IF to IF Simulation of Wireless Links Using Commercial CAD Software

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Abstract

This work explores, by way of example, the application of modern CAD software to the simulation of RF communication system hardware. We restrict attention to the front-end analog portions of a typical communication link; that is, our coverage is from IF-to-IF. A 915 MHz breadboard system is used in a case study that compares measurements and simulations of various receiver and transmitter sub-system scenarios; the IF frequency is 70 MHz for both sub-systems. Performance parameters examined for the transmitter and receiver sub-systems include small signal frequency response, 1 dB gain compression power levels, and third-order-intercept (TOI). In addition, simulated and measurements for the receiver noise figure are compared. Finally, the transmitter and receiver are connected together with a variable attenuator to examine overall link performance, while leaving free-space propagation and channel modeling issues for future work. It is shown that after "calibrating" the system CAD representations of the transmitter and receiver sub-systems using component behavior, good predictions of in-band performance can be achieved for all parameters examined. The differences between CAD library (ideal) filters and measured filters can cause significant out-band discrepancies between simulated and measured sub-system behavior.

Biography of Presenter

Lawrence P. Dunleavy received the B.S.E.E. degree from Michigan Technological University in 1982, and the M.S.E.E. and Ph.D. degrees in 1984 and 1988, respectively, from the University of Michigan. He has worked in industry for ESystems and Hughes Aircraft Company and was a Howard Hughes Doctoral Fellow. In 1990 he joined the Electrical Engineering Department at the University of South Florida, where he now holds the title of Associate Professor. From August 1997 to to August 1998 he enjoyed a 1 year sabbatical research appointment with the Microwave Metrology Group of the National Institute of Standards and Technology (NIST) in Boulder, CO. His current research interests are in the area of accurate microwave and millimeter-wave measurements, measurement-based active and passive component modeling, MMIC design, and wireless systems characterization and CAD. Dr. Dunleavy is a Senior Member of IEEE, is very active in the IEEE MTT Society, and has been an Automatic RF Techniques (ARFTG) member since 1986.

Acknowledgements

- **This work was supported in part by separate grants from Intersil and Ansoft companies.**
- **The measurement data was acquired in the WAMI laboratory which was made possible by grants from NSF, Agilent, and sponsorship of many other companies.**
- **The coaxial system hardware examined here is comprised of components donated by the companies Mini-Circuits, Miteq, and Piezo-Technologies (PTI).**
- **The authors also thank Ansoft and Agilent for making their CAD software available on the USF campus.**

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Agenda

- Motivation of Work
- Description of Transmitter/Receiver Hardware
- Simulation and Measurement Comparisons
  - Filter Responses
  - Conversion Gain and Bandwidth
  - 1-dBc Point
  - TOI
  - NF
  - IMT
- Conclusion

Motivation and Goals

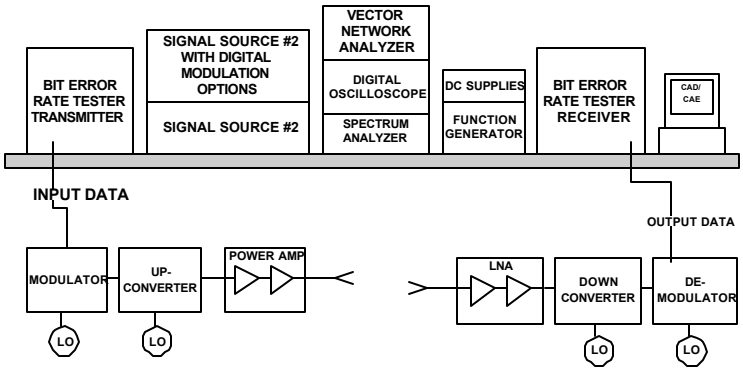
- This work explores, by way of example, the application of modern CAD software to the simulation of RF communication system hardware.
- A 915 MHz transmitter/receiver system is used in a series of measurement and simulation comparisons.
- This effort is part of a longer range effort that involves students in system level studies that are building greater understanding of how to effectively model communication system hardware.

Motivation and Goals

- Two different simulators – Agilent ADS and Ansoft Serenede are exemplified to varying degrees.
- Considered are swept small signal response, noise figure/conversion gain, 1 dB compression, third order intercept (TOI), and mixer intermodulation (spur) analysis. Antennas/channel modeling not studied here.
- Goals:
  - Illustrate modern CAD solutions to system hardware simulation.
  - Explore which measures and simulations make sense to compare at sub-system level.
  - Determine where problems arise in system hardware simulations, or answer the question: what works / what doesn't?

