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Advanced Wireless LAN Receiver Testing

July 22, 2003

presented by:

Afshin Amini

Agenda

- Receiver testing and Packet Error Rate
- Case example 1: Measuring PER at RF/IF/Analog baseband section
  - Minimum level Receiver Sensitivity test for 802.11g OFDM with a LNA – RF
  - Adjacent Channel Rejection for 802.11g OFDM- IF
  - Bluetooth interference on 802.11g OFDM-RF
  - IQ gain imbalance for 802.11a or 802.11g- Analog baseband
- Case example 2: Measuring PER at IF to Digital baseband section
  - Sensitivity test for 802.11g OFDM measured at ADC output- Digital
- Summary

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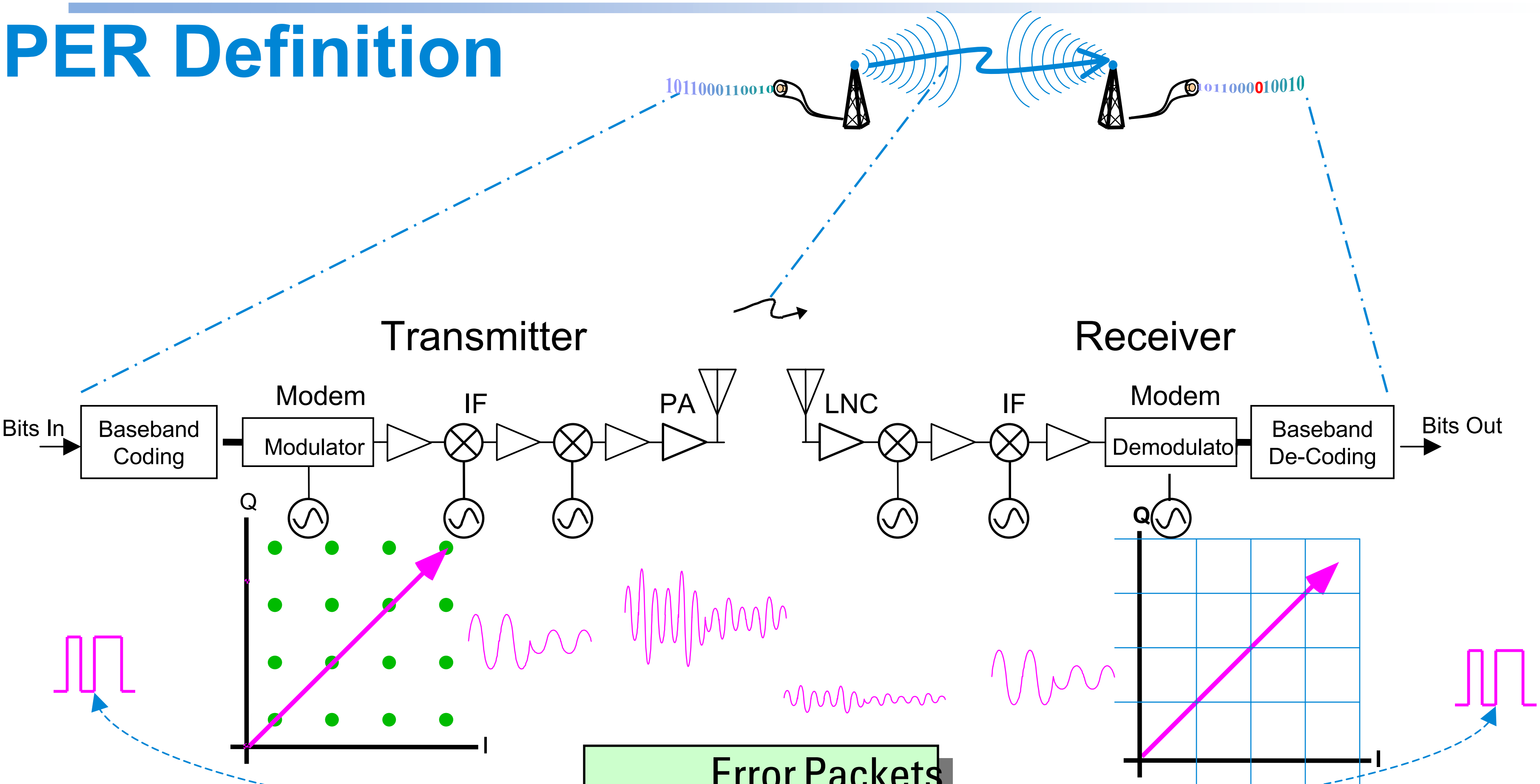
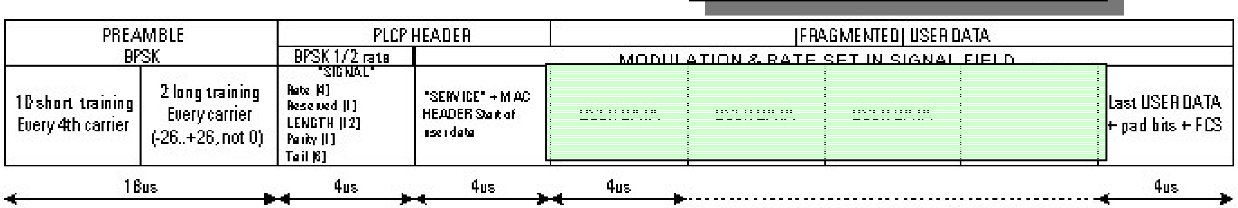
Radio System Diagram

PER Definition



$$PER = \frac{\text{Error Packets}}{\text{Total Packets}}$$



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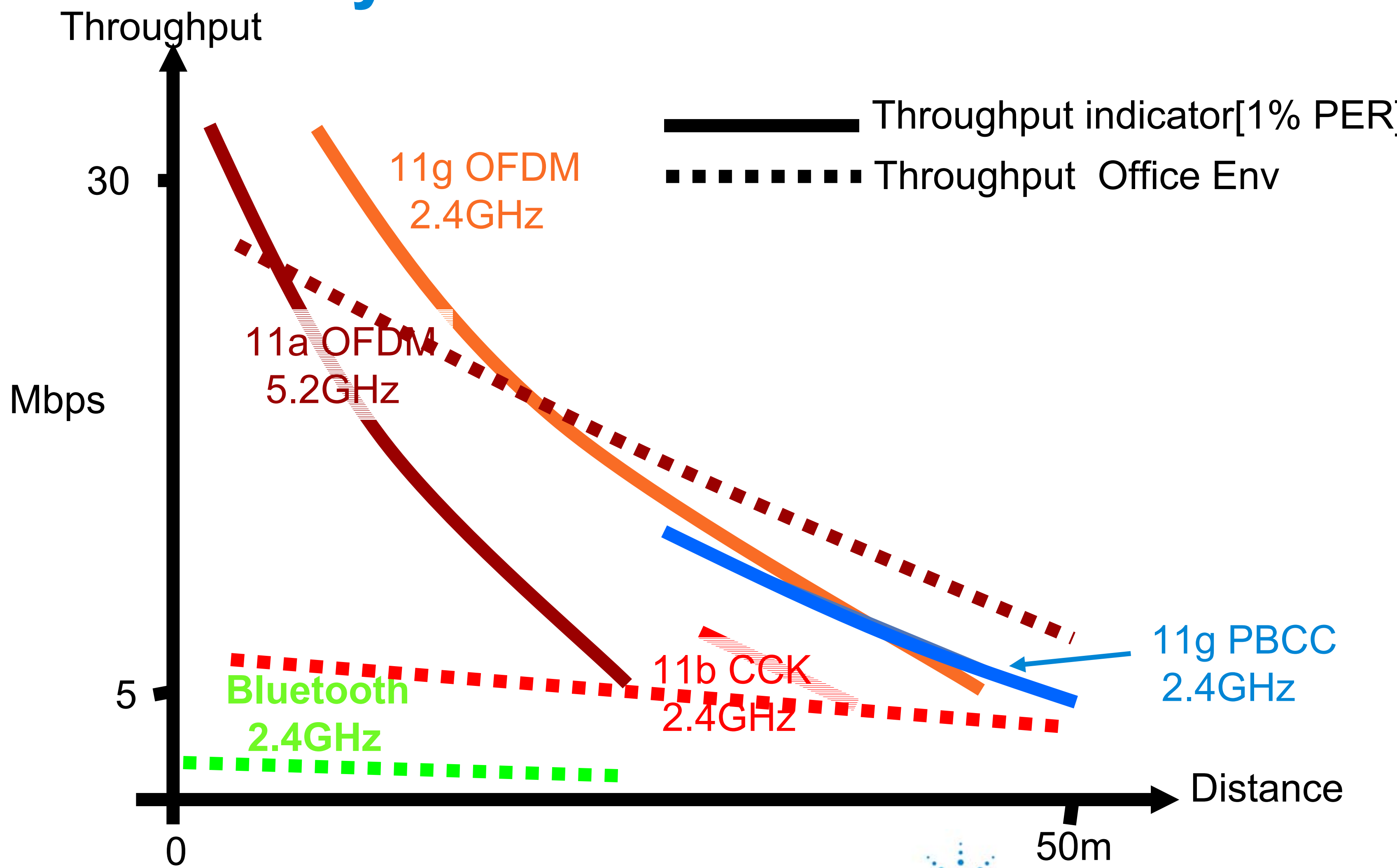
Throughput versus Range

Need for early test and verification



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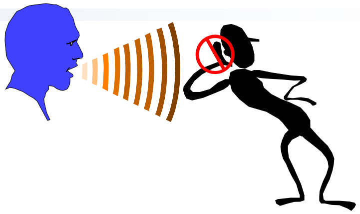
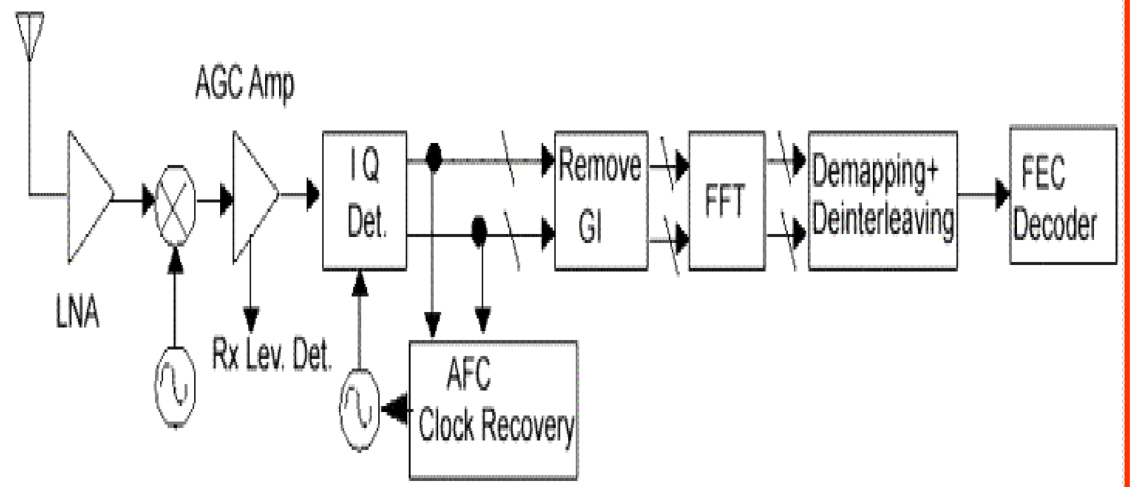
WLAN Receiver performance--Issues



- Receiver Sensitivity-rate dependent measured at 10% PER
- Interference-adjacent channel, radio co interference (ISM)
- Random noise, phase noise
- Improved receiver performance can improve range & data rate



802.11g OFDM Rx

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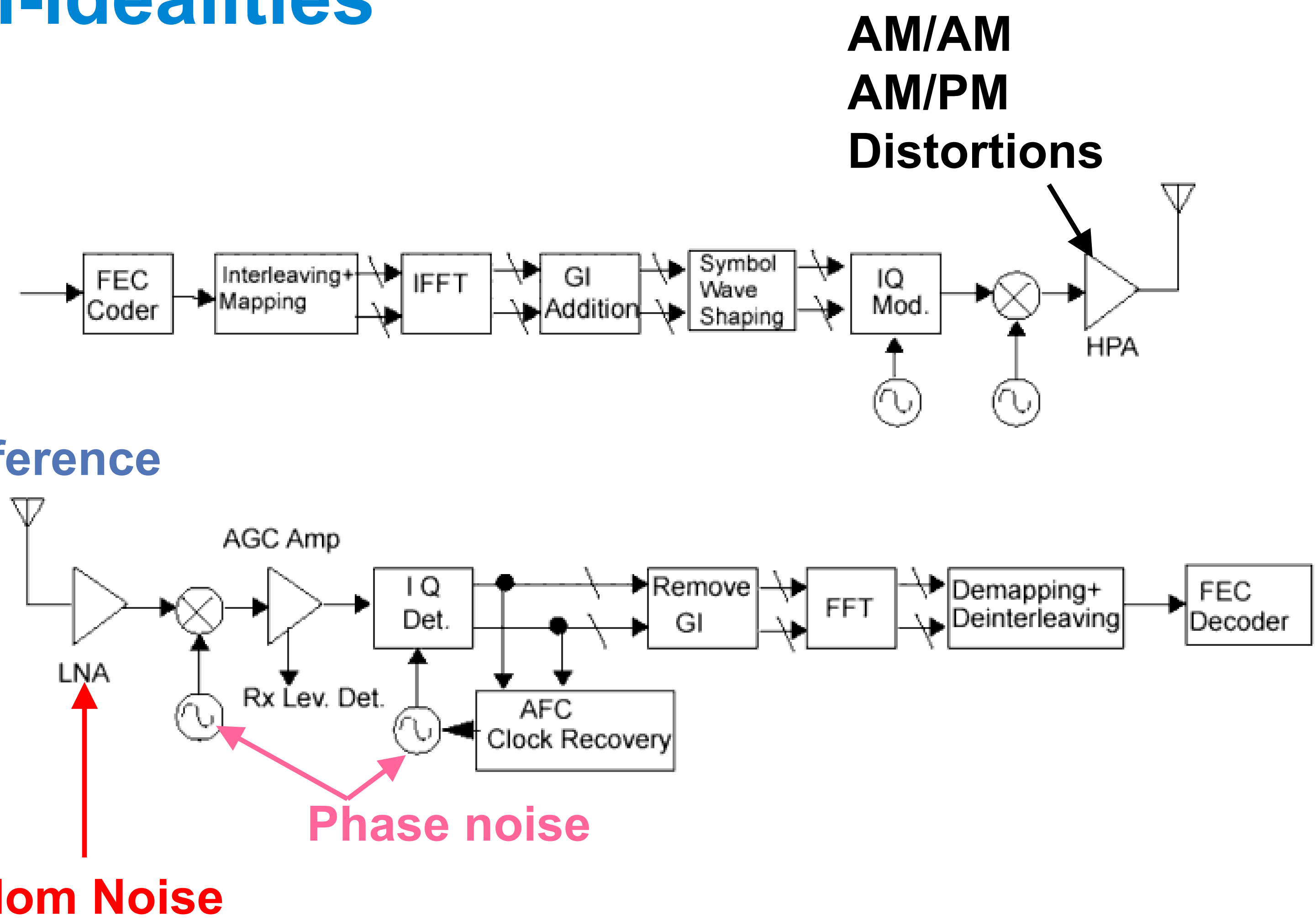
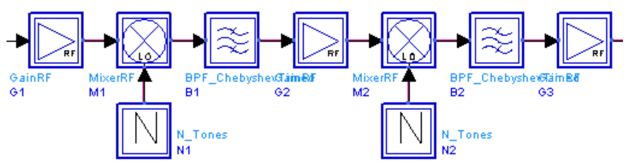
WLAN -transceiver

