown in the associated data display. Due to the use of a moving average over 512 symbols, the data display will require several minutes to open (about 2 minutes for a PIII/650 under Windows NT). Select *Display Impulse Response* after the schematic is displayed to show the data display window.

Note The Multipath subnetwork requires a large memory space due to its complexity. Performance will be reduced on systems having less than 256 MB of RAM.



Tap coefficients for one burst (typical)

The Multipath_Exponential model implements an exponential power decay multi-path channel model that is widely used for indoor propagation. The mean excess delay and the tap delay can be specified in microseconds. Each tap coefficient has a Rayleigh power distribution, and a uniform phase distribution. For a specified value of time *Tburst*, the channel snapshot is kept fixed. For the next *Tburst* duration, a new channel snapshot is taken. The tap coefficients for each snapshot are available. The corresponding values of the RMS delay spread and the mean excess delay are also available. TK plots for these measurements can also be enabled.

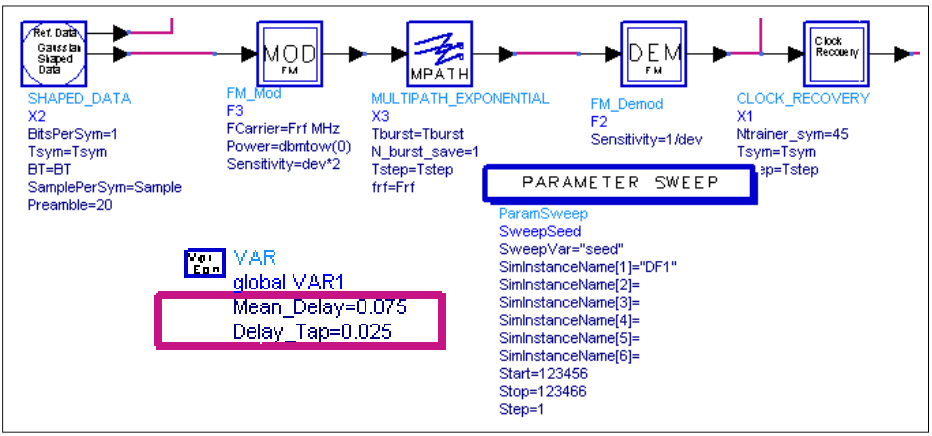
The tap coefficients are calculated by:

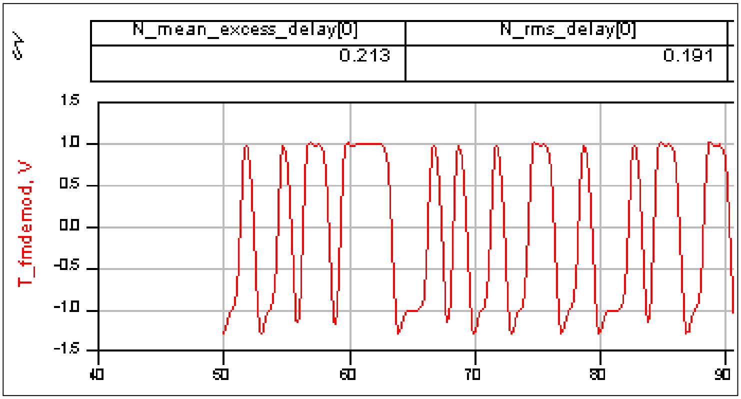
$$r = exp(-Delay\_Tap / Mean\_Delay)$$

$$a0 = 1 / Mean\_DelayDelay\_Tap,\ a1 = r*a0,\ a2 = r*a1, ...,\ an = r*a(n-1)$$

BER/Outage w/MPath, Noise, No Chan. Filter (TEST_MULTIPATH_BER_NOFILT)

Summary This test bench calculates the BER without a channel filter, but with multipath included. It will usually exhibit ideal BER because the C/N is large (the transmit power is 0 dBm and no noise is included). The mean delay is larger than for the other Multipath test benches, being set to 0.2 usec, and the tap delay is 0.05 usec. To observed channel outage, activate SweepSeed to vary the random seed value used by the Data Flow simulator. A channel with BER > 0.1% is considered to have caused a failed burst transmission. The simulation time is about 120 seconds (with ParameterSweeps deactivated), for 250 bits using a PIII/650 MHz under NT with 256 MB RAM. The simulation time will significantly increase if less than 256 MB of RAM are available.