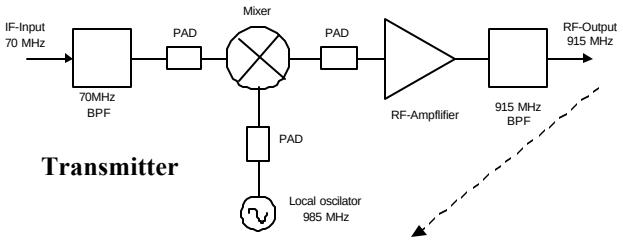
Wireless Communications Test-Bed (In-development)

Project-based learning in a complete communications system context



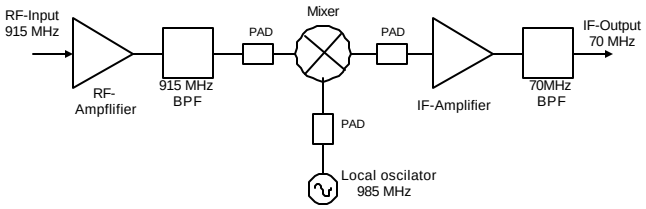
- Test-bed at 915 MHz – generic transmit receive pair ← Today's focus
- Test-bed at 2400 MHz – Intersil PRISM Wireless LAN hardware
- Bits-to-bits treatment as goal
- Simulation and measurement comparisons reveal and validiate needed improvements for system hardware simulations

Simulation and Measurements of Wireless Transmitter and Receiver Hardware



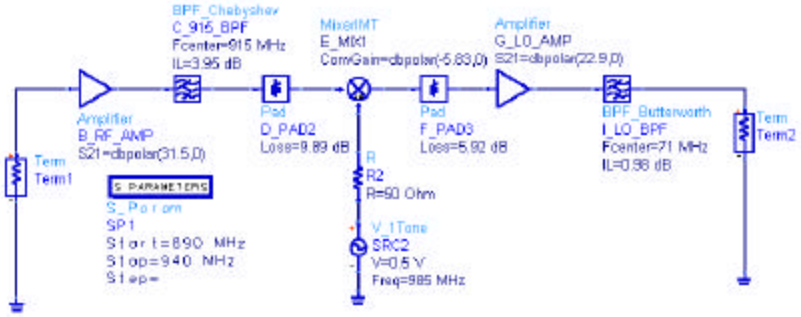
Transmitter

Receiver



Receiver Simulation

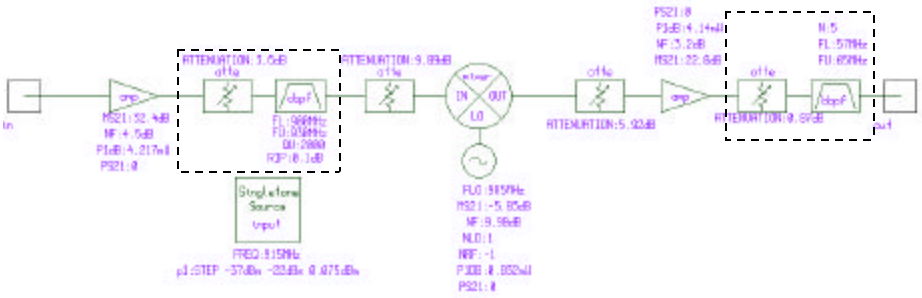
ADS



System components are modeled with functional models selected from the CAD simulator library.

Serenade

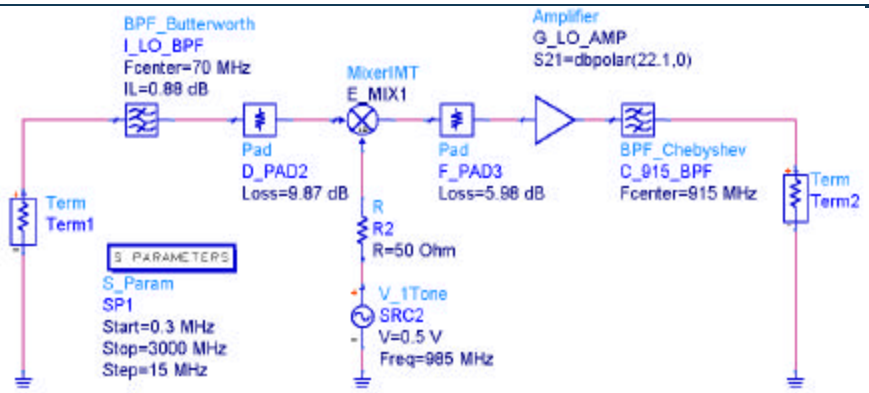
Receiver



Similar schematic representations are used to define the sub-systems in the two simulators.

Transmitter Simulation

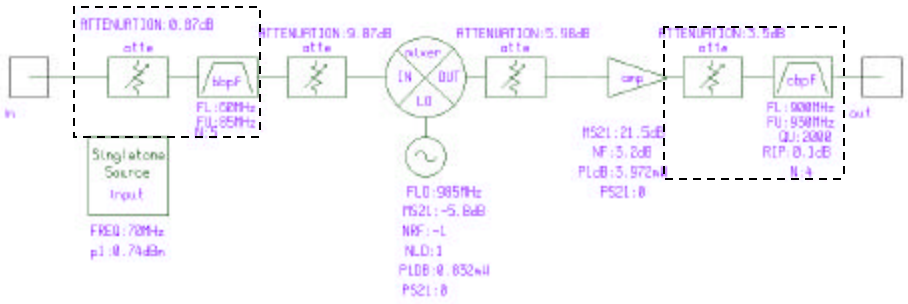
ADS



Parameters used to define the components are selected initially from component specifications, then "calibrated" using measured component data.