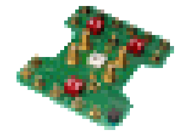
Non-idealities



Transitioning from Design to Hardware

Receiver Design Example





- Requires End-to-End Hardware (RF + Baseband)
- Baseband Functionality Needed for Coded PER
- Difficult to Verify Early in a Design Process
- Can Receiver be Verified under Impaired Conditions? (e.g. fading, multipath)
- May have Significant Schedule & Cost Risk if Problem Identified Late in the Design Cycle

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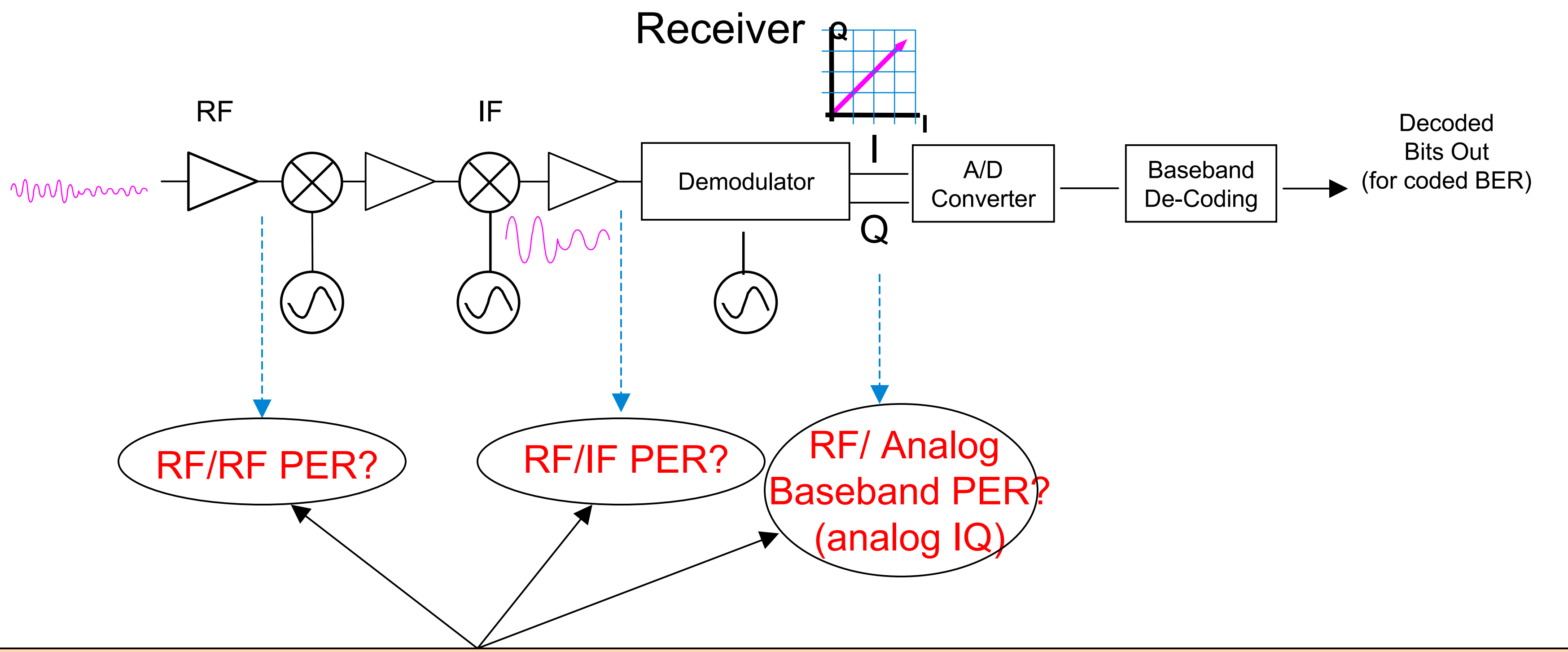
Where Does this Case Study Apply?



This case study can be applied to RF component testing or RF/IF subsystem testing, or RF/analog baseband testing

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Measuring *RF/RF PER for WLAN*

IEEE 802.11g

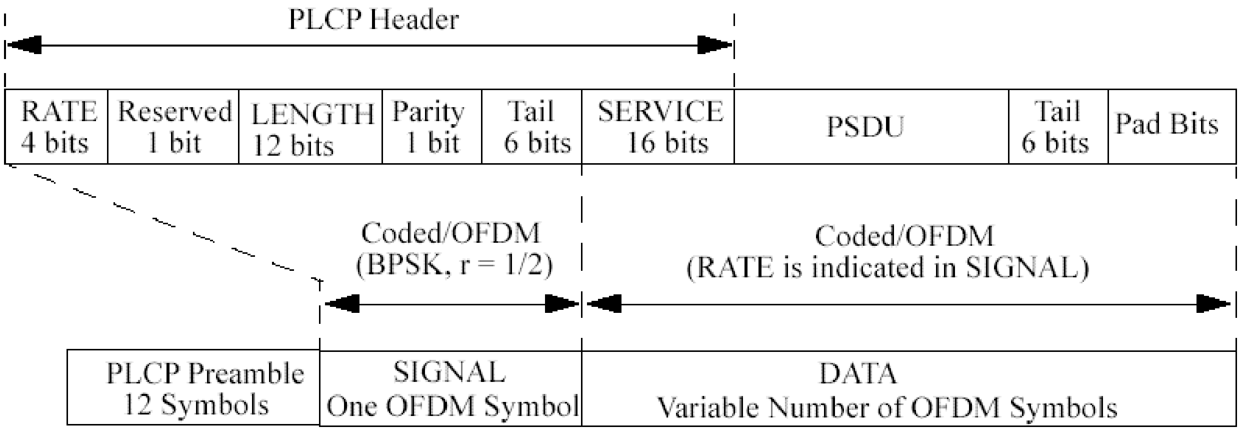
Challenges:

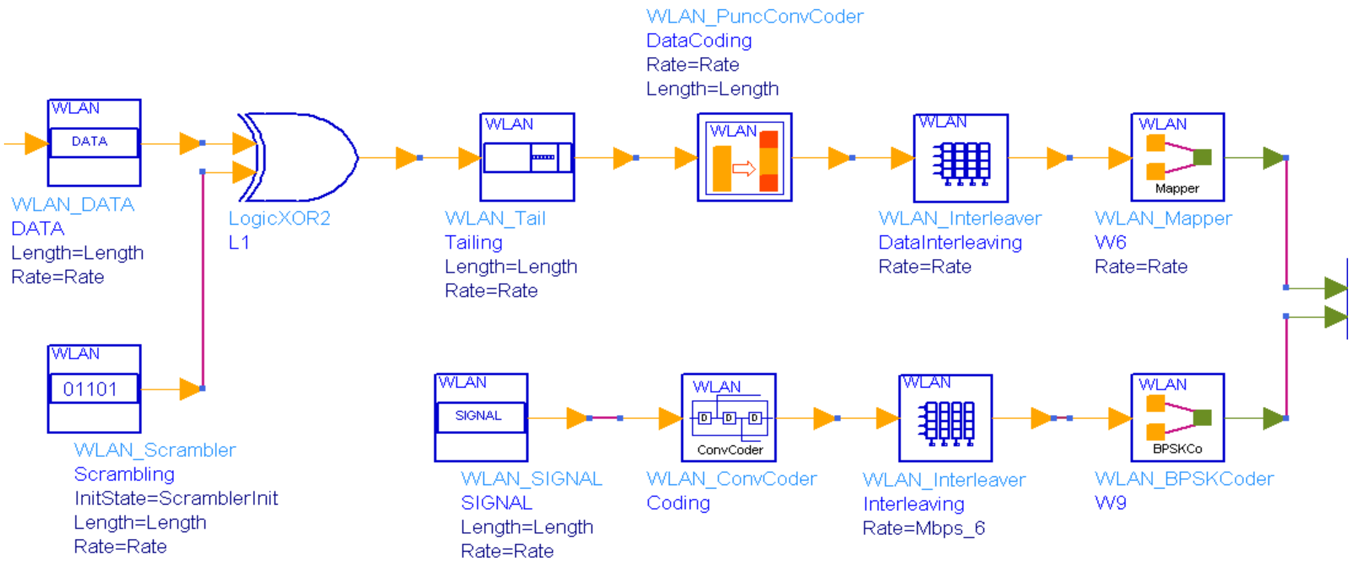
How does one show the system-level coded PER effect of an RF component

Case Study Objective:

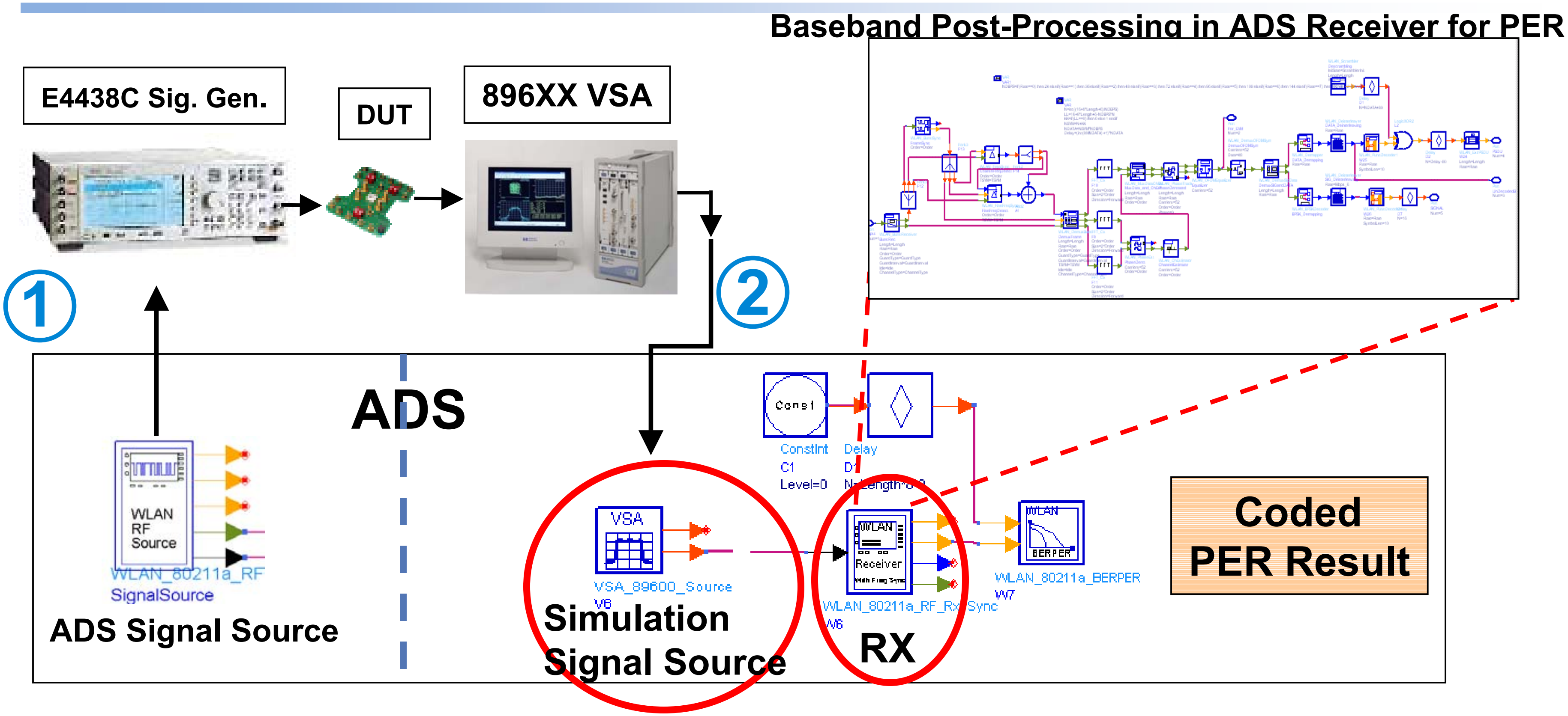
Show WLAN coded PER measurement with a Low Noise Amplifier (LNA) DUT

