



Agilent Technologies

Design & Verification of 3G Handset Power Amps

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The Handset PA World

- Limited number of sockets
- Many chipmakers vying for the same sockets
- Winning or losing a socket = 10s of M\$

Critical elements:

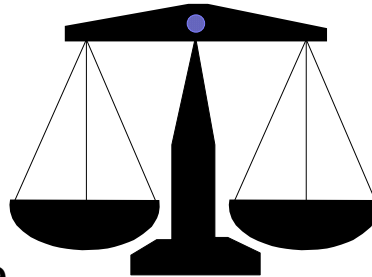
- Time to Market
- Meeting handset specs



Let's take an in-depth example focused on a specific class of design. To understand customer needs effectively it is necessary to characterize the business requirements initially.

Requirements for PA

- **Balance conflicting requirements**
 - **Efficient battery usage**
 - **Distortion in all its forms**
- **Include several alternative designs to choose best**
- **Satisfy specifications of communication format**



Here are the primary outside pressures for the handset power amplifier (PA) designer, which this application addresses.

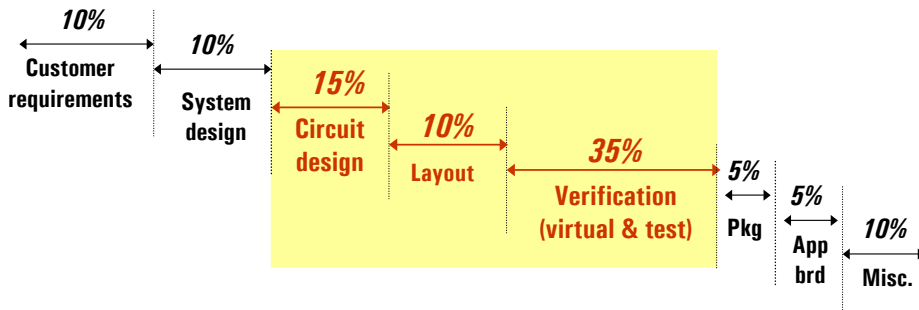
Simulation programs for device design should account for circuit non-linearities so you can optimize the tradeoff with PA efficiency.

The design software should virtually (via simulation) test the design to prove it meets the test specifications for the key 3G cellular formats.

It is necessary to be efficient at testing and evaluating designs to minimize the time to market. Efficient testing means having “canned” test procedures that meet the appropriate cellular specification and automatically perform the tests.