Serenade

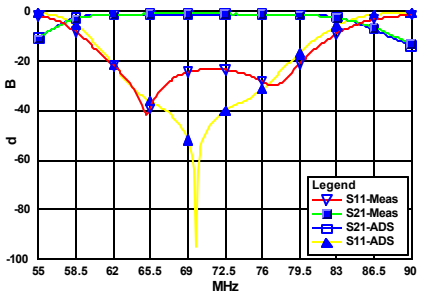
Transmitter



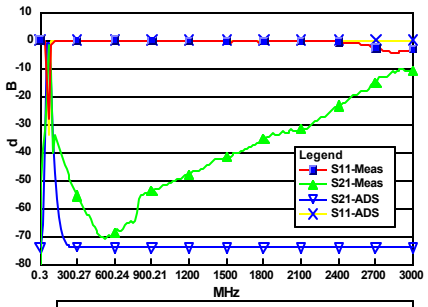
Receiver Measurements and Simulation

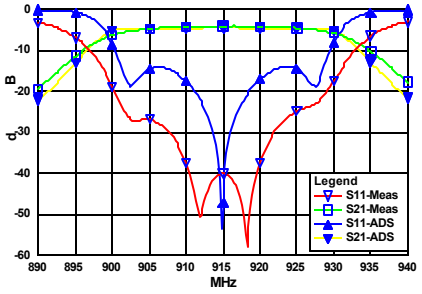
Filter effects: Ideal vs. Measured

ADS

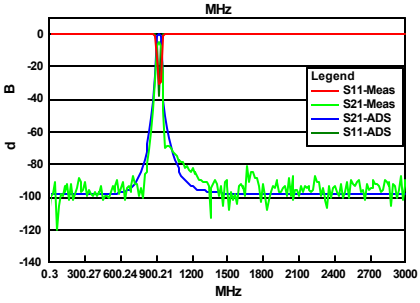


IF-Filter





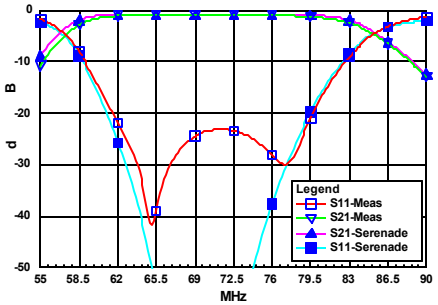
RF-Filter



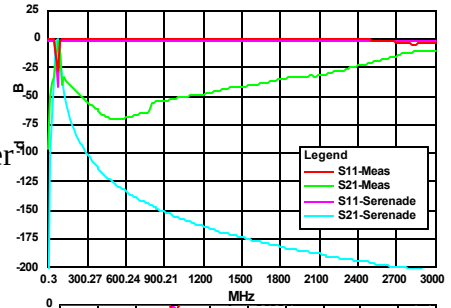
Receiver Measurements and Simulation

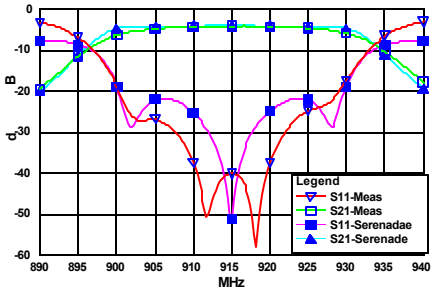
Filter effects: Ideal vs. Measured

Serenade

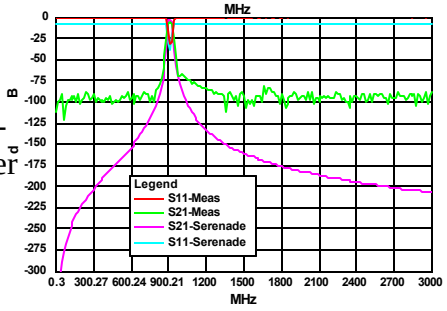


IF-Filter





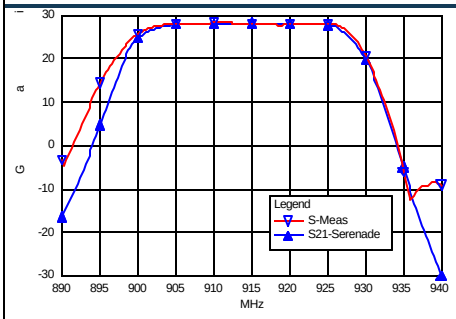
RF-Filter

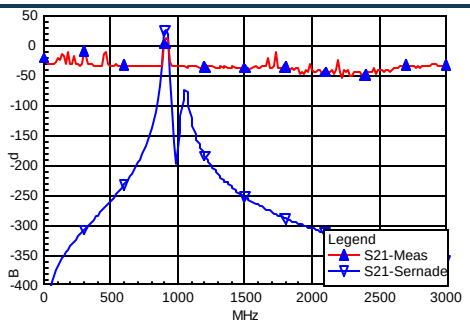


Receiver Measurements and Simulation