IEEE 802.11g- Frame structure





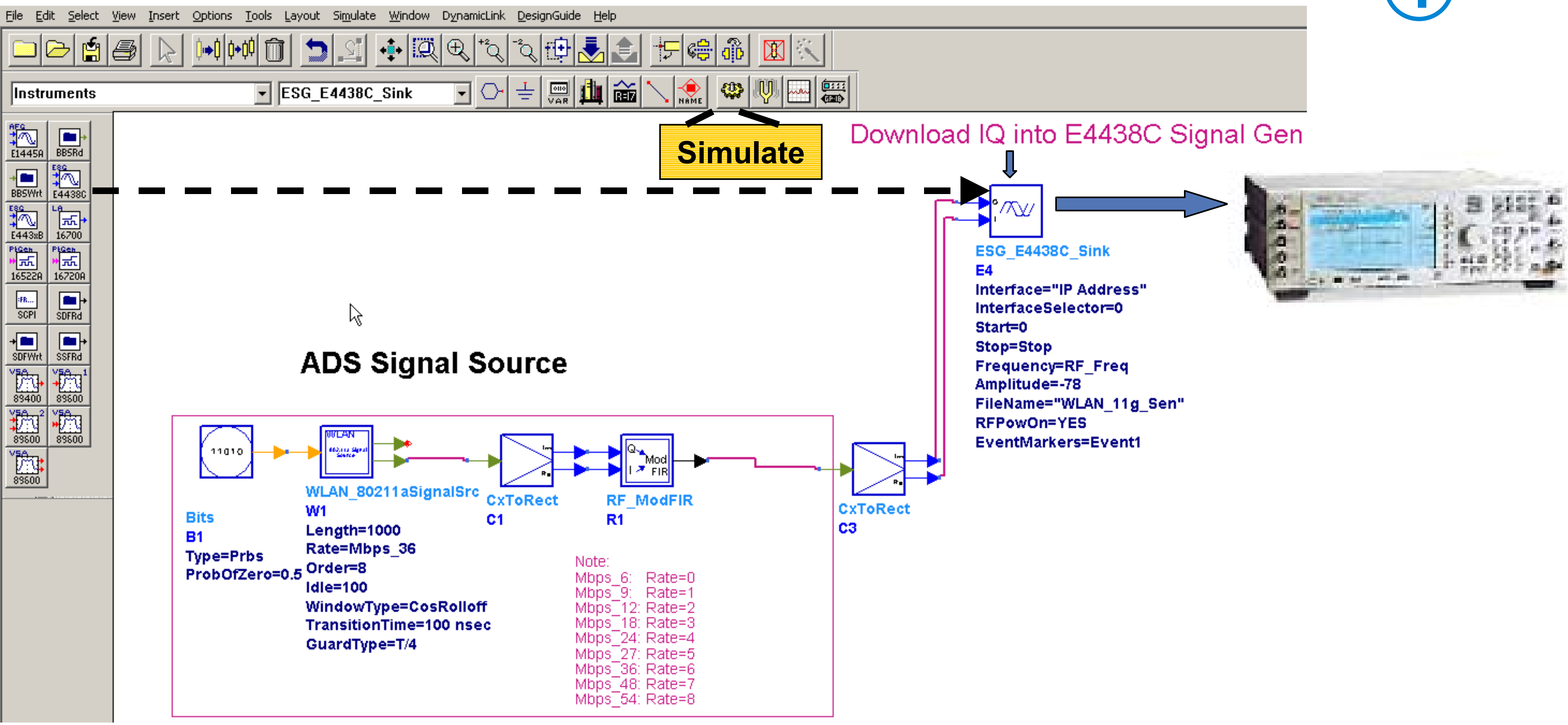
Simulation + Test



- Baseband Receiver Functionality
- Perform Coded Packet Error Rate Measurements for WLAN, and other Signal Formats
- Get More Functionality Extend the Capability of the VSA by Simulating ADS by Combining Design & Test Solutions Together

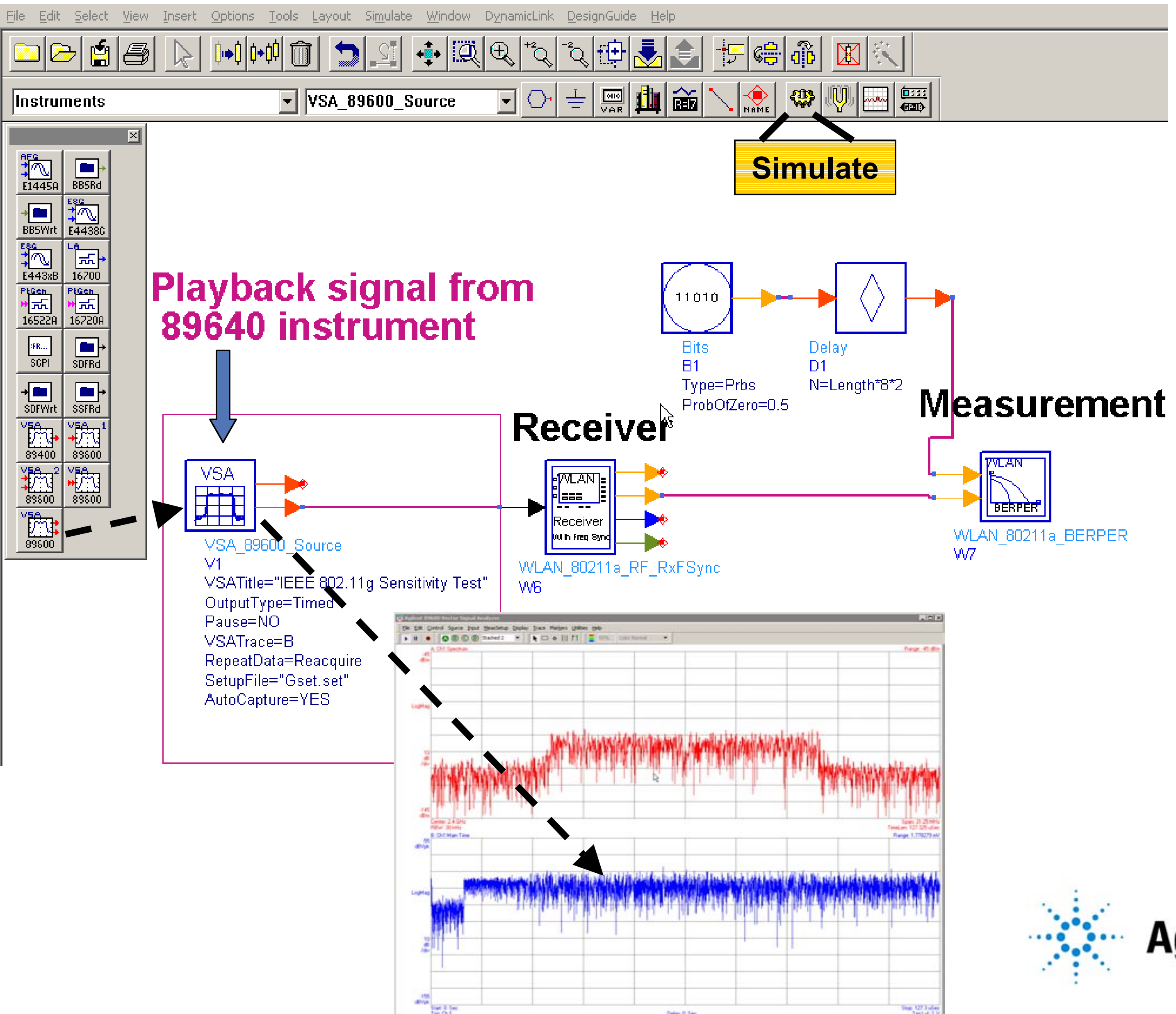
Download IQ into Signal Generator

①



Signal Analyzer Playback

②



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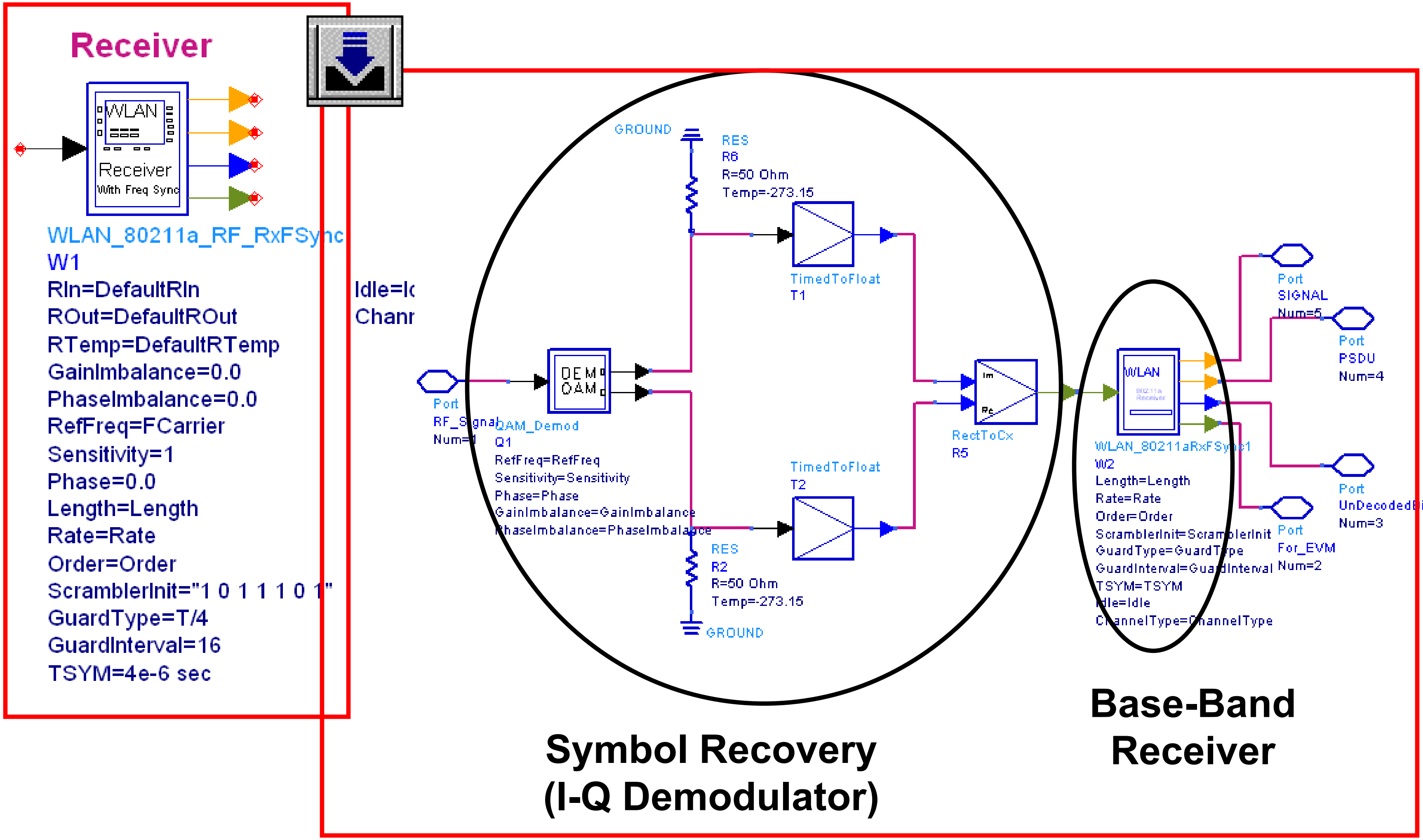
ADS WLAN RF Receiver



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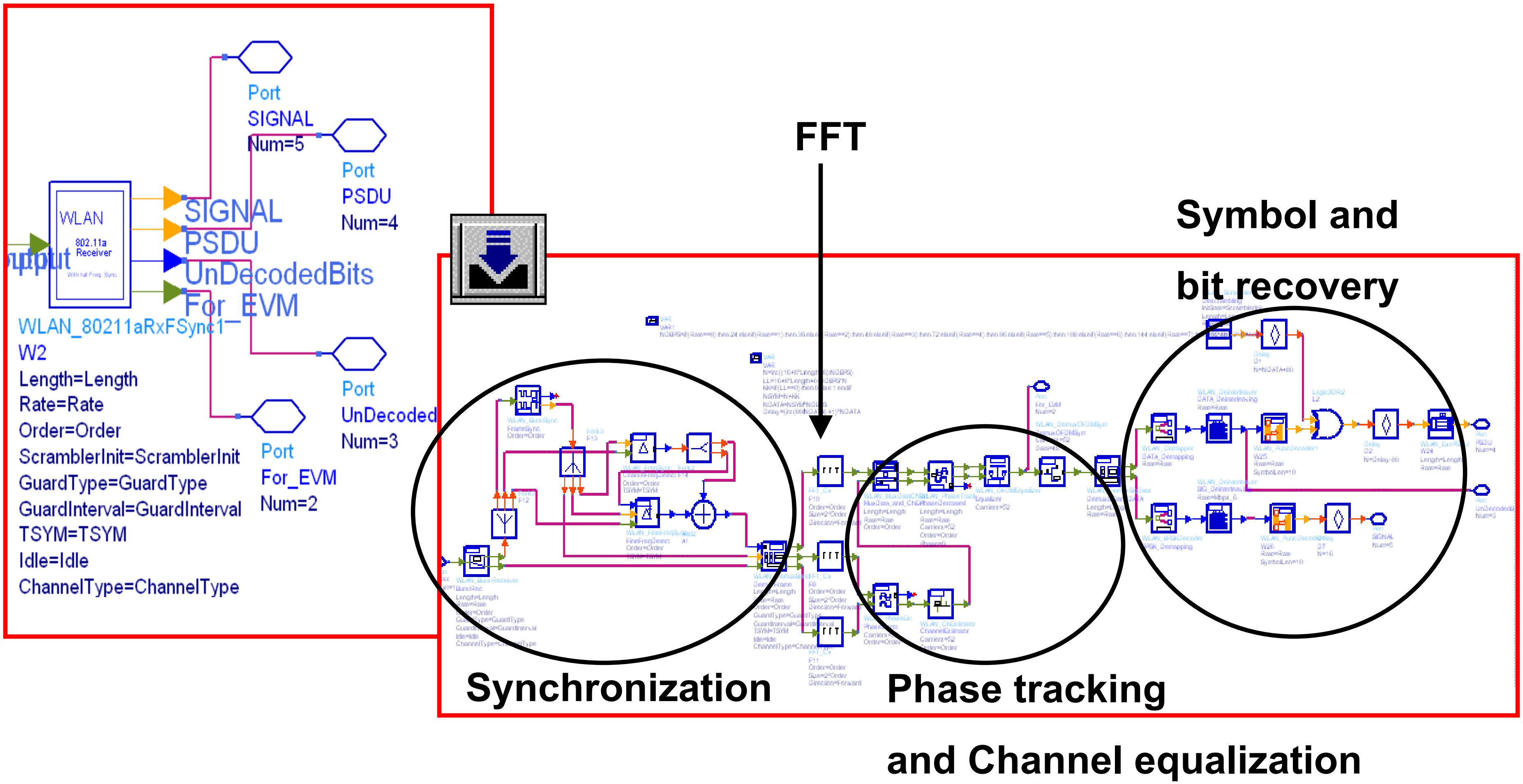
ADS WLAN Baseband Receiver



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802.11g Receiver Sensitivity Level

IEEE standard

Receiver minimum input level sensitivity

Table 91

The PER shall be less than 10%, when the minimum sensitivity is set to the data-rate dependent value below.