The preceding figure shows a portion of the output display for multipath (0.2 usec delay setting) with no channel filter, at the output of the ideal FM demodulator. The Clock Recovery action must accept this distorted input and re-synch the data. It might be informative to vary this test bench by substituting other non-ideal demodulators such as the subnetworks provided with the DesignGuide, and observe their performance under multipath conditions.

System Compliance Tests

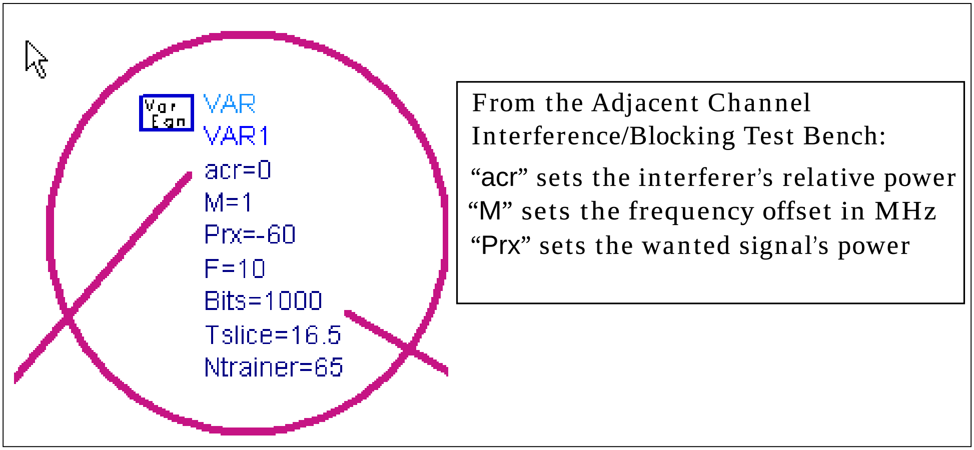
This category of test benches is intended to provide a convenient starting point for validating a Bluetooth system. The tests are based on the Bluetooth Specification version 1.0 B *Radio Specification*, Section 4, Receiver Characteristics and the RF Test Specification v.0.9r7, section on C/I performance, and are summarized in Table 2-1.

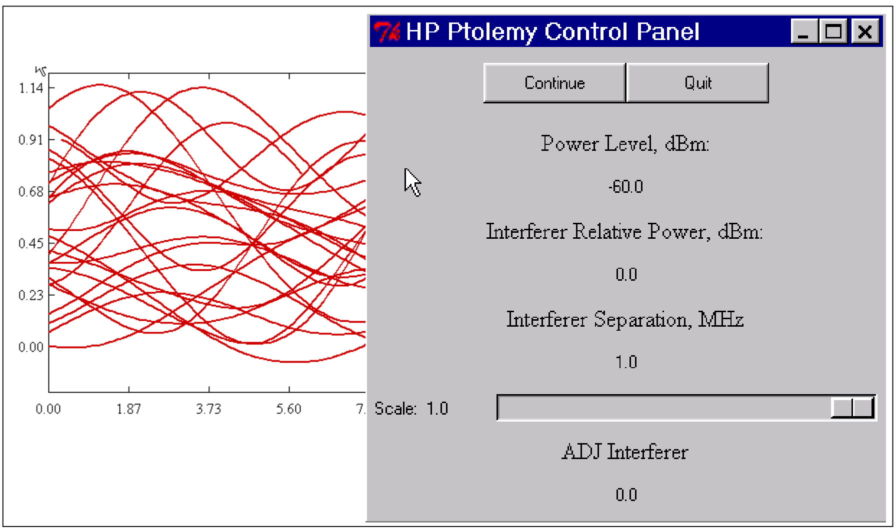
Table 2-1. Interference Performance Requirements

Interferer Type	**Interferer level P[dBc]**	**Wanted signal level, P[dB]>reference sensitivity**
Co-Channel interference, C/I	11 dB	10
Adjacent (1 MHz) interference, C/I Adjacent (2 MHz) interference, C/I Adjacent (1 MHz) interference, C/I	0 dB -30 dB -40 dB	10 10 3

Each test bench sets up a starting condition according to Table 2-1, and other conditions might be easily specified. For example, the adjacent interferer offset can be set to 1, 2, 3 or more MHz away from the wanted signal. An interactive slider provides for attenuating the interfering signal while observing the EYE diagram. For BER tests, the interactive slider is not used, and the appropriate components are de-activated as described on the test bench. In addition to the Co-Channel and Adjacent Channel tests, the following are also available:

- Combined Co-Channel/Adjacent Channel test
- Intermodulation test
- Pulsed Interferer with 2nd-order Intercept (IP2) Test Bench.