Conversion gain and Bandwidth: Simulated vs. Measured

Serenade



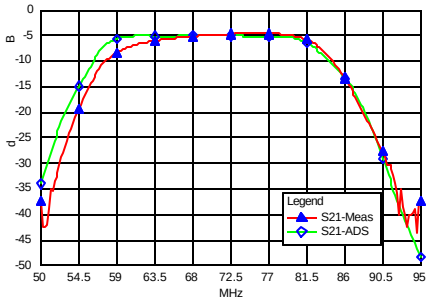


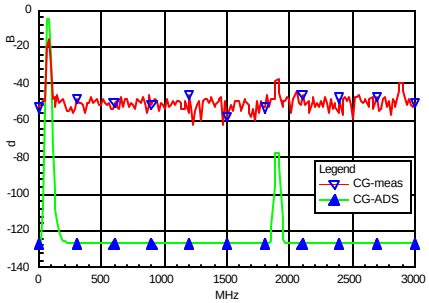
		Bandwidth (MHz)	Conversion Gain (dBm)
Receiver	**Measured**	29.0	28.0
	Simulated	29.5	28.2

Transmitter Measurements and Simulation

Conversion gain and Bandwidth: Simulated vs. Measured

ADS



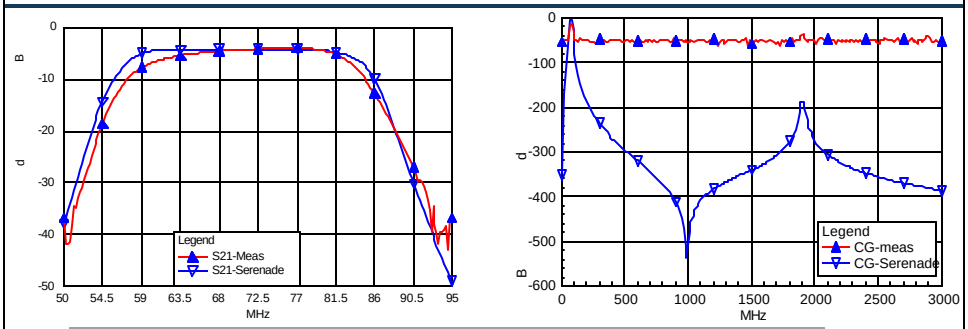


		Bandwidth (MHz)	Conversion Gain (dBm)
Transmitter	**Measured**	**24.1**	**-5.1**
	Simulated	**25.8**	**-5.2**

Transmitter Measurements and Simulation

Conversion gain and Bandwidth: Simulated vs. Measured

Serenade

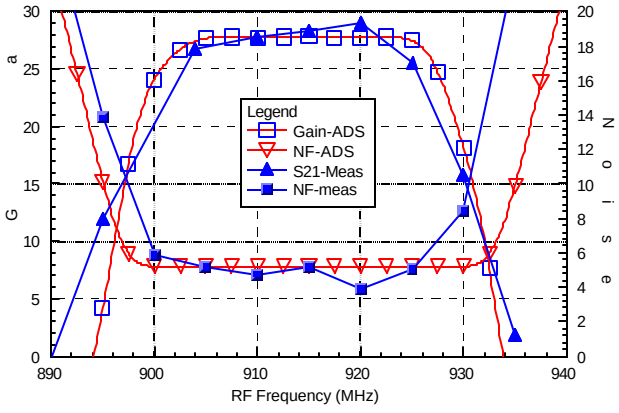


		Bandwidth (MHz)	Conversion Gain (dBm)
Transmitter	**Measured**	24.1	-5.1
	Simulated	25.9	-4.8