Data Rate (Mbps)	Minimum sensitivity (dBm)
6	-82
9	-81
12	-79
18	-77
24	-74
36	**-70**
48	-66
54	-65

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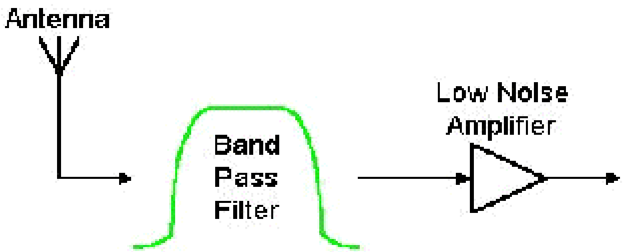
Sensitivity Test with LNA Component

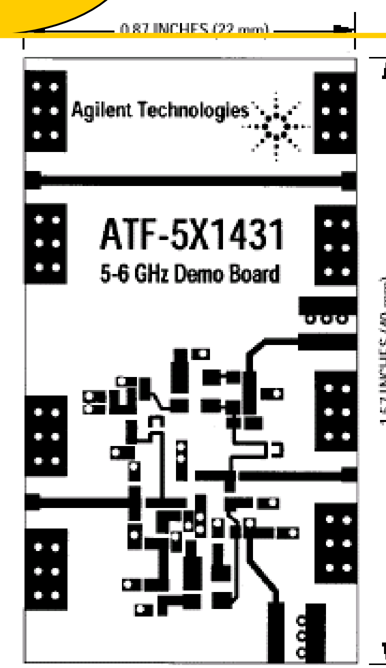


functional receiver frontend

Verify HW Amplifier using ADS Connected Solution

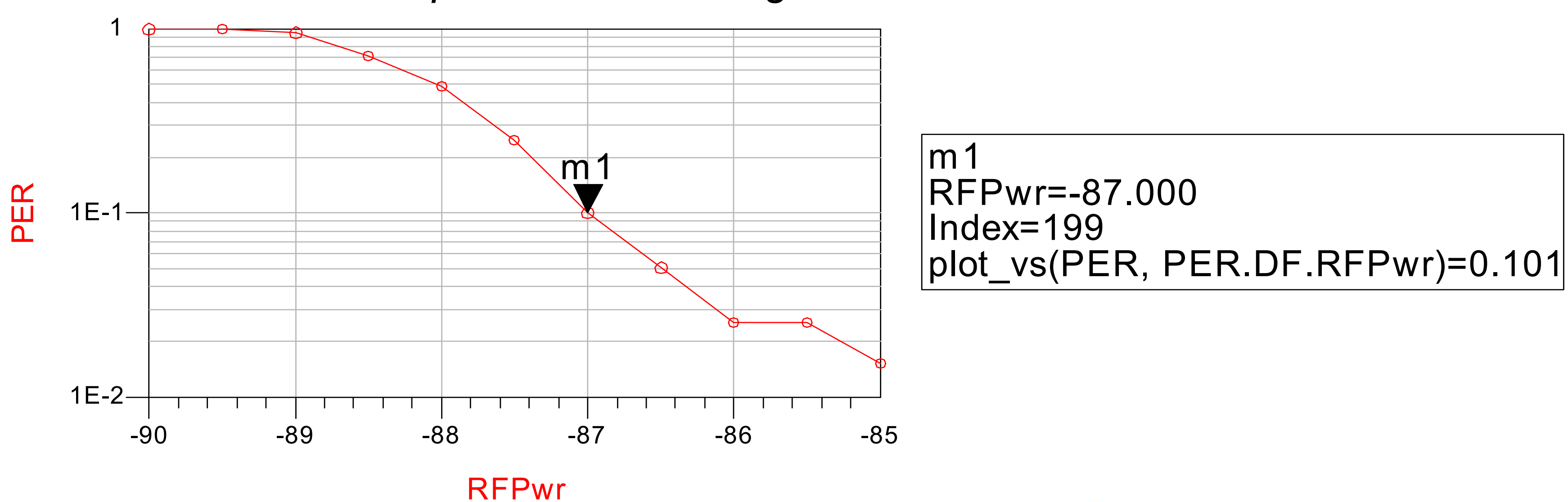
Single Stage E-pHEMT based Amplifier

Supply Voltage/Id =3.3 V/15 mA
P-1 dB= 10 dBm
Gain = 10 dB
Noise Figure = < 1.5dB



ADS Ideal Receiver Sensitivity Results

- Ideal Rx: sensitivity = -87 dBm
- Standard requirements: sensitivity < -70dBm (36 Mbps)
- *There is room for (the standard allows for):*
  - » *NF = 10 dB*
  - » *Implementation margin = 5 dB*



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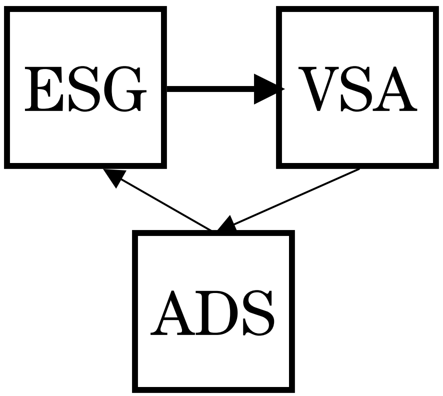
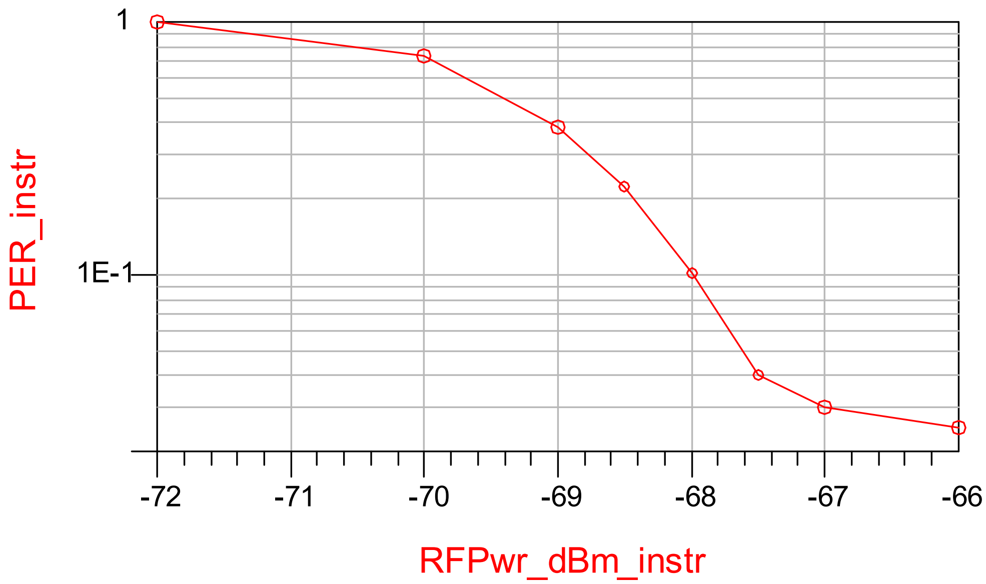
WLAN Connected Solutions Baseline

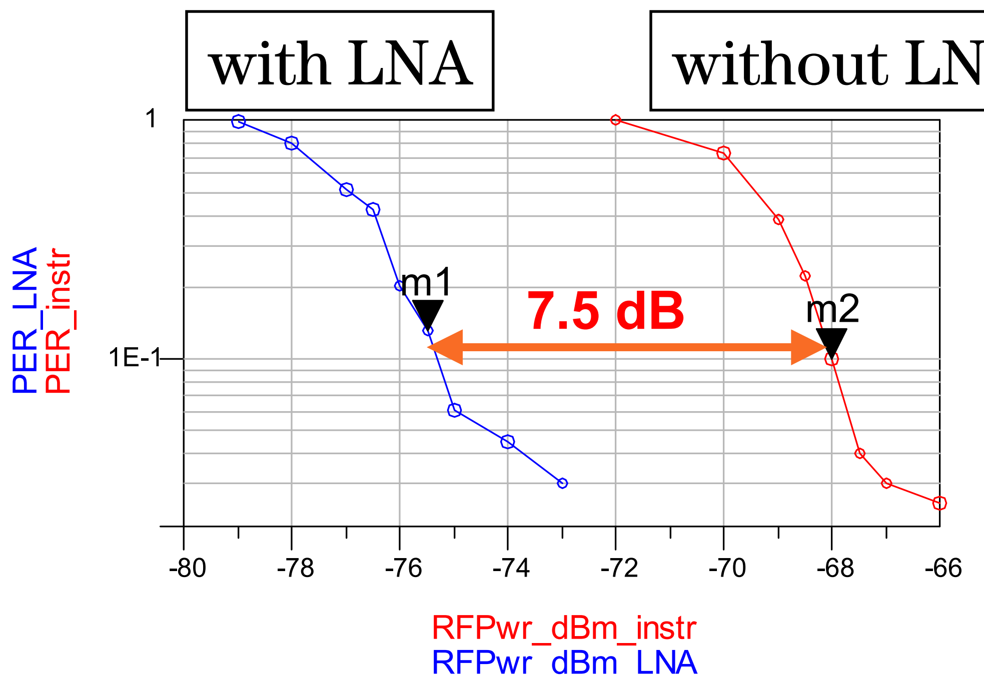
- Waterfall curve:
  - Point-by-point measurement (manual “sweep”)
  - Level on ESG – set manually (same signal in the ARB)





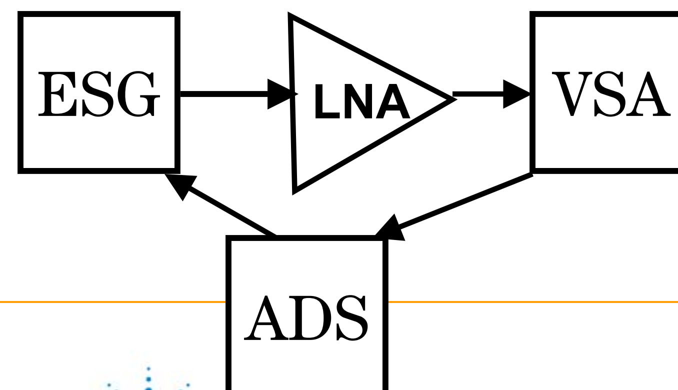
Sensitivity Measurement

- The point on the waterfall curve where PER = 10 %



m1
indep(m1)=75.500
plot_vs(PER_LNA, RFPwr_dBm_LNA)=0.13

m2
indep(m2)=68.000
plot_vs(PER_instr, RFPwr_dBm_instr)=0.10



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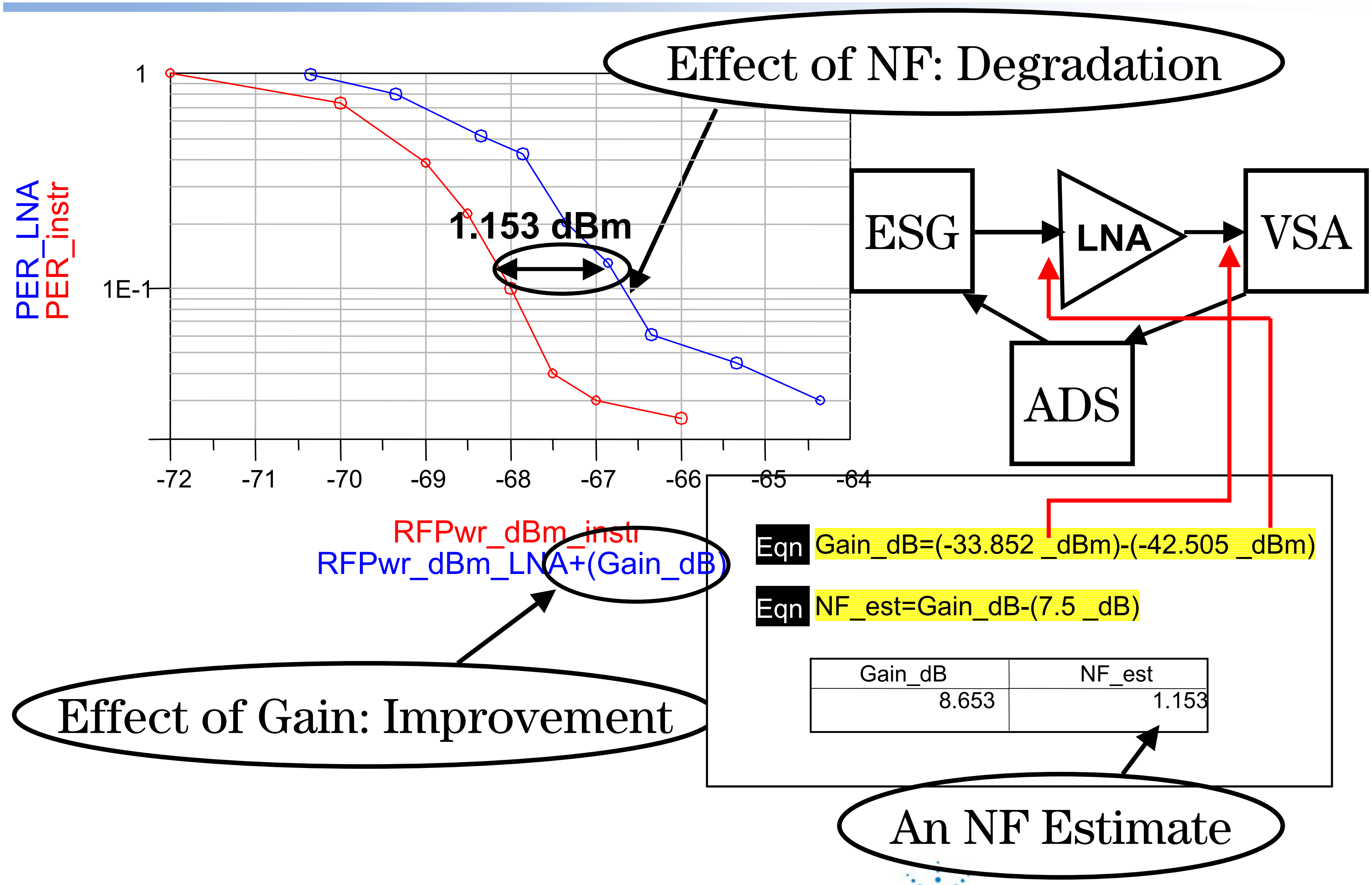
Coded PER with LNA Gain Normalized



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802.11g Adjacent channel Rejection