The preceding graphics show the EYE diagram and Control Panel for the Adjacent Channel Interference Test Bench. Moving the slider to the left will attenuate the interferer level.

Catalog of Test Benches and Subnetworks

Following are details on the available test benches and subnetworks.

Test Benches

Following are details on the available test benches/

Basic System Test Benches

TEST_TX_SPECTRUM.dsn. The spectrum of the transmitter can be simulated here. The effects of phase noise and Gaussian filter quantization can be observed, and checked against the allowed spectral template for various standards.

TEST_EYE.dsn. This is a quick simulation to observe the eye diagram due to the combined effects of the transmitter and the complete receiver.

TEST_TX_RX_EYE.dsn. The eye diagram corresponding to the detailed-model (full Transmitter and lowIF-Receiver with phase noise and filters) end-to-end link can be simulated in this design.

Component/Subnetwork Evaluations

SHAPED_DATA.dsn. This design models a two-level or four-level Gaussian filtered data source. It includes an initial two-level training sequence.

SLICER.dsn. This design extracts the average level of the analog de-Modulated signal and uses this level as the slicing reference to a comparator input. The incoming analog signal is sliced into digital bits by the comparator. The slicer behavior is depicted in the display SLICER.

TEST_CHANNEL_FILTER.dsn. The combined behavior of the high pass DC notch filters and the complex channel filter is simulated in this design.

TEST_FILTER_COMPLEX.dsn. The complex channel filter behavior of his simulated in this design.

TEST_FILTER_COMPLEX_TIME.dsn. The time domain response of the complex channel filter is simulated here.

TEST_FILTER_IMPULSE.dsn. The impulse response of circuit level and system level low pass Bessel filters are compared in this simulation. These low-pass Bessel filters were used in the design of the band pass complex Bessel filter. The system level model of the filter was preferred to speed up the simulation. However, it had to have an impulse response that was identical to that of the circuit level filter model.

TEST_GAUSSIAN_FIR_FILTER.dsn. The Gaussian filter is implemented digitally as a 17-tap FIR filter with a the six bit word length for each tap. The impulse response of the filter is simulated in this design. The impulse response is saved into a file. Data from this file is then used to define the tap coefficients of an FIR filter. The display TEST_GAUSSIAN_FIR_FILTER shows the impulse response.

TEST_LOWIF_FILTER_DEMOD.dsn. This test bench is used for comparing and optimizing the combination of the channel filter along with various types of poly phase FM Demodulators.

TEST_LOWIF_FMDEMOD.dsn This is similar to the TEST_LOWIF_FILTER_DEMOD.dsn test bench. The effect of a poly phase harmonic suppression band pass filter at the output of the hard limiters is investigated.

TEST_LOWIF_RECEIVER.dsn. This is similar to the TEST_LOWIF_FILTER_DEMOD.dsn test bench. The complete receiver chain is investigated.

VCO/PLL (Phase Locked Loop) Investigations

TEST_PLL_SS.dsn. The RF synthesizer reference frequency spurs due to charge pump mismatch can be observed in this harmonic balance steady state simulation.

TEST_PLL_TR.dsn. The transient response of the RF synthesizer is simulated in this test bench.

TEST_PLL_TR_linear.dsn. This is the main test bench for optimizing the RF synthesizer parameters. The loop filter components are defined in terms of 2 parameters: *z* (related to damping constant) and *fn* (related to loop band with). The various results are shown in displays beginning with the name TEST_PLL_TR_linear.

Multipath Propagation Test Benches

TEST_MULTIPATH_ IMPULSE. The impulse response of the multi-path channel is simulated in this design. The frequency response of the channel is obtained, with and without averaging done over any given modulation bandwidth, e.g. 1 MHz for Bluetooth. The results are shown in the display TEST_MULTIPATH_ IMPULSE. At frequencies where there is a large relative channel loss without averaging, one can expect severe intersymbol interference due to multi-path. It can also be seen that the correlation bandwidth is approximately the inverse of the RMS delay spread.