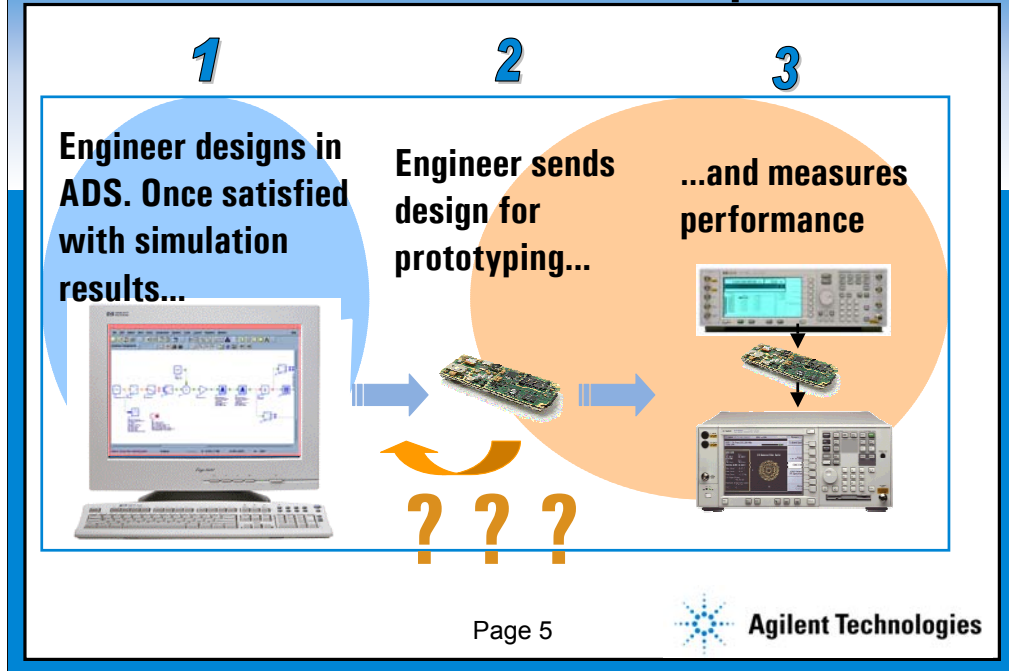
Handset PA Design Cycle

- 50%+ of the total cycle is spent in design & verification



These numbers are based on the experience of the Agilent Solution Services consulting team; they've charted the design cycle for a number of RFIC companies, and this is consistent overall. The integrated Simulation and Measurement system targets the largest piece of this cycle: the verification segment.

Real World / Virtual World Gap

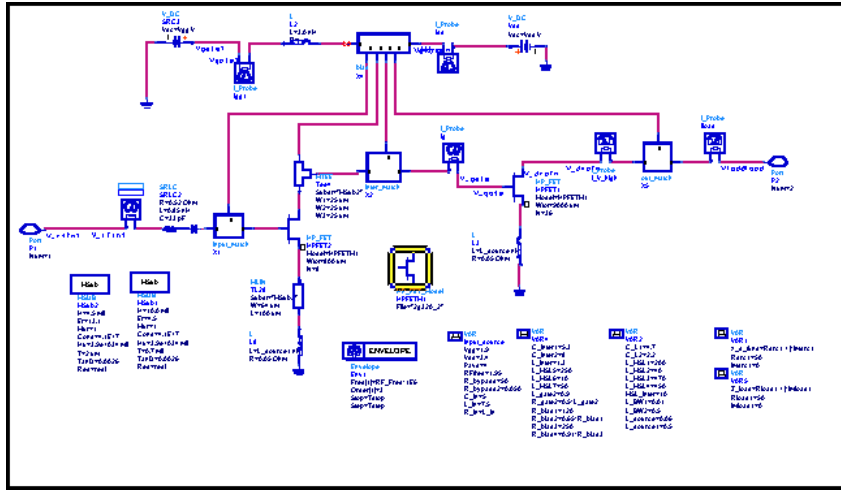


Prior to the system we are describing in this paper, there has been no easy yet effective way to close the gap from measurement back to simulation. In fact, it has been difficult for customers even to know whether there was a gap. Examples:

- We have been told stories of engineers who, with no other method to correlate results, have printed out their simulation results on a piece of paper, printed out their measurement results on another piece of paper, stacked the two sheets of paper together, and held them up to the light to see if they matched.
- In several of the RFIC companies we've visited, engineers are hand-writing and hand-drawing notes and results into paper lab notebooks. Again, no electronic method exists for them to compile and compare results.

Customer need a single environment and user interface to manage both simulations and measurements for an EDGE or 3GPP handset PA design. This is the system called ValiFire recently introduced by Agilent.

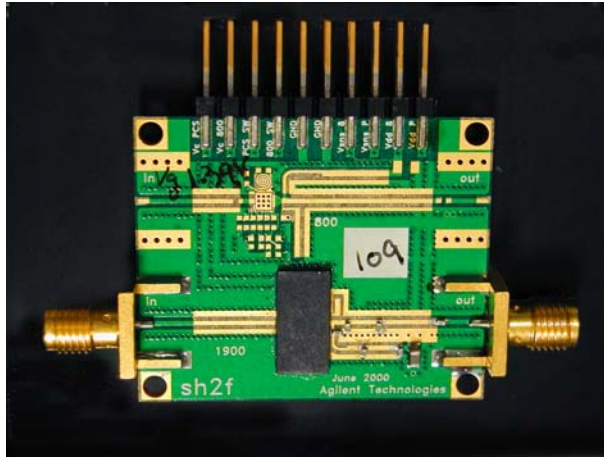
Let's Take a Typical PA



This is an amplifier design that ValiFire can test in either the simulation mode (virtual testing) or, once devices are available, it can actually measure.

To protect the intellectual properties of the design, the amplifier IC is purposefully not shown in all its detail.

PA on Application Board



This is the 3G amplifier on its application board that we tested for most of this presentation. It is encapsulated in a plastic package and, in this phase of the design, the output matching network is placed on the PC board.