IEEE standard

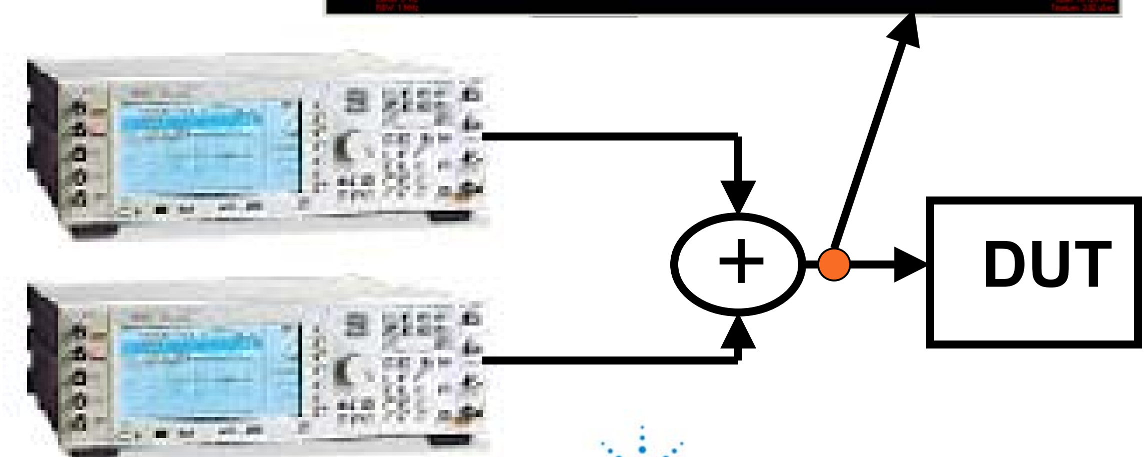
Table 91—Receiver performance requirements

Data rate (Mbits/s)	Minimum sensitivity (dBm)	Adjacent channel rejection (dB)	Alternate adjacent channel rejection (dB)
6	–82	16	32
9	–81	15	31
12	–79	13	29
18	–77	11	27
24	–74	8	24
36	–70	4	20
48	–66	0	16
54	–65	–1	15

IEEE802.11g

✓ ***Adjacent Channel Rejection***

- 36 Mb/s
-Main channel = -67 dBm
-Adj channel = 4 dB above
-Raise Adj channel power until PER=10%
-Adj channel OFDM signal is unsynchronized with the test channel



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IEEE802.11g

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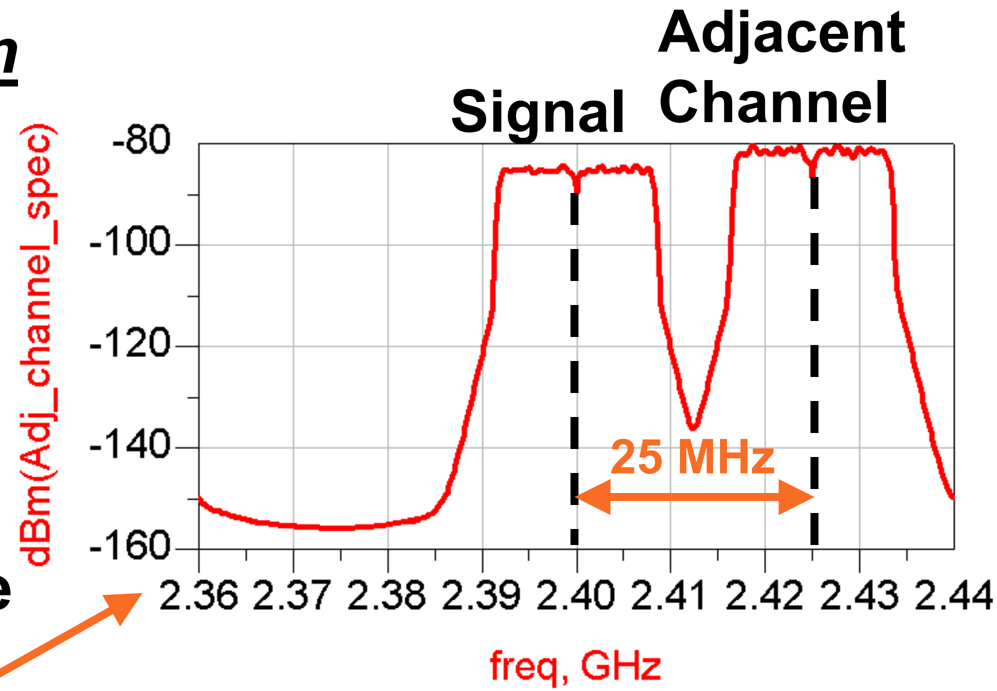

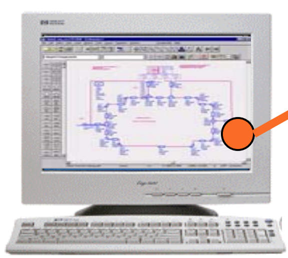

ADS

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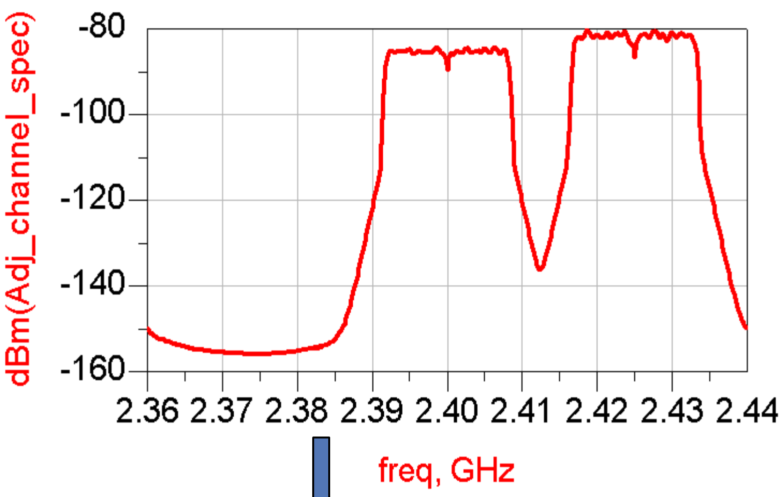
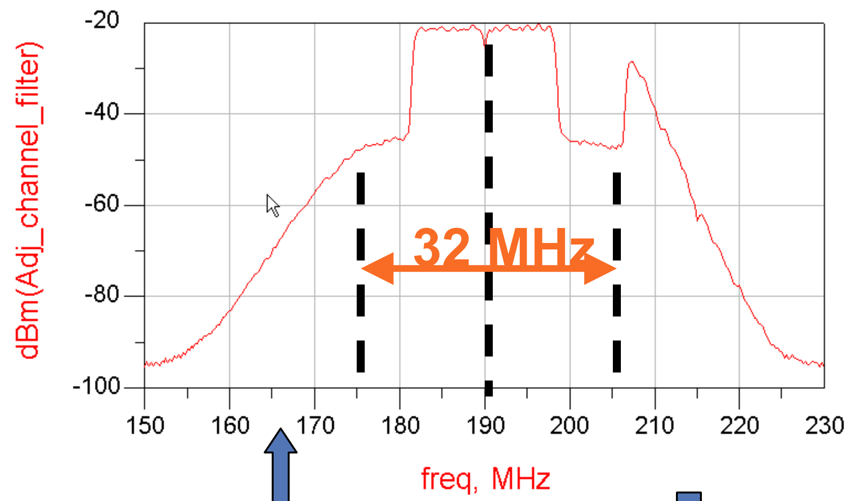
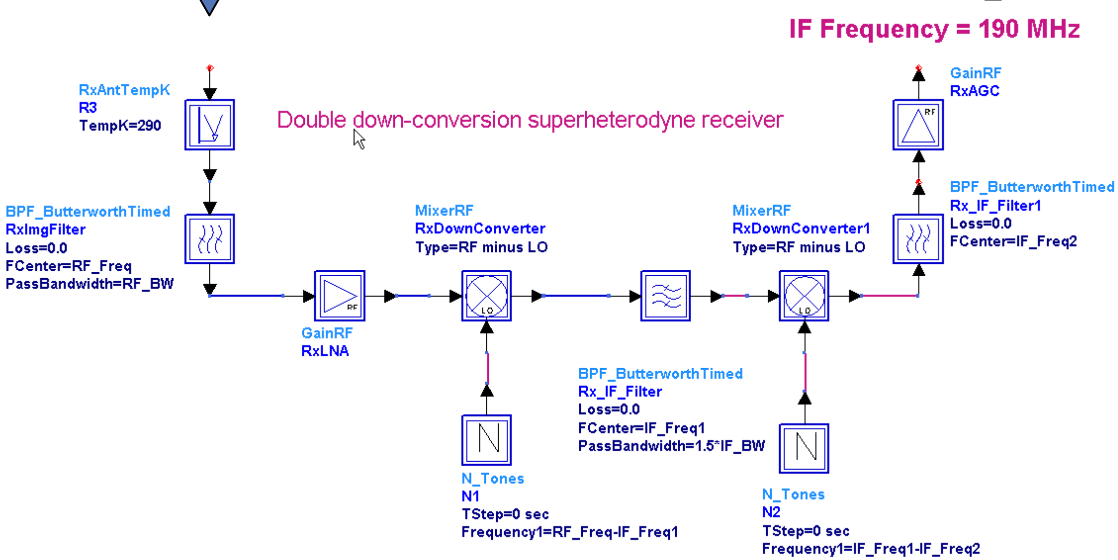
Effect of Down conversion- Filtering at IF







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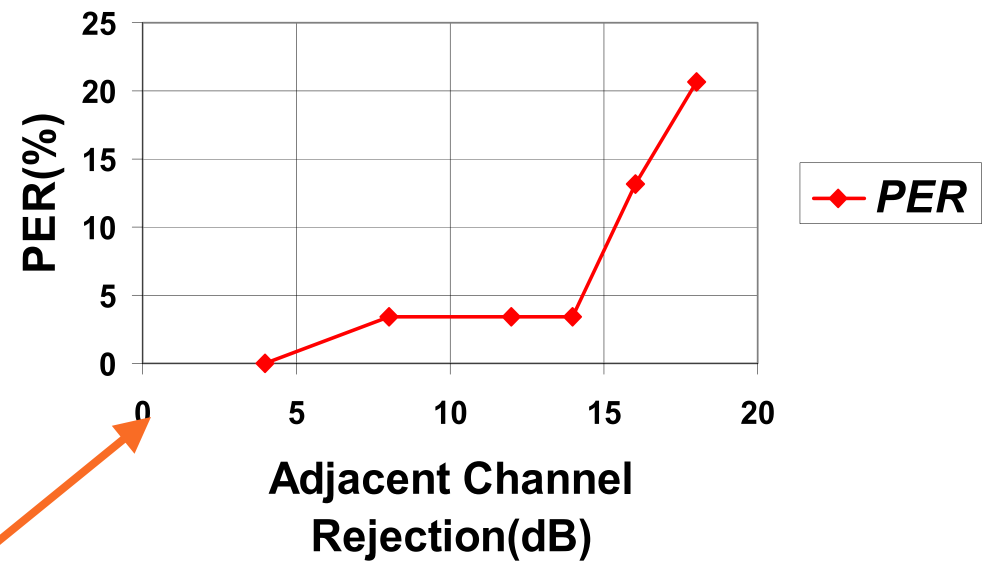
IEEE 802.11g

✓ ***Adjacent Channel Rejection***

- 36 Mb/s
- Main channel = -67 dBm
- Raise Adj channel power until PER=10%

➢ **Study receiver frontend effects with ADS**



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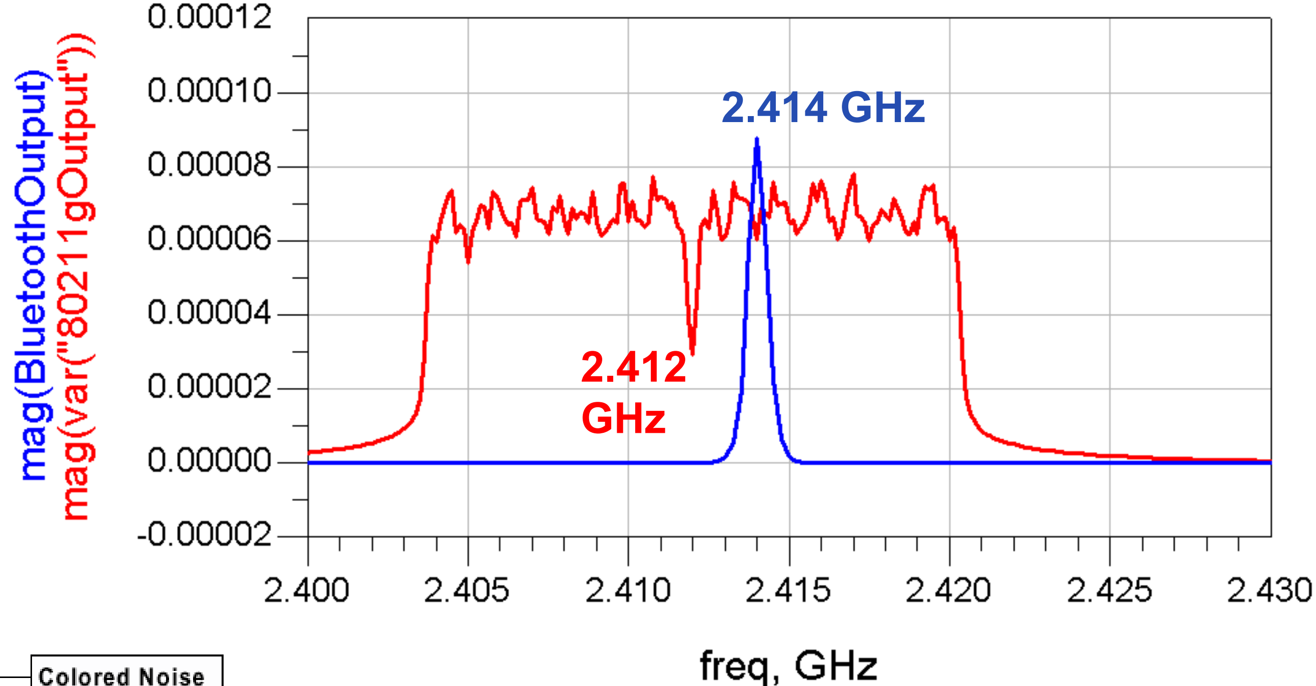
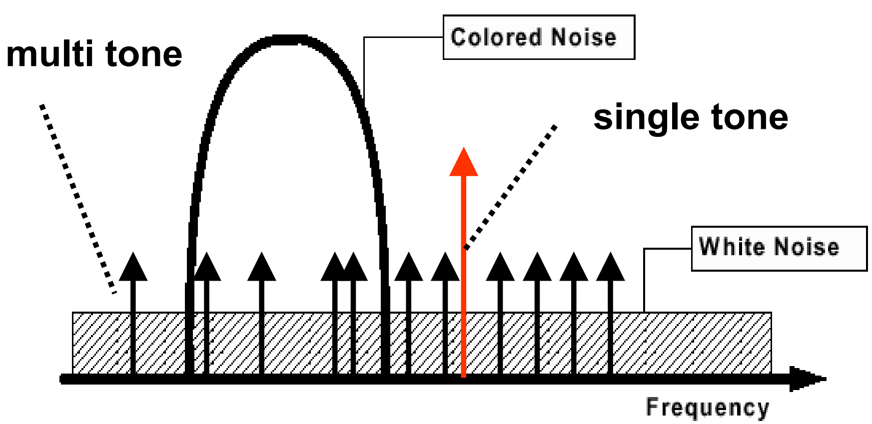
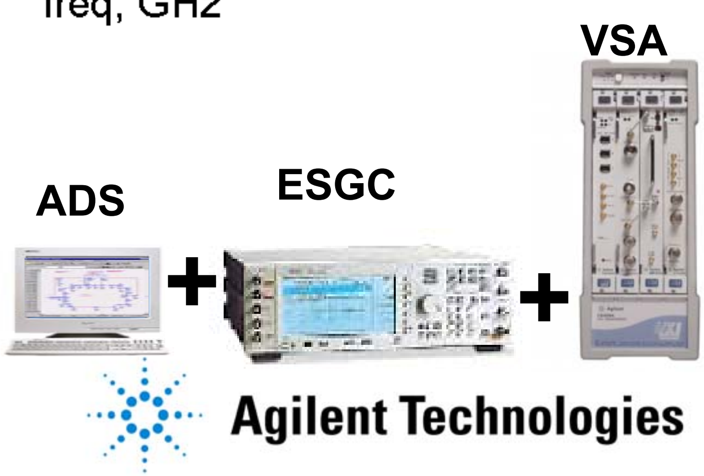
IEEE802.11g