TEST_MULTIPATH_POWER. Varies the channel snapshot, and measures the corresponding Modulated signal average power at the output of the channel. The corresponding RMS delay spread values are also available. The display TEST_MULTIPATH_POWER_200_50_seed shows the simulation results for a 200 ns delay spread using tap spacing of 50 ns. A large number of channel snapshots were taken for the simulation. The pdf and cdf distributions of the multi-path loss are also shown.

TEST_MULTIPATH_EYE. This shows the TK plot of the FM de-Modulated eye diagram under multi-path conditions. The corresponding multi-path tap coefficients and RMS delay spread values are also shown.

TEST_MULTIPATH_ EXPONENTIAL. This simulation shows the variations in both the mean power and the instantaneous Modulated power for various channel snapshots, along with the corresponding delay spreads.

TEST_MULTIPATH_BER. This simulation measures the BER for various channel snapshots. It is useful for computing the channel outage when the signal to noise ratio is large. See display TEST_MULTIPATH_BER for one particular channel snapshot. It shows the eye diagram, the channel snapshot, the recovered and transmitted bits, the BER, and the RMS delay spread. For channel outage simulations, only the BER should be enabled and the seed and/or frequency varied over a large number of points.

TEST_MULTIPATH_BER_AWGN. This performs simulations similar to that in TEST_MULTIPATH_BER, but it also includes additive white Gaussian channel noise. The input signal power level to an ideal receiver (0 dB noise figure) can be set. It shows the BER for both channel noise and multi-path. For channel outage simulations, only the BER should be a enabled, along with the channel power measurement if required. For an example, see display TEST_MULTIPATH_BER_AWGN (100 ns delay spread simulation for channel outage) in which the signal power was set 3 dB above the 1% sensitivity level (AWGN case without multipath).

TEST_MULTIPATH_BER_NOFILT. This performs simulations similar to that in TEST_MULTIPATH_BER, but the channel filter is not included. In therefore shows the ideal BER underlarge signal to noise conditions.

System Compliance Tests

TEST_RECEIVER_ADJ.dsn. The receiver adjacent channel rejection can be simulated in this test bench. The rejection at alternate channel frequency, the image frequency, and the alternate channel to image frequency are the interesting points for the simulation.

TEST_RECEIVER_CCR.dsn. The co-channel rejection of the receiver can be simulated here.

TEST_RECEIVER_TEST_INTERMOD.dsn. The effects of two-tone jammers due to third order receiver non-linearity and the reciprocal mixing of these jammers due to phase noise are simulated here.

TEST_RECEIVER_SENSITIVITY.dsn. The receiver sensitivity in an addictive white Gaussian noise channel at -174 dBm/Hz is simulated in this design.

TEST_RECEIVER_IP2.dsn. The effect of out of band pulsed jammers on the receiver sensitivity is modeled in the RECEIVER_IP2 design. The pulsed jammers produce pulsed DC offsets in the baseband quadrature signal paths. The relative power of the jammer and the co-channel rejection of the receiver are the variables that can be set in the TEST_RECEIVER_IP2.dsn top level simulation. Based on this, the required IP2 is computed and use in the top level BER simulation.

Subnetworks

AGC. This block is used at the output of the MULTIPATH_EXPONENTIAL block for setting the mean output power to a given fixed level, instead of letting it vary with each channel snapshot. It measures the mean power of the signal coming from the MULTIPATH_EXPONENTIAL block in a small time window, after which it adjusts the gain in order to set the mean power at the design level.

AWGN CHANNEL.dsn. Models the Thermal Noise of an RF channel.

CLOCK_RECOVERY.dsn. Used for a bit-timing recovery and sampling of sliced data in the receiver. This sub-network extracts the bit timing from an initial stream of data, and then freezes the recovered block phase after *Ntrainer_sym* bits. It also samples the de-Modulated bits at the middle point of each bit using the recovered clock.

DEMFM_OHZ.dsn. A zero-IF poly phase FM demodulator including a down converter from low-IF zero-IF.

DEMFM_BESS_MULT.dsn. A delay and multiply poly phase FM demodulator. The delay is implemented using a Bessel filter. This novel method provides exceptional performance when compared to the other demodulators.

DEMFM_DAMCKT.dsn. A *differentiate and multiply* poly phase FM demodulator at the A/RF circuit level.

DEMFM_DELAY_MULT.dsn. A system level delay and multiply poly phase FM demodulator.