Critical Tests for 3G PA

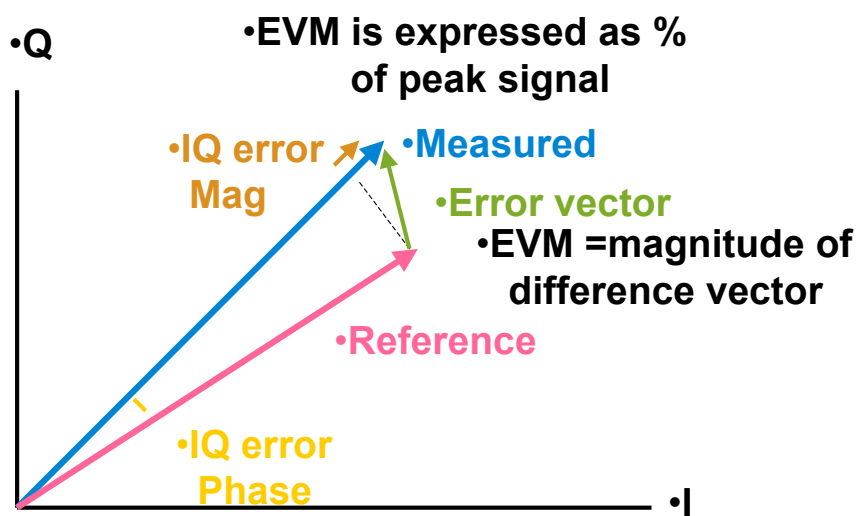
- **Tests = Verification
Both Virtual & Actual**
 - Power added efficiency (PAE)
 - Power vs. frequency
 - Error Vector Magnitude (EVM)
 - Adjacent channel leakage ratio (ACLR)

Here is the list of the critical tests for PAs. The second column shows the many ways you can expect ValiFire to expedite the validation process with automatic testing. Procedures and specifications are updated to keep up with the latest revision.

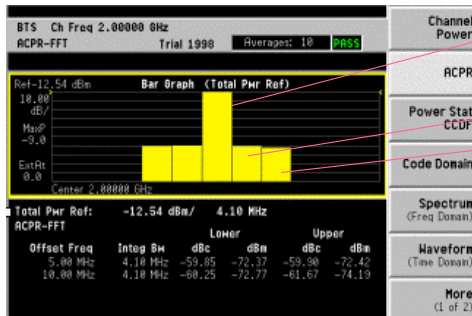
Power added efficiency

- **PAE = (RF Power out from amplifier
- RF Power into amplifier) /
DC Power into amplifier**
- **Higher PAE means longer handset battery life**
- **Key Spec for PA**