Receiver Measurements and Simulation

Noise Figure: Simulated vs. Measured

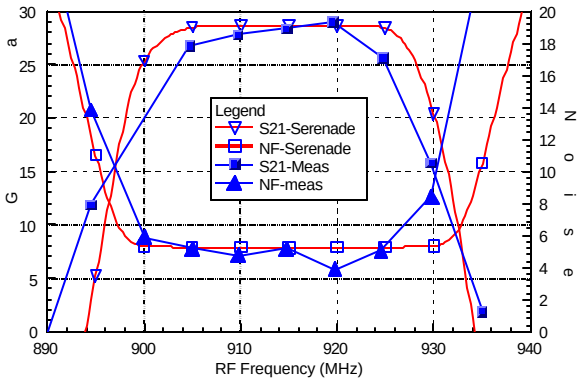
ADS



Receiver Measurements and Simulation

Noise Figure: Simulated vs. Measured

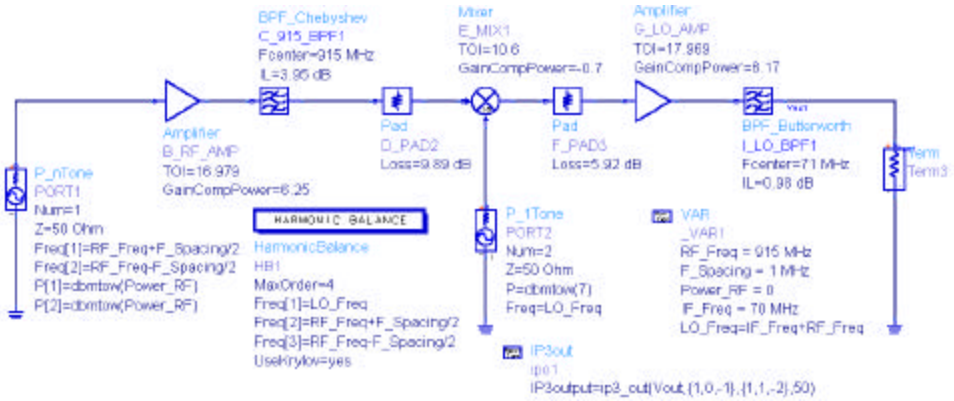
Serenade



Receiver and Transmitter Measurements and Simulation

TOI: Simulated vs. Measured

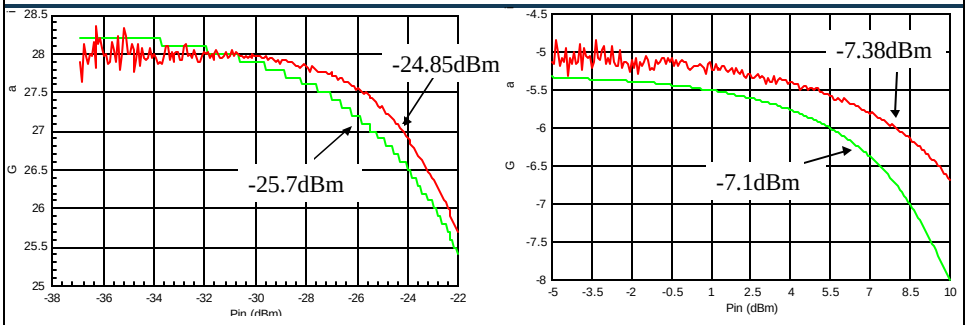
ADS



Receiver and Transmitter, Measurements and Simulation

1- dB Compression point

ADS



Receiver Transmitter

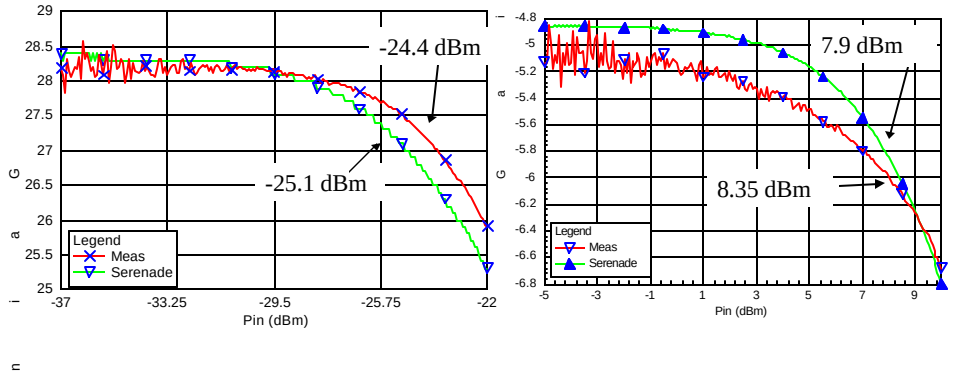
• Harmonic Bench

•Conditions: IF Frequency 70MHz, LO Frequency 985MHz, RF Frequency 915 MHz

Receiver and Transmitter, Measurements and Simulation

1-dB Compression point: Simulated vs. Measured

Serenade

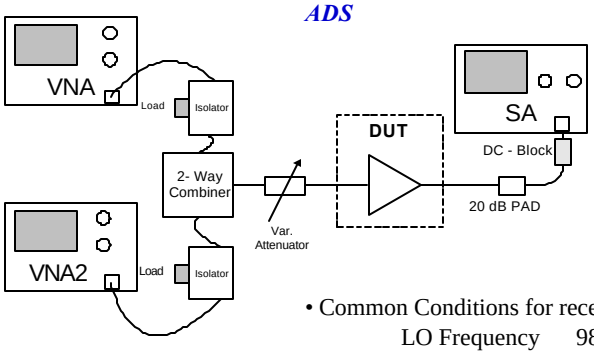


•Conditions: IF Frequency 70MHz, LO Frequency 985MHz, RF Frequency 915 MHz

Receiver and Transmitter Measurements and Simulation

TOI: Simulated vs. Measured

ADS



• Common Conditions for receiver/transmitter:
LO Frequency 985MHz, + 7 dBm

	2-Tone Frequencies (MHz)	Measured TOI (dBm)	Simulated TOI with ADS (dBm)
Receiver	915,916	9.65	8.79
Transmitter	70,71	11.78	11.05

