Welcome

Innovations in EDA Webcast Series
RF System Architecture – Techniques for Optimal Design
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Agenda

• RF Architecture Definition
• Costs of Poor Architecture
• RF Architecture Debugging Demo 1 (Antenna VSWR Tester)
• RF Architecture Debugging Review 1
• RF Architecture Debugging Demo 2 (LTE Receiver)
• RF Architecture Debugging Review 2
• Modulated Signal RF Architecture Debugging Demo (802.11ac WLAN Receiver)
• Summary
• Questions and Answers
What is RF Architecture?

- RF architecture is the design phase where engineers create a design that meets customer requirements using behavioral models or functional blocks
  - How many stages to use
  - What type of stages are required
  - Parameters for each Stage
  - Order of each stage

**Coupler**
- IL = 2 dB
- CPL = 20 dB
- DIR = 30 dB
- $Z_0 = 50$ ohm
What is RF Architecture?

- RF architecture is the design phase where engineers create a design that meets customer requirements using behavioral models or functional blocks.
  - How many stages to use
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  - Parameters for each stage
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Sometimes this is also referred to as System Design.

Example of a coupler:
- IL=2 dB
- CPL=20 dB
- DIR=30 dB
- Z0=50 ohm
What are the costs of poor architecture?

- Failure to meet customer requirements
  - Spurious RF products interfering with circuit operation
  - Impedance mis-match issues
  - Noise problems
  - RF sneak paths (radiated or conducted)
  - Regulator radiated and conducted compliance failures (i.e. FCC, ETSI)
  - Variation analysis, reliability, and environmental issues
- Longer time to market
  - More design spins cause more delays
- Poor product quality
  - Above cited issues also affect quality
Lowering Architecture Costs

- Identify weak links as soon as possible
- Generally spreadsheets that are typically used for RF architecture design excludes many of the issues that lead to RF architecture design failures such as VSWR issues, sneak paths, spurious RF components, etc.
- The RF architecture is the foundation for the entire RF design
RF Architecture Debugging Demo #1

Antenna VSWR Tester.wsx
# Antenna VSWR Tester Simulation Summary

<table>
<thead>
<tr>
<th>Problem Types</th>
<th>Design Issues Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spurious RF Products</td>
<td>We identified DC generated from the mixer LO as well as other mixer intermod products and harmonics.</td>
</tr>
<tr>
<td>Impedance Mismatch</td>
<td>We saw this in the forward and reflected waves at the mixer input.</td>
</tr>
<tr>
<td>RF Sneak Paths</td>
<td>We identified the S/N ratio problem at the mixer input because of leakage issues.</td>
</tr>
<tr>
<td>Noise Problems</td>
<td>The absolute bottom end of the log detector is limited by noise. We didn’t take the time to investigate this.</td>
</tr>
<tr>
<td>Regulator Emissions</td>
<td>We didn’t have time to look at these. However, it would be easy to look at the antenna spectrum.</td>
</tr>
<tr>
<td>Variation Analysis</td>
<td>We didn’t have time to look at this.</td>
</tr>
</tbody>
</table>
RF Architecture Debugging Demo #2

LTE Receiver.wsx
### LTE Receiver Simulation Summary

<table>
<thead>
<tr>
<th>Problem Types</th>
<th>Design Issues Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spurious RF Products</td>
<td>We identified mixer image products that fell in-band through a new type of graph called a ‘<strong>sweepplot</strong>’. We could have eliminated the poor IF frequency choice by using the frequency planning tool <strong>WhatIF</strong> at the beginning of the design.</td>
</tr>
<tr>
<td>RF Sneak Paths</td>
<td>It would be easy to miss the frequency planning issue using traditional spreadsheet designs.</td>
</tr>
</tbody>
</table>
Modulated Signal RF Architecture Debugging Demo

802.11ac WLAN Receiver
SystemVue LTE Performance Evaluation

802.11ac WLAN Receiver Sensitivity Analysis
IEEE 802.11ac is a wireless computer networking standard of 802.11 under development which will provide high throughput Wireless Local Area Networks in the 5 GHz band. This standard has generated much interest in both the aerospace/defense and commercial marketplace.