Error Vector Magnitude



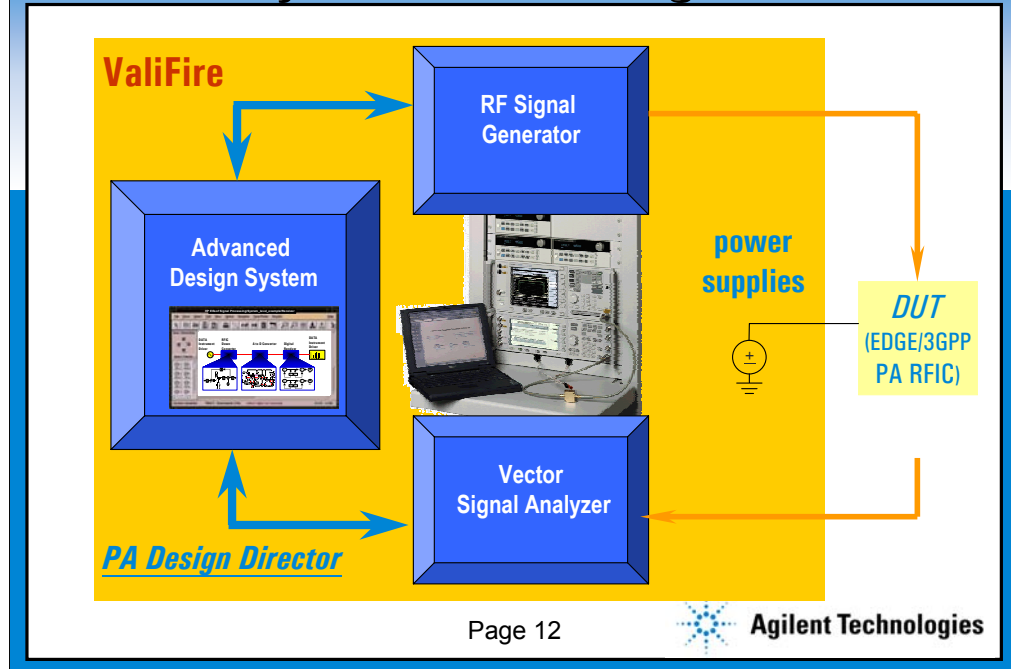
ACLR = ACPR = ACP



- Transmit band main channel
- Adjacent bands + 5 MHz & + 10 MHz

• Ratio of Power in adjacent bands to Power in main channel band

ValiFire System Block Diagram



PA Design Director is the system “wrapper” software that integrates the ADS modules and the test equipment included with the system. Refer to the product overview literature for more specifics on what’s included. To summarize here:

The ADS modules included are:

- Design environment
- Data display
- Linear simulator
- Harmonic Balance simulator
- Circuit Envelope simulator (for co-sim)
- Ptolemy
- Choice of EDGE or 3GPP Design Library

In addition to the major pieces of test equipment shown (ESG, VSA, power supplies) the system also includes:

- E2050A LAN-to-GPIB converter (so no need for an GPIB card in the PC)
- E4416A EPM-P power meter
- E9323A 5 MHz BW power sensor
- All necessary cables, adapters, power cords, and rack hardware to integrate

A Standard Solution...

- **A standard system, all from Agilent**
 - **Integrated**
 - **Verified**
 - **One support number to call**
 - **Updated as 3G specs change**



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We've included 3 dual power supplies with the system in order to meet the minimum needs of customers who are creating PAs for multiband products.

The complete Valifire has one key advantages

It is factory-integrated - the customer merely needs to open the box and plug in the rack to get going. This can save days of assembly effort.

We are not providing the PC/laptop with the system, since so many customers already have computers. If the customer needs to purchase a computer for the system, it should be at least 500MHz with 256 MB of RAM. The software is compatible with Win NT, 98, 2000. We recommend at least 4 GB hard drive (1+ needed for ADS install, ValiFire SW takes a little more).

Tasks of Measurement

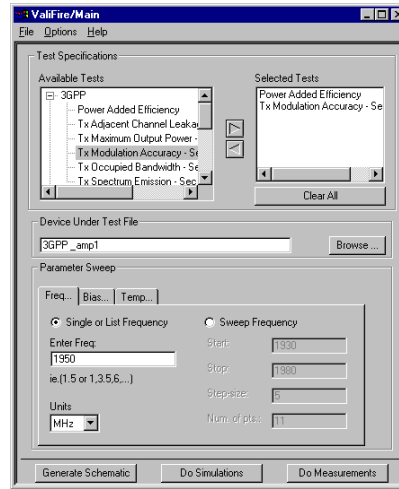
- **Assemble test equipment**
- **Develop procedures**
- **Assure procedures satisfy the latest format specifications**
- **Perform measurements**
 - **Measure the different designs**
 - **Versus bias**
 - **Versus temperature**
 - **Use a statistically valid sample**

Unless special steps are taken, testing can become the critical path. This is especially true because testing is often not part of the device designer's core competency.

Developing procedures and ensuring they meet the latest specifications can be greatly facilitated by using a test solution that pledges to stay up to date. That solution can also provide the automated test capability to do all the tests listed here.

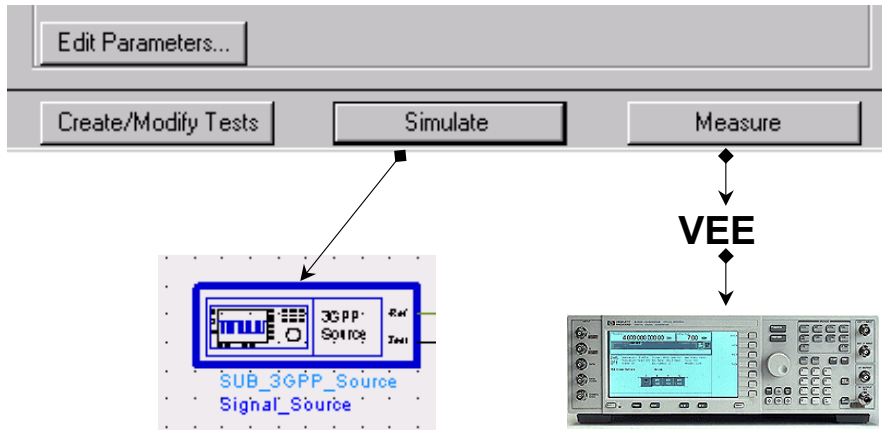
Test Automation

- **Sequence and automate**
 - **Built-in 3G test specs**
 - **Guided user interface**
 - **Data collection**
 - **Spec checking**