Receiver and Transmitter, Measurements and Simulation

TOI Compression point: Simulated vs. Measured

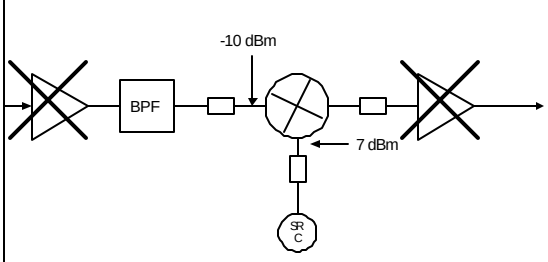
Serenade

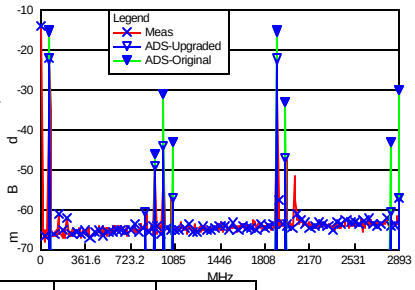
	Measured (dBm)	Simulated (Serenade) (dBm)
Receiver	**9.65**	**9.41**
Transmitter	**11.78**	**12.2**

Receiver Measurements and Simulation

IMT: Simulated vs. Measured

ADS



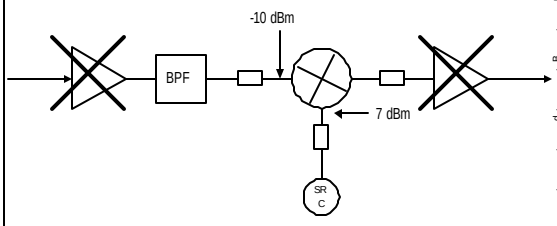


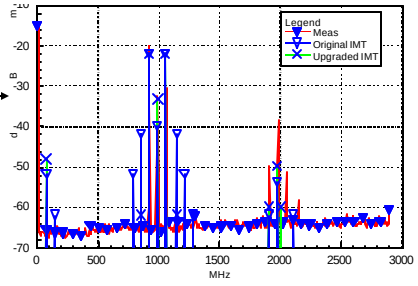
Frequency (MHz)	70	915	985	1055	1900	1970
Original (dBm)	-15.2	-46.2	-30.8	-43.2	-15.2	-32.8
Measured (dBm)	-22.6	-49.2	-44.9	-57.0	-31.9	-47.0
Upgraded (dBm)	-22.2	-48.8	-44.1	-56.6	-22.2	-46.2

Receiver Measurements and Simulation

IMT: Simulated vs. Measured

Serenade



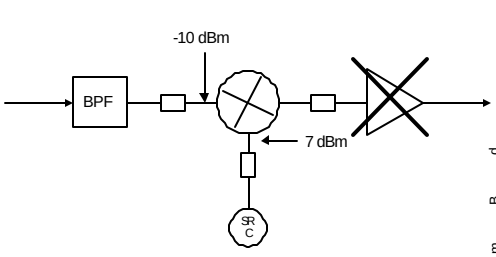


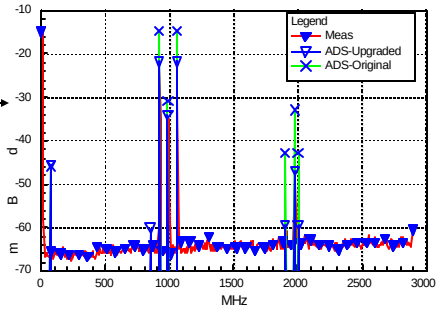
Frequency (MHz)	70	915	985	1055	1900	1970
Original (dBm)	-22.1	-52.1	-40.1	-62.1	-22.1	-54.1
Measured (dBm)	-22.6	-49.2	-44.9	-57.0	-31.9	-47.0
Upgraded (dBm)	-22.1	-48.7	-44.4	-56.5	-22.1	-46.5

Transmitter Measurements and Simulation

IMT: Simulated vs. Measured

ADS



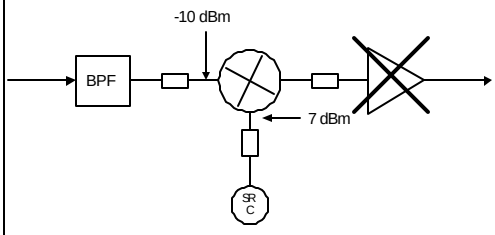


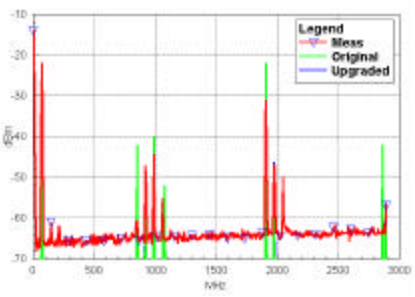
Frequency (MHz)	70	915	985	1055	1900	1970
Original (dBm)	-45.8	-14.8	-30.8	-14.8	-42.8	-32.8
Measured (dBm)	-63.3	-22.4	-32.1	-33.1	-60.0	-36.5
Upgraded (dBm)	-47.6	-21.6	-33.0	-21.6	-59.5	-49.6