DEMFM_IQDIGITAL.dsn. A poly phase digital FM demodulator.

FILT_HP_50KHZ N1.dsn. First- order high pass filter generated from the DSP filter designer in ADS. It is used in the RECEIVER to remove DC following down-conversion.

FILT_LP_N1.dsn. First order low pass filter.

FILTER_BESSEL_COMPLEX.dsn. Poly phase band pass filter with Bessel response.

FILTER_BESSELckt.dsn. Circuit level (Analog/RF) sub-network used in FILTER_BESSELckt_COMPLEX.dsn.

.FILTER_BESSELckt_COMPLEX.dsn. Complex filter sub-network used in DEMFM_BESS_MULT.

FILTER_CHEB_COMPLEX.dsn. Complex filter sub-network used as a channel filter in the RECEIVER.

MIXER_COMPLEX.dsn. Complex mixer used in the system-level implementation of poly phase bandpass filters.

MULTIPATH_EXPONENTIAL. This design implements an exponential power decay multi-path channel model that is widely used for indoor propagation. The mean excess delay and the tap delay can be specified in microseconds. Each tap coefficient has a Rayleigh power distribution, and a uniform phase distribution. For a specified value of time *Tburst*, the channel snapshot is kept fixed. For the next Tburst duration, a new channel snapshot is taken. The tap coefficients for each snapshot is available. The corresponding values of the RMS delay spread and the mean excess delay are also available. TK plots for these measurements can also be enabled.

MULT_RF_BB.dsn.Subnetwork used in MULTIPATH_EXPONENTIAL.

MULTIPATH_TAP_C.dsn. Sub-network used in MULTIPATH_EXPONENTIAL to generate random noise and phase characteristics according to the exponential tap coefficients.

OSC_PN.dsn. System level RF oscillator with phase noise.

OSC_PN_FMMOD.dsn. Baseband phase noise generator use as modulation input voltage to an FM modulator.

PLL_TR_linear.dsn. Used in TEST_PLL_NOISE and TEST_PLL_TR_linear.

POWER.dsn. Output is a signal that has a value equal to the input signal power in dBm. It is useful in evaluating the effect of multipath fading.

POWER_GATED.dsn. Time-gated version of POWER.dsn.

TRANSMITTER.dsn. The Transmitter is used in most of the Test Benches. It is constructed using SHAPED_DATA and OSC_PN_FMMOD, plus an ideal FM modulator. Top-level parameters include the phase noise level and Q.

RECEIVER.dsn. The Bluetooth receiver has a front-end low noise amplifier that models the noise figure and the third-order intercept point. It is followed by a quadrature amplitude demodulator that includes the phase and gain imbalance. The local oscillator for this demodulator/down converter includes the phase noise. The output of the quadrature amplitude demodulator is a 1 MHz low IF complex signal comprising the in-phase and quadrature phase signals. These signals are high pass filtered to remove DC offsets due to local oscillator self mixing, and to remove time varying DC offsets as a result of second order non-linearity effects on out of band pulsed jammers. After the high pass filters, there is a complex channel filter with quadrature inputs and outputs. This filter is centered at 1 MHz and has an asymmetric positive and negative frequency response The quadrature outputs of the channel filter are hard limited and then de-Modulated by a complex FM demodulator. This FM demodulator can be implemented in various ways. The preferred Solution is to have a complex Bessel filter that implements a delay, with the delay signals cross-multiplied with the inputs signals and then summed at the output. The combination of the complex channel filter and this Bessel filter have to be carefully designed to produce the minimum distortion of the de-Modulated signal. The demodulator and signal have unwanted high frequency components that are removed by the following data filter. Following the data filter is the data slicer that converts the analog demodulated signal into digital bits.

RECEIVER_IP2.dsn. The effect of out of band pulsed jammers on the receiver sensitivity is modeled in the RECEIVER_IP2 design. It is otherwise similar to RECEIVER.dsn. The pulsed jammers produce pulsed DC offsets in the baseband quadrature signal paths. The relative power of the jammer and the co-channel rejection of the receiver are the variables that can be set in the TEST_RECEIVER_IP2.dsn top level simulation. Based on this the required IP2 is computed and use in the top level BER simulation.

SHAPED_DATA. This sub-network implements both 2 and 4 level pulse shaping for GFSK modulation. In addition, a {10101010.....} preamble is inserted at the start of the simulation.

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