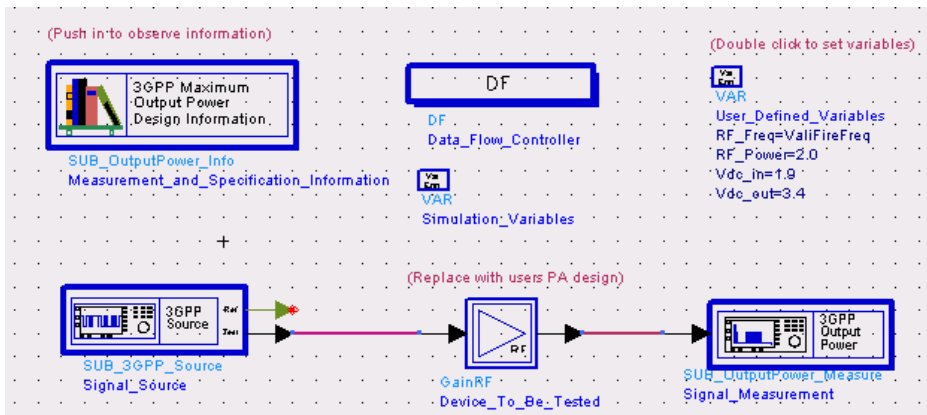


The above is the software front panel for the Design Director. It sets up a test schematic within ADS and switches between Simulated and Measured with the push of a single button

Switch between Simulate & Measure

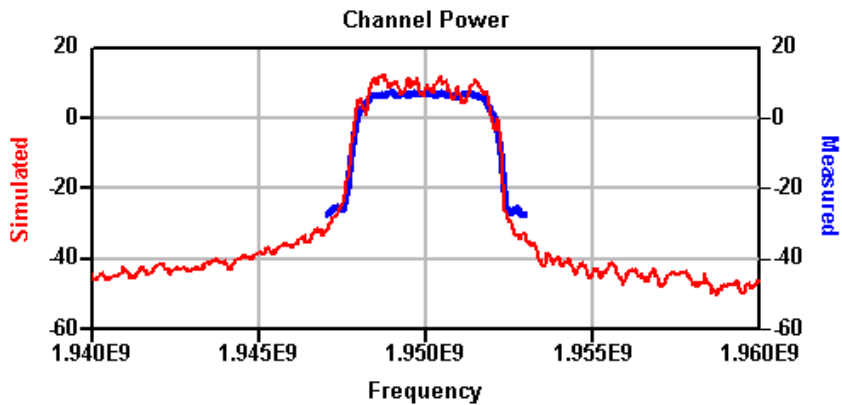


ADS Design for Testing Power



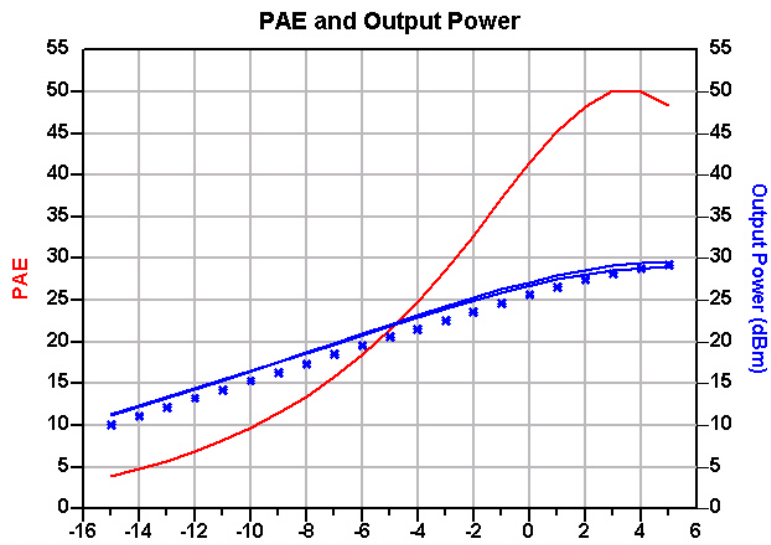
Here is the setup for testing the adjacent channel leakage ratio (ACLR). It also shows the expanded details about the signal generator and the vector signal analyzer (VSA).