Transmitter Measurements and Simulation

IMT: Simulated vs. Measured

Serenade



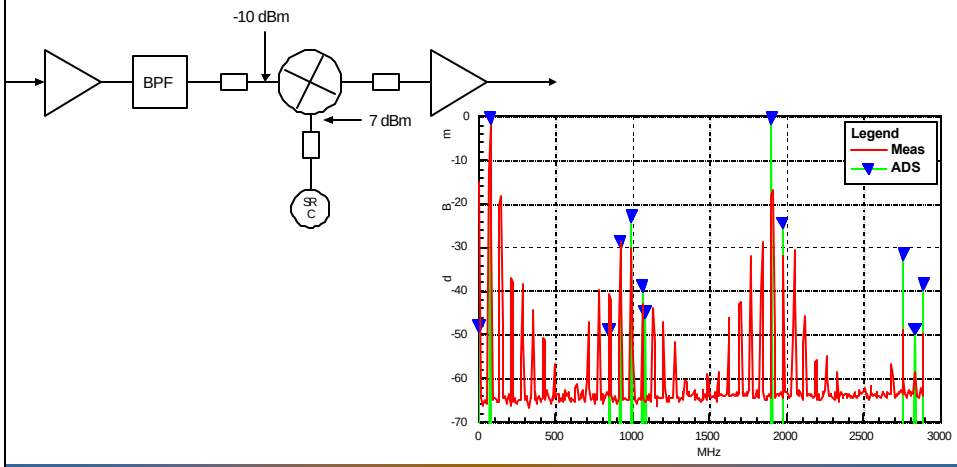


Frequency (MHz)	70	915	985	1055	1900	1970
Original (dBm)	-51.8	-21.8	-39.8	-21.8	-61.8	-53.8
Measured (dBm)	-63.3	-22.4	-32.1	-33.1	-60.0	-36.5
Upgraded (dBm)	-47.9	-21.8	-33.1	-21.8	-59.8	-49.7