Narrowband Jammer







IEEE802.11g

Receiver test- Bluetooth interferer

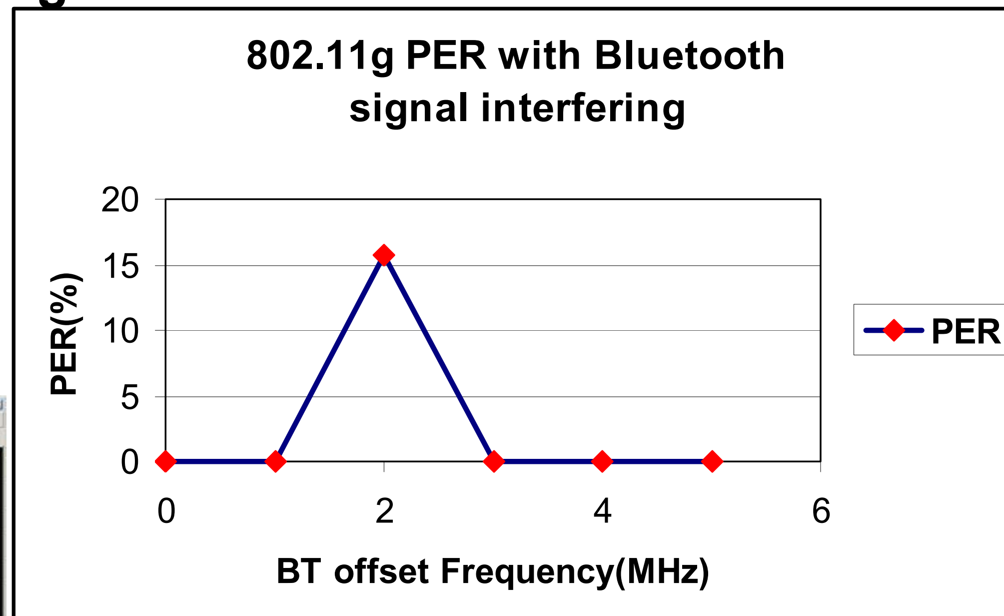
✓ ***Bluetooth Interference on 802.11g***

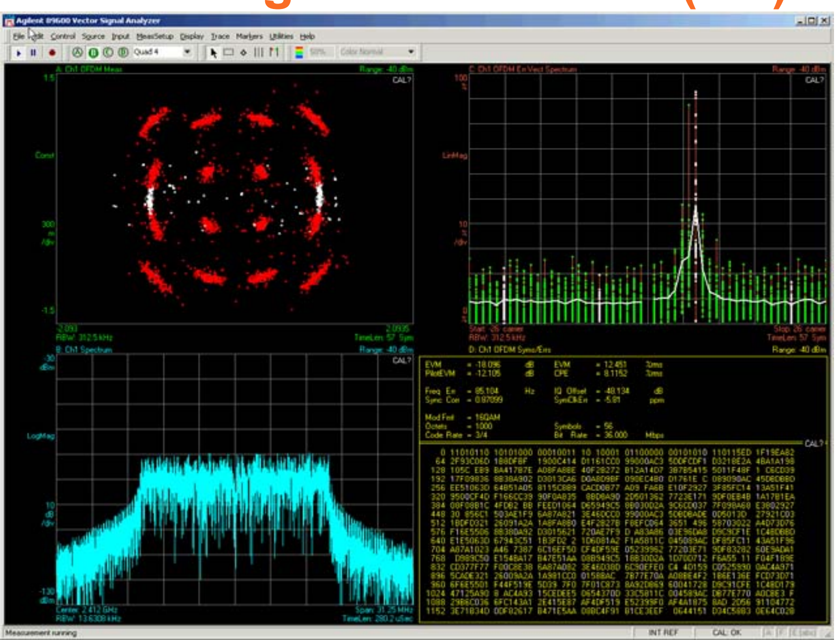
-BT signal 32 dBm above 802.11g

-BT in the same channel as WLAN

-BT hopping pattern coincide With WLAN sub-carrier(SC)

➢ **Severe PER penalty due to BT falling on WLAN Pilot(SC)**





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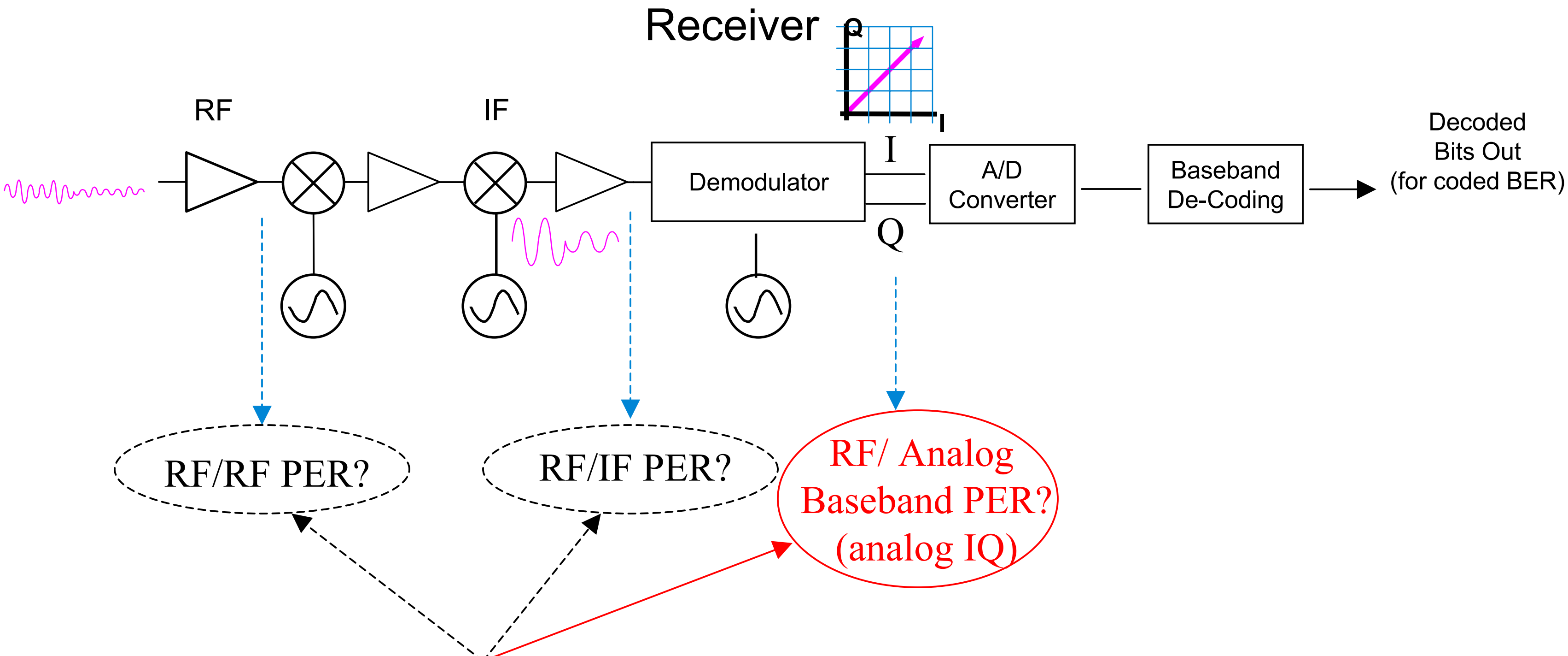
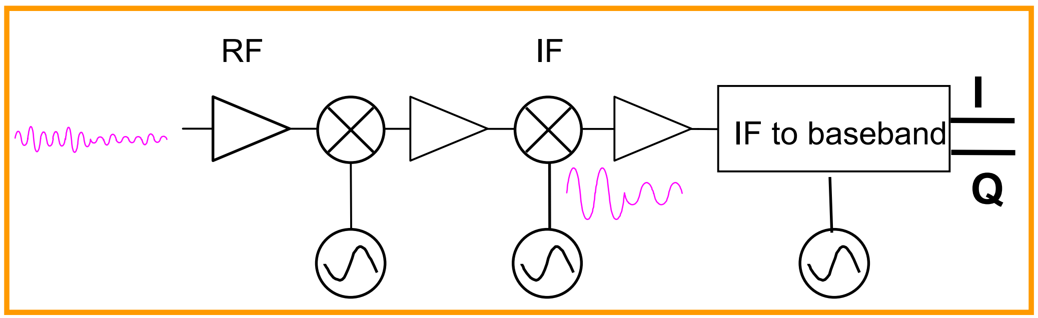
Extension to Analog IQ Baseband



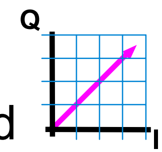
Extend this concept for RF/analog baseband testing by reading analog IQ data into ADS

Analog IQ Baseband Signal Analysis



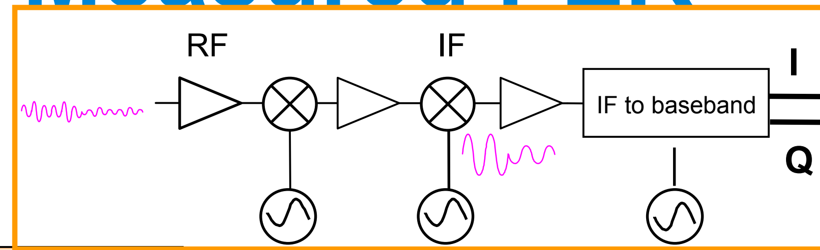
2 channel I+jQ

Receiver
RF frontend

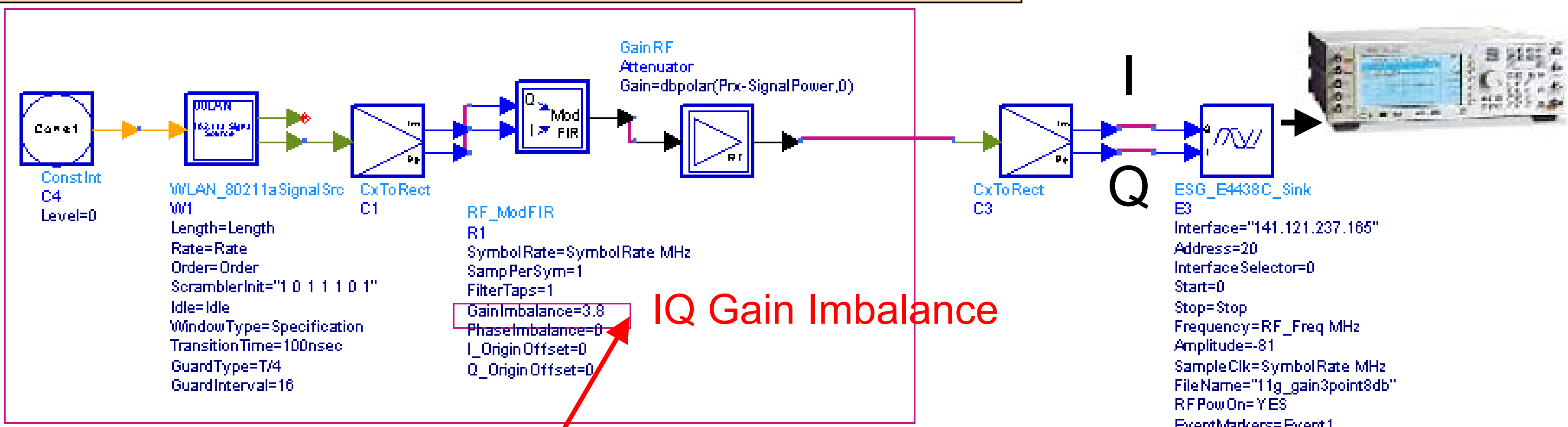


Receiver IQ baseband signal analysis using VSA

Example: Simulating the Effects of IQ Gain Imbalance on Measured PER



Could be an IQ Modulator Circuit Design or Other System/Component Designs Which May Impair BER/PER