Data for Complex Channel Power



This shows data for both the simulated (virtual) test and the measured (actual) test.

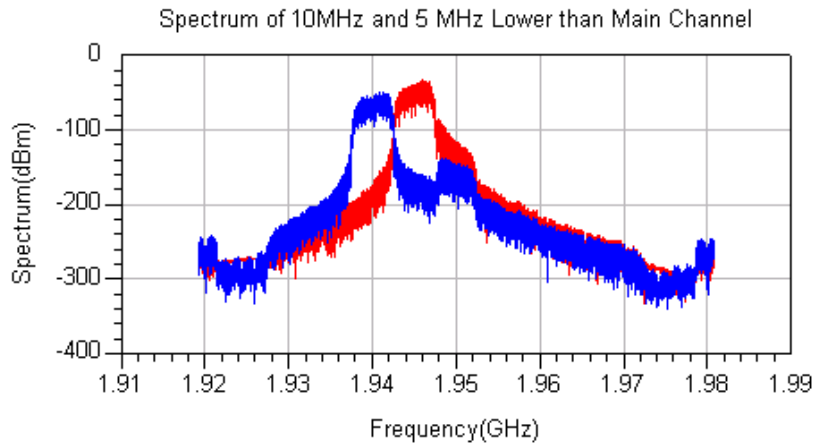
Data for PAE vs. Input Power



This shows both the power output and the Power Added Efficiency (PAE) vs. the input power for both a simulated (virtual) test and the actual test. The same scale on the left is in two units: % for PAE and dBm for power output. You can read the corresponding power input on the bottom scale.

The PAE rises as the input power increases and reaches a maximum of 50% at an output greater than 27 dBm, which is what the amplifier was designed for. The gain of the amplifier is about 26.5 dB.

ACLR below channel



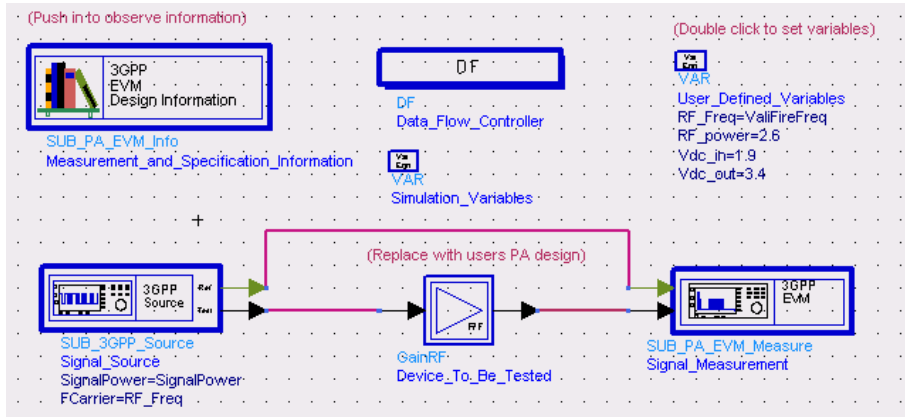
Simulated ACLR

		Simulated		PASSED	
Main Channel Pwr 26.47		Lower		Upper	
Offset Frequency	dBc	dBm		dBc	dBm
5.00 MHz	-38.14	-11.67		-38.72	-12.255
10.00 MHz	-53.57	-27.10		-53.76	-27.290