Theoretically, this specification will enable multi-station WLAN throughput of at least 1 Gigabit per second. This is accomplished by using wider RF bandwidths (up to 160 MHz), and more MIMO spatial streams (up to 8), multi-user MIMO, and high-density modulation (up to 256 QAM).[1]

The performance specification that will be tested in this example is Receiver Sensitivity. According to the standard, the system must be able to maintain less than a 10% Packet Error Rate (PER) at an input signal level of -60 dBm.
WLAN 11ac Receiver sensitivity measurements

802.11ac 'Golden' Transmitter

802.11ac Source

Path Loss

Noise

Recon Radiation: 0 kHz

BER & FER Tests

802.11ac Receiver

Polymorphic RF Receiver Model

DataFlow Receiver Model

RF Fc = 5000 MHz
LO Fc = 4920 MHz
LO Pwr = 10 dBm

IF Fc = 80 MHz
IF BW = 100 MHz

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IEEE 802.11ac Sensitivity Analysis
Initial Simulation Results: Failed Sensitivity Test

Bit Error Rate: 0.0075 (0.75%)

IEEE 802.11ac Spec.
FER < 0.1 @ -60 dBm

Frame Error Rate: 1 (100%)

All Frames Require Retransmission!

Tasks:
1. Investigate the cause
2. Fix the problem
Swept Signal Level Sensitivity Test Results

Bit Error Rate & Frame Error Rate vs. RF Signal Level

IEEE 802.11ac
Packet Error Rate Spec:
PER (FER) < 0.1 (10%) at -60 dBm

No Errors

IEEE 802.11ac Sensitivity Analysis

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Switch to Polymorphic Spectrasys Receiver Model

Switch from the Data Flow Receiver Model to the Spectrasys RF Model

Manually Sweep Freq. 1.25 MHz = 80MHz/64
This Spectral Data was imported into the Spectrasys Multisource component from the DF Receiver Spectrum.
Cascaded Analysis Inside of Receiver

Step 1: Identify Potential Problem

Compression occurring in IF Amplifiers
Cascaded Analysis Inside of Receiver

Cascaded Channel Power, Total Power & Gain Compression (Right Axis)

Could switch to X-Parameter, GoldenGate or ADS model (Polymorphic)

Double-Click on Component to modify its parameters.
Cascaded Analysis Inside of Receiver

Monitoring the effects of changes to the IF Amplifiers

Referenced Results before modifications.

After IF Amps are modified.
Cascaded Analysis Inside of Receiver

Cascaded Channel Power, Total Power & Gain Compression (Right Axis)

Could this potentially effect system performance?

Total Power (TNP)
Node 4, -16.822 dBm

Channel Power (CP)
Node 4, -21.057 dBm
Cascaded Analysis Inside of Receiver

Receiver Component Dynamic Range Effects

Note: The Receiver Dynamic Range is now limited by the LNA.

Output SDR After Mods. To IF Amps 20.587 dB

Original: SDR 1.17 dB
Envelope Signal Representation

Signal Peaks Could Potentially Cause Problems

\[ x(t) = (I(t) + jQ(t)) \exp(j2 \pi f_c t) \]

Where \( f_c = 5000 \text{ MHz} \) (Note that the \( \text{abs()} \) is displayed here)

-60 dBm CW Carrier Level

Peak to Avg 9.966 dB

The RF signal shown here is sampled at 32 GHz, \( f_c = 0 \text{ Hz} \), (Like you might see on a high speed oscilloscope)

Both waveforms represent the same signal information, but the Envelope waveform uses a sample rate that is 160 MHz, while the RF signal representation is sampled at 32 GHz, which would take much longer to simulate and significantly more memory, to get the same results.
Final Receiver Error Rate Results

Bit Error Rate & Frame Error Rate vs. RF Signal Level

IEEE 802.11ac Packet Error Rate Spec.
Summary: WLAN 802.11ac System Evaluation

In this example we have demonstrated:

1. The ability to model and simulate a leading edge IEEE 802.11ac system using Agilent’s SystemVue software.
2. How to perform a Bit and Frame Error Rate analysis.
3. Identify potential problems in our design very early in the development cycle, when fixes are significantly less costly.
4. Polymorphic modeling of a receiver RF chain using both a Data Flow and a RF Spectral domain model.
5. Identifying and fixing “hidden” problems in the receiver chain quickly.
6. Showing how Envelope simulation can efficiently and accurately model RF signals.
7. Do a final verification that our system now meets the Spec.
Thank you

Questions ?
Spectrasys RF System Simulation is in Genesys, SystemVue and ADS

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