$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

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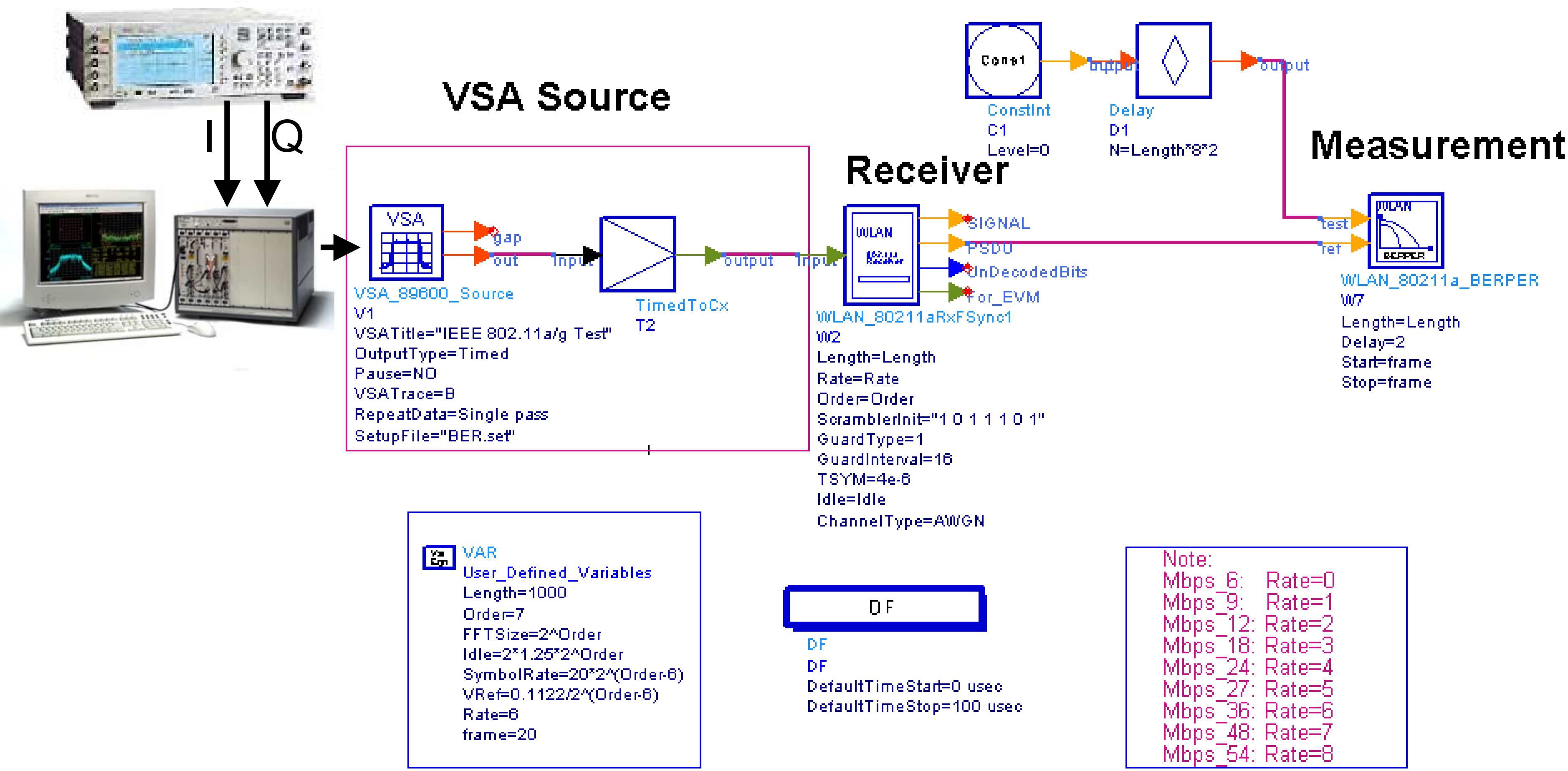
PER Measurement Using ADS



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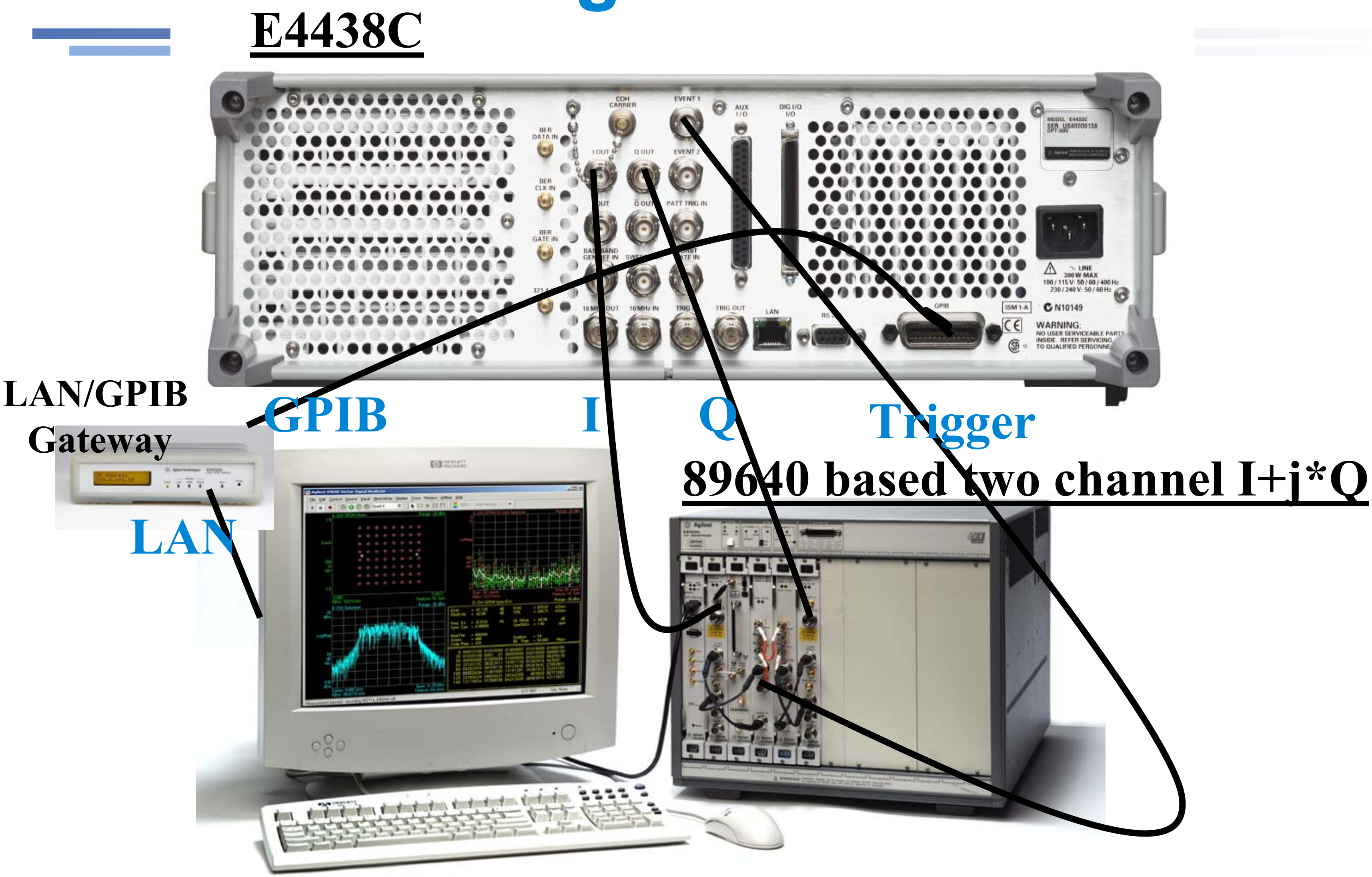
Hardware Configuration



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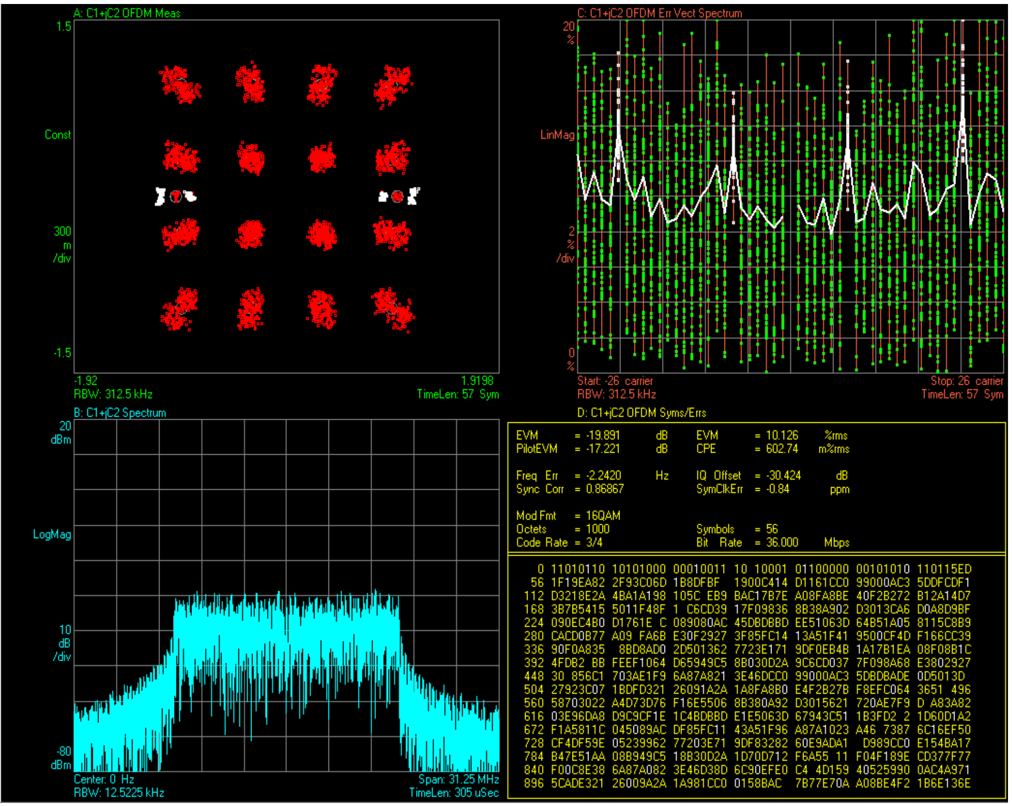
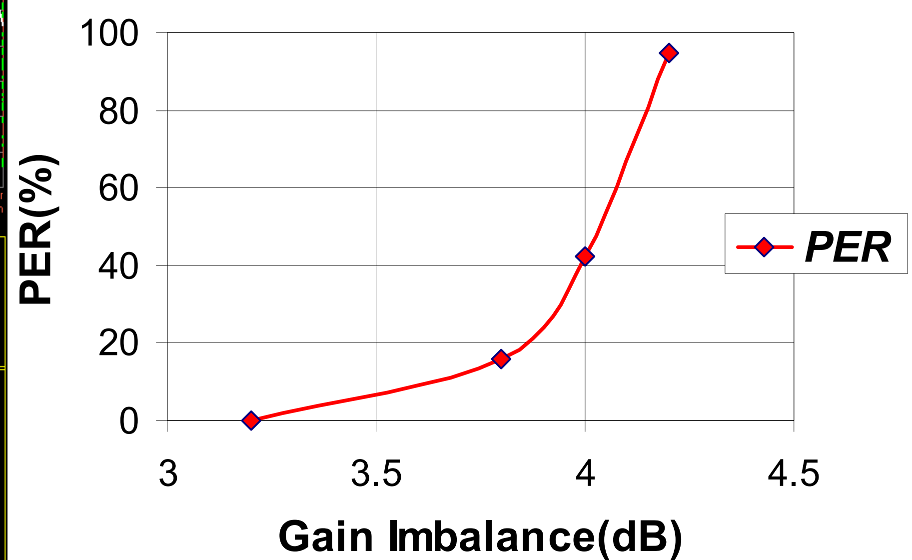
PER Measurement

IQ Gain Imbalance





1 dB Gain Imbalance

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Summary of examples

- Connected Solutions allows the RF Designer to Evaluate the System-Level PER Impact of an RF Component
- Can be Extended for a Number of Components or Subsystem
- Example Showed RF-RF Component Measurement, but can be Extended for RF-IF Measurements
- Interference issues can be studied
- Can be Extended for Analog Baseband I and Q

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Measuring IF/Digital PER for WLAN

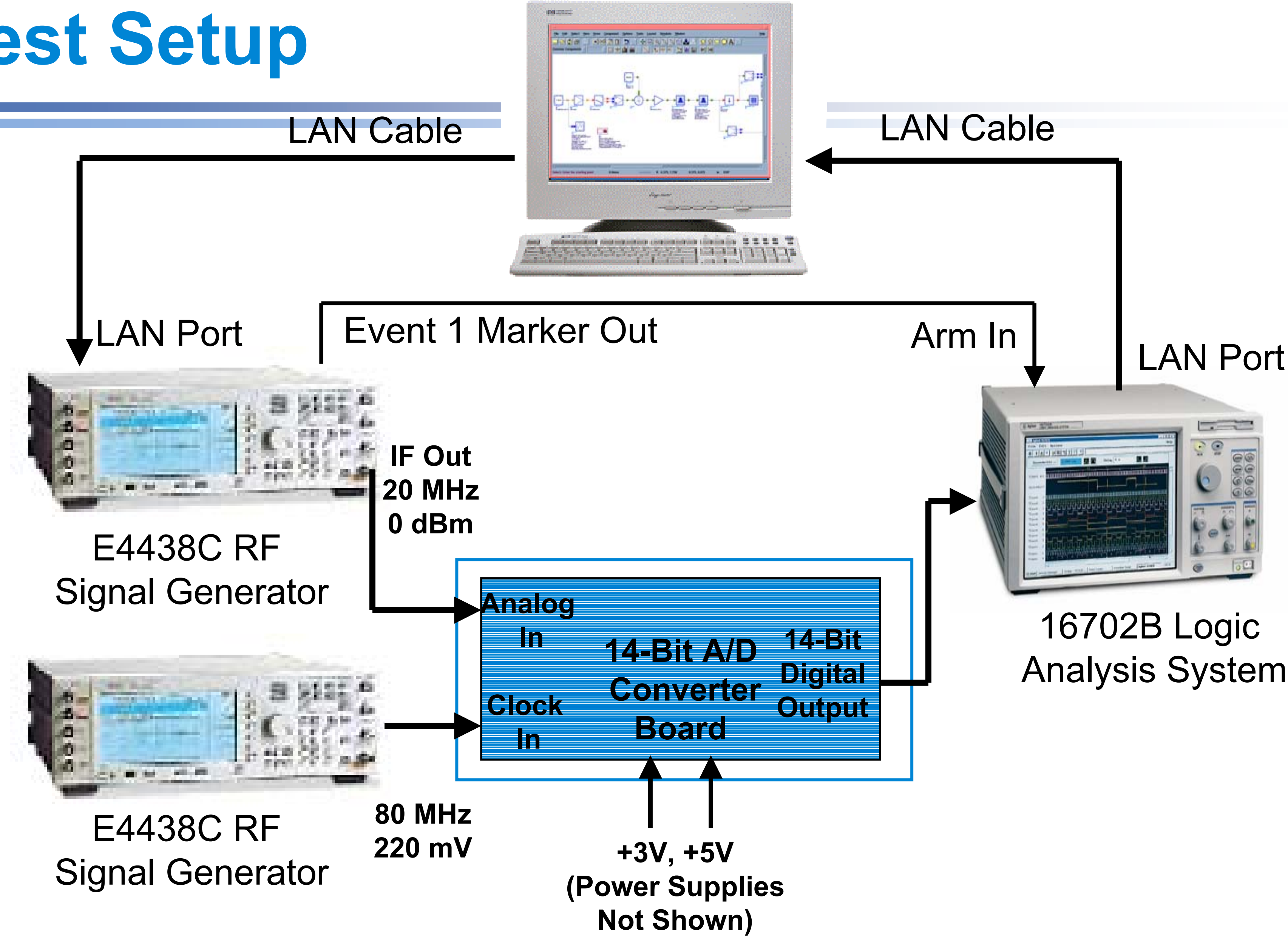
Challenges:

- **How does one measure coded PER for a receiver with an IF input and digitized output ?**
- **How can integration risks between the RF/Analog groups be reduced?**
- **How can an RF system engineer evaluate RF performance such as spectrum measurements & EVM once an IF has been digitized with an A/D converter?**

Case Study Objective:

- **Show coded PER measurement for WLAN using an Analog-to-Digital (A/D) Converter**
- **Show how to perform RF measurements on a Digitized IF signal**

Test Setup



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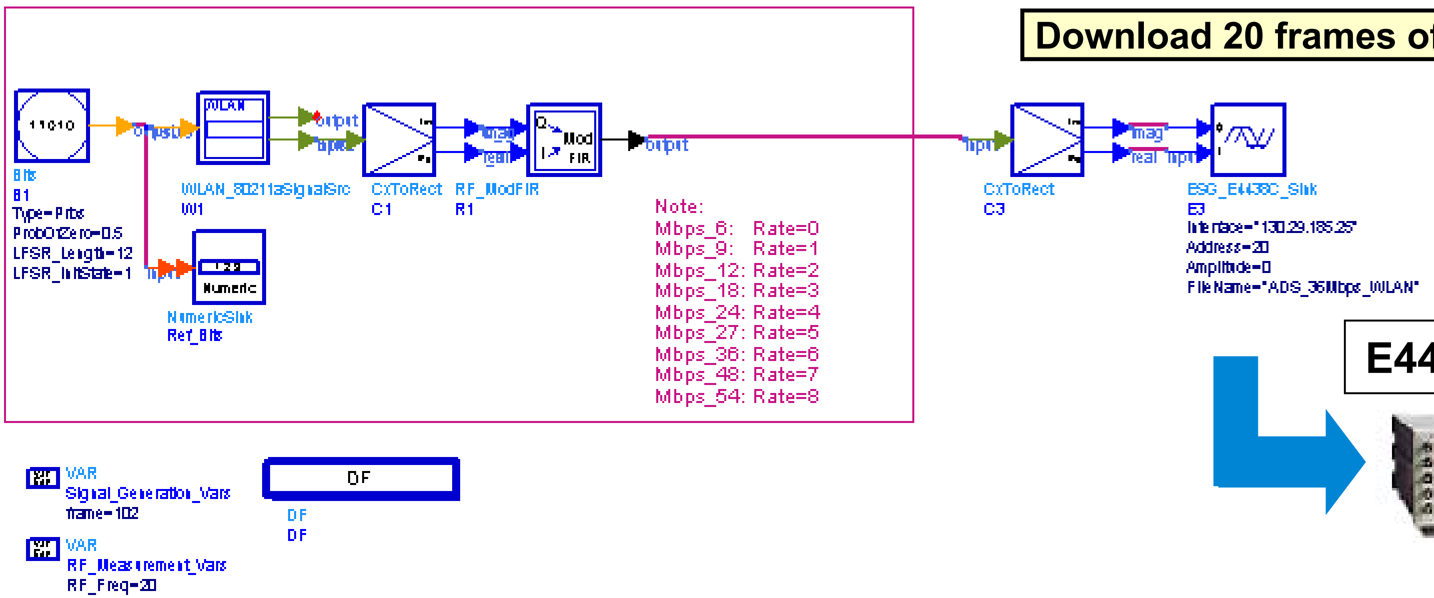
Download ADS Waveform to E4438C Arb

Generate WLAN Signal for Receiver Minimum Input Level Sensitivity Test

This example shows how to generate signal sent to ESGc for measuring the receiver minimum input level sensitivity of data rate 36 Mbps as defined in section 17.3.10.1, IEEE 802.11a(1999-10).

ADS Signal Source

Download 20 frames of data



E4438C Sig. Gen.

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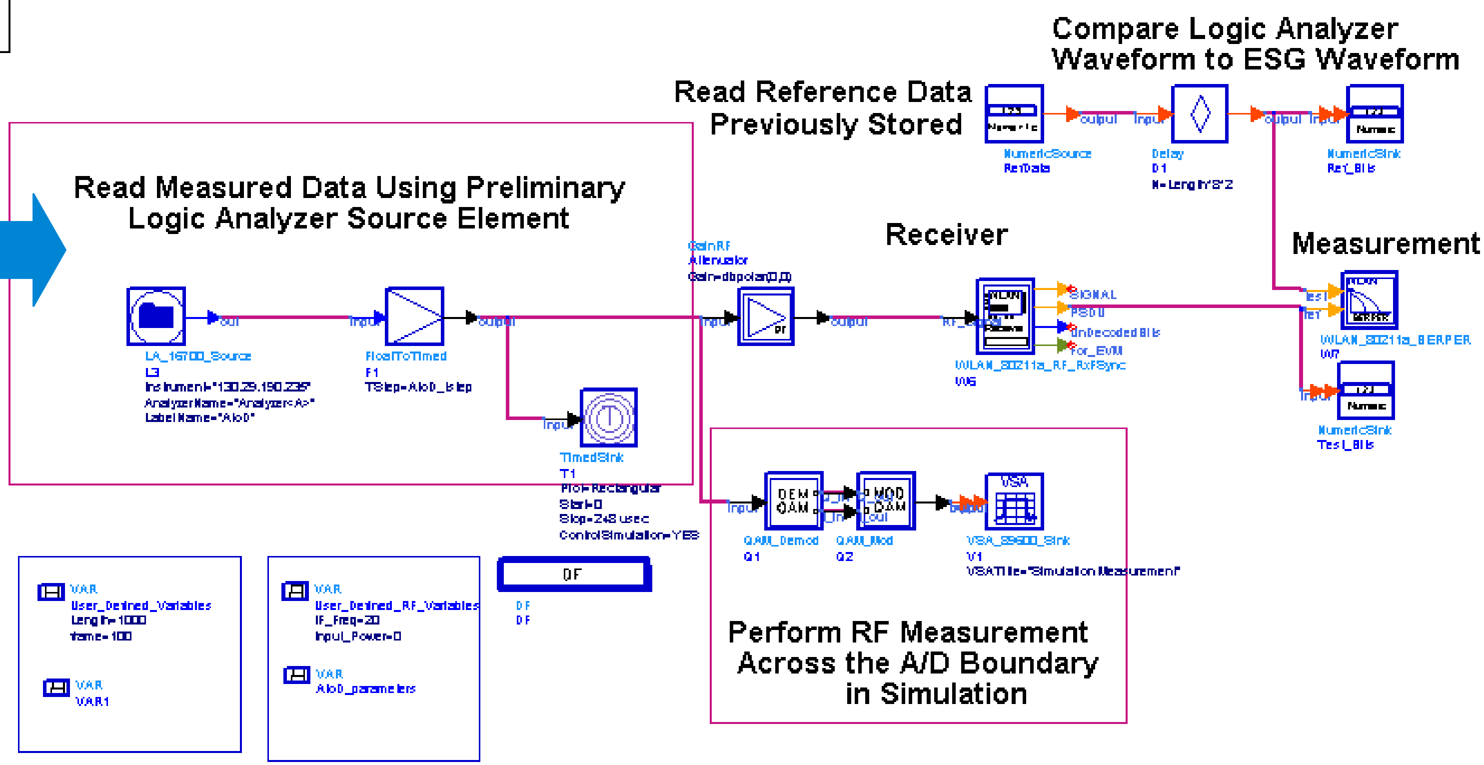
Perform RF & PER Measurement

Receiver Minimum Input Level Sensitivity Measurement Based on 802.11g Std:

This example measures the receiver minimum input level sensitivity of data rate 36Mbps as defined in section 17.3.10.1, IEEE 802.11a(1999-10). .

16702A Logic Analyzer System



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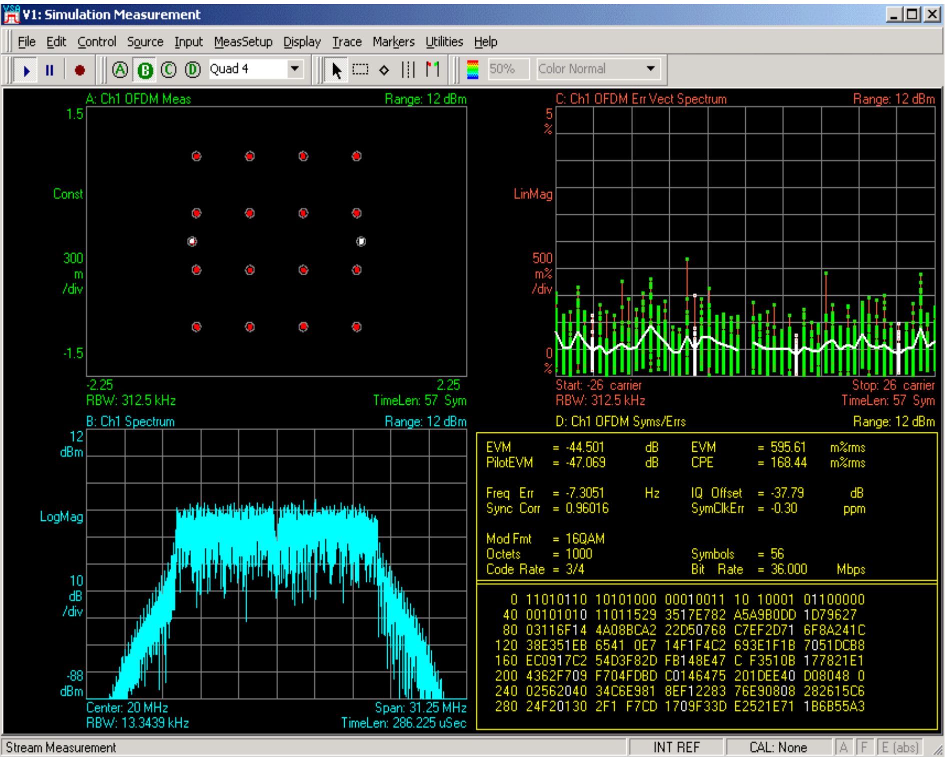
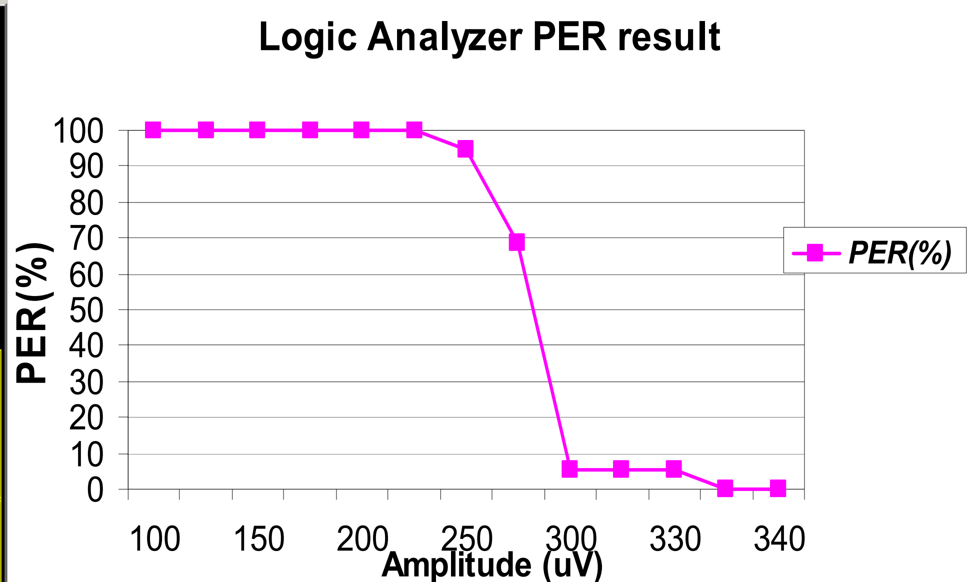
Digital Data Analysis-Results

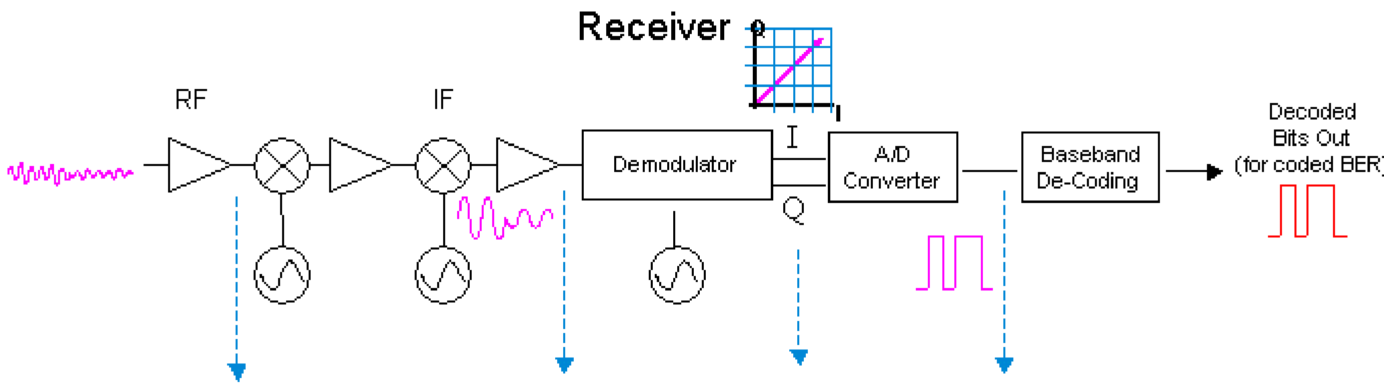
PER and RF measurement





Agilent Technologies

Measure Bit Error Rate



RF/RF BER?

RF/IF BER?

RF/ Analog Baseband BER? (analog IQ)

IF/ Digital BER?

ADS

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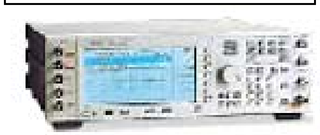
Signal Sources



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896XX VSA

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16702 Logic Analyzer System

Connected Solutions

Summary

- Connected Solutions Provide a Flexible R&D Solution for Coded PER Measurements of Wireless LAN systems
- Component or Subsystem PER Measurements
- Apply at Various Receiver Stages (RF/RF, RF/IF, IF/Digital)
- Reduce Integration Risk Between RF & Digital
- Find Issues Earlier to Save Time and Costs

Q & A