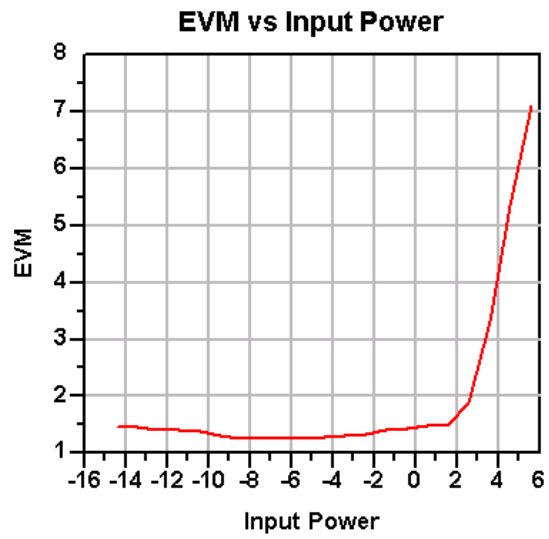
Measured ACLR

		Measured		PASSED	
Main Channel Pwr 28.00		Lower		Upper	
Offset Frequency	dBc	dBm	dBc	dBm	dBm
5.00 MHz	-39.94	-11.94	-39.03	-11.023	
10.00 MHz	-55.87	-27.87	-55.67	-27.669	

ADS Design for EVM



Data for EVM



Closing the Real / Virtual Gap

- Shared algorithms for simulate and measure
- Compare simulate and measure
- Same display and same settings
- Common test platform for both IC vendor and handset maker

Finding simulated-measured discrepancies

Getting specs validation from your customer



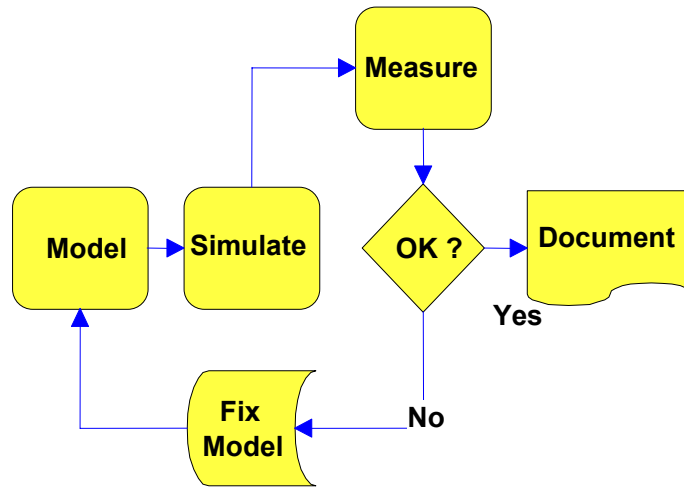
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The ValiFire system validates the algorithms used in both simulation and measurement. It provides standard displays and charts both simulated and measured data and compares them to the specification. By automating data taking, ambiguity on measurement technique is eliminated leading to much quicker correlation between the chip maker and their customer the handset designer.

When Measure & Simulate Don't Match



It takes time to go back and fix the models when the simulated data doesn't agree with the actual measurements. However, with many designers sharing the design library, your payback comes on the next design using that model component. Design labs that strive to reduce their design turns normally adopt this strategy.

Making Engineers More Effective

- **For lead engineers:**
 - Reduce time spent on system setup & coding
 - Reduce time spent learning 3G specs
- **For junior engineers:**
 - Provide guidance in 3G simulation & measurement

ValiFire should provide leverage to RFIC companies by:

- **Making junior engineers more effective (through design & test guidance)**
- **Relieving the burden on scarce lead engineers (since the system assembly and integration is done, and since the ValiFire software incorporates significant intellectual property that can help others become more self-sufficient)**

The end result should be time savings in the design cycle, and greater effectiveness for the scarce engineering resources. How much is shorter TTM worth to your customer? or the reduction of need to hire more engineers?

Summary

- **The Handset PA ValiFire is the first integrated design *and* verification solution from Agilent.**
 - **Pre-configured and pre-coded**
 - **Built-in tests to 3G specs**
 - **Guidance in 3G verification**
 - **Comparison and validation of simulated and measured**
- **Look for more ValiFire solutions in the future!**

Note that we have come back to tie together the major challenges of handset PA design that we described early in the presentation with the major benefits ValiFire provides.

Handset PA ValiFire is just the first in a series of application-specific solutions integrating simulation and test equipment that Agilent is planning over the coming months and years.

For More on ValiFire

- **MTT**
 - **Visit Agilent in Booth 1233 at the 2001 IEEE MTT-S Microwave Symposium in Phoenix, Arizona - May 22-24.**
- **DAC**
 - **Visit Agilent in Booth 210 at the 38th Design Automation Conference in Las Vegas - June 18-20.**
- **www.agilent.com/find/valifire**