Receiver Measurements and Simulation

IMT: Simulated vs. Measured

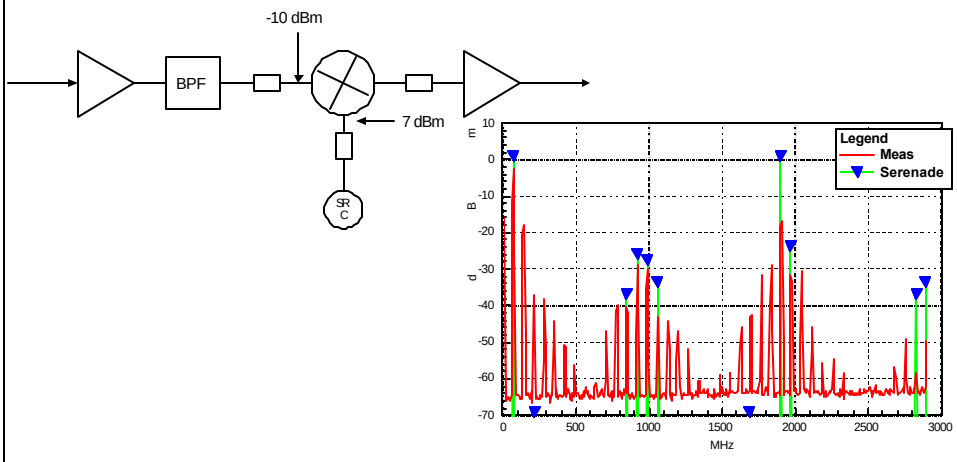
ADS



Receiver Measurements and Simulation

IMT: Simulated vs. Measured

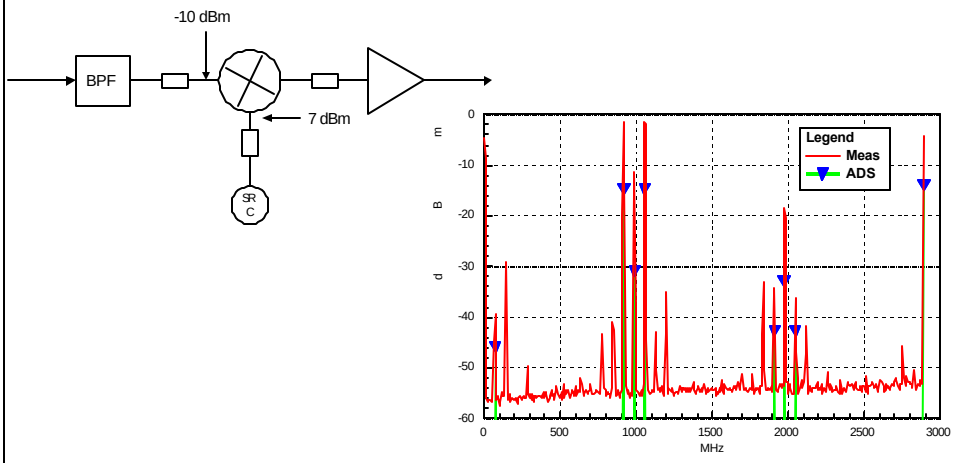
Serenade



Transmitter Measurements and Simulation

IMT: Simulated vs. Measured

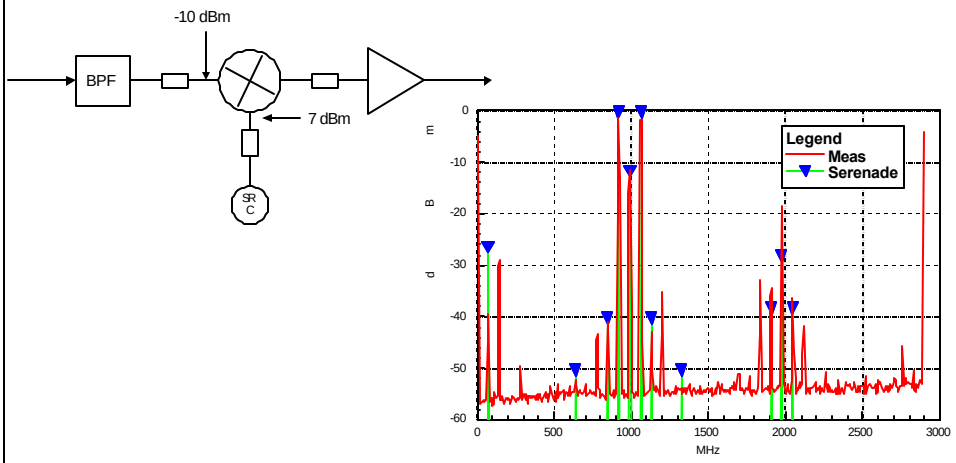
ADS



Transmitter Measurements and Simulation

IMT: Simulated vs. Measured

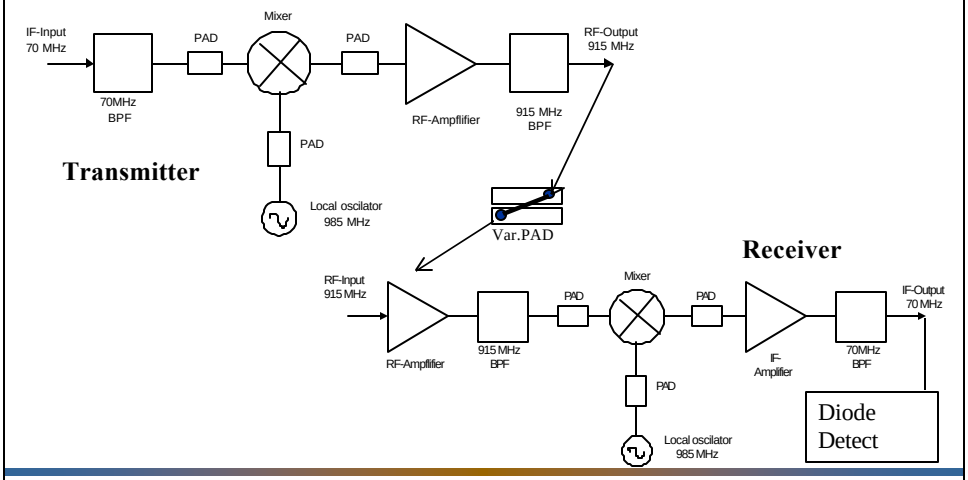
Serenade



Receiver and Transmitter Link

Measured

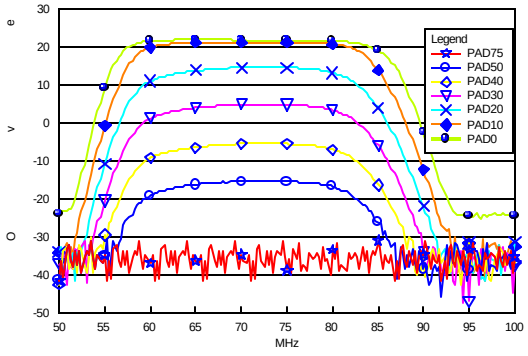
ADS



Receiver and Transmitter Link

Measured

ADS



University of South Florida USF

Wireless and Microwave (WAMI) Program
Department of Electrical Engineering

Summary

- **Good predictions of in-band performance can be achieved for all parameters examined.**
- **The differences between CAD library (ideal) filters and measured filters can cause significant out-band discrepancies.**
- **Mixer product (spur) simulations are much improved after using custom intermodulation tables; unexplained discrepancies remain for some frequencies.**
- **The lack of non-linear representation of amplifiers was evident when amplifiers were included in mixer spur analysis and measurement. Many frequency components not predicted in output.**
- **Future work will study 2.4 GHz "Prism" WLAN hardware, extend consideration to "modulation domain", and time domain, and include antenna/channel considerations.**