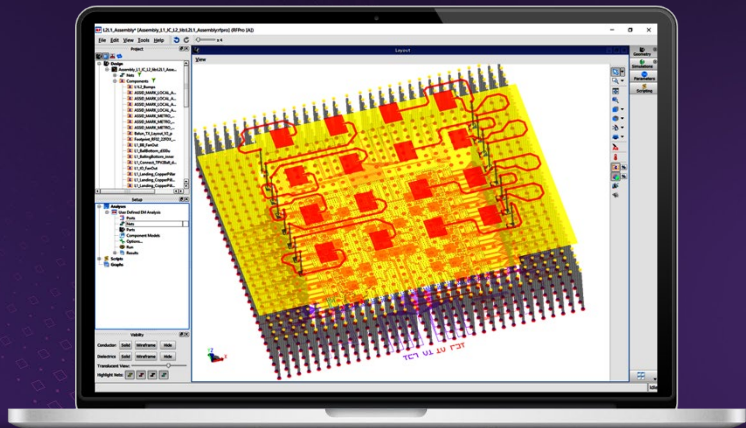

TECHNICAL OVERVIEW

5G RF/Microwave EDA Design Flow

Design, simulation and verification for mmWave wireless and aerospace/defense applications

PATHWAVE

PathWave Advanced Design System (ADS) streamlines multi-technology IC-package-board design of densely integrated RF modules

PathWave Advanced Design System (ADS) addresses 3 critical requirements for 5G product development that had not been satisfactorily met by other EDA tools in the market before. These are:

- Assembling and performing 3D EM-circuit co-simulation on multi-technology 5G modules
- Designing for modulated signals and verification against 5G modulation standards
- Stability analysis of large signal multi-device amplifiers

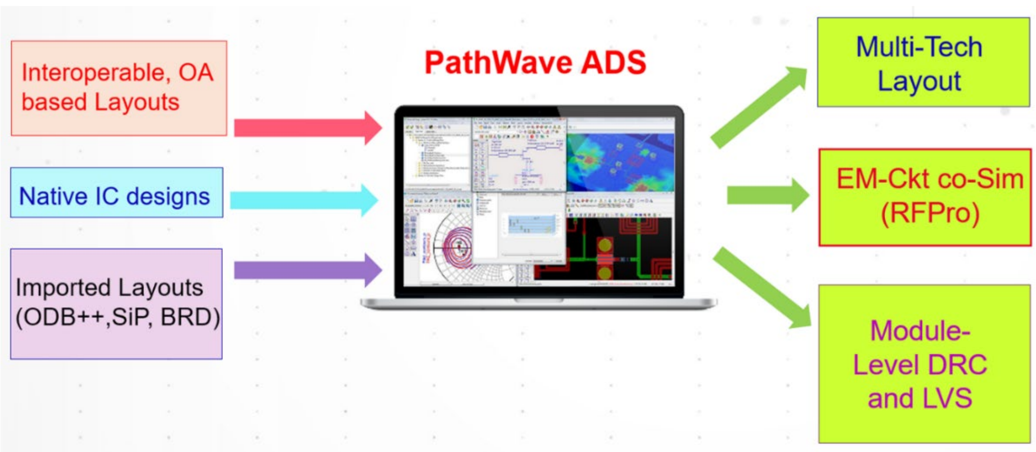

Figure 1. PathWave ADS unique multi-technology design flow assembles IC, package and board into RF module 3D layout for EM-circuit co-simulation and verification to enable 5G, automotive radar and aerospace/defense mmWave component design wins.

KEYSIGHT TECHNOLOGIES

Industry trends towards ever higher frequencies, digital modulations and complex integrated systems – The Implications

Going from 4G to 5G, frequencies have increased by a factor of 40 (700 to 2600 MHz to 28 to 40 GHz), while automotive radar frequency bands are going from 24 GHz to 77 GHz. Not only are frequencies increasing, so are the density and complexity of system integration such as the inclusion of phased array antennas. Digital modulations have also replaced traditional analog schemes. These trends have significant implications on the design of components and systems for RF/MW applications, namely:

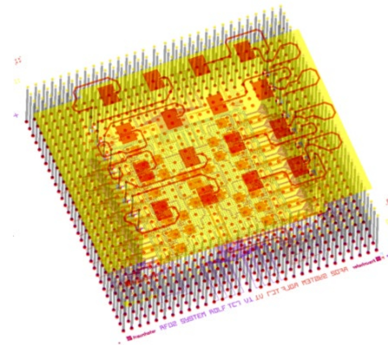

Figure 2. WiGig 60 GHz multi-technology RF module with integrated phased array antennas assembled and simulated in PathWave ADS.

Credits: Design from GLOBALFOUNDRIES and Fraunhofer IIS/EAS/IZM

- Design flows need to support assembly and interconnect of multi-technology components (RFICs, MMICs, wafer-level package, phased array antennas, laminates and PCBs) into dense, complex RF modules. The flows must then include verification by entire module level DRC (Design Rule Check) and LVS (Layout vs. Schematic) for manufacturing sign-off.
- Electromagnetic effects of dense, complex system integration at mmWave frequencies degrade circuit performance such as loss, coupling, and frequency shifts. Circuit designers need to interactively include 3D EM effects of packaging and interconnects during design exploration, tuning, and optimization – not just for final verification of the completed design.
- Digitally modulated RF signals require new figures of merit for circuit design and optimization, the most important of which is distortion EVM (Error Vector Magnitude). Traditional analog rules of thumb or relying on instruments that were adequate for 3G, and barely adequate for 4G, will lead to off spec or over-design of circuits for 5G digitally modulated signals.
- Since transistor gains roll off at higher frequencies, overall gain must be increased to offset this. High gain amid dense integration is a recipe for unintended coupling that often cause unstable amplifiers. Analyzing instability in amplifiers operating under nonlinear large signal conditions is now required to avoid building costly unsalable amplifier hardware in an extremely competitive market.

The Consequence

The consequence of the above implications is that current existing flows are no longer adequate to achieve wins for the 5G, automotive radar and aerospace/defense market.

- Engineers can no longer design pieces of their system on a standalone basis; but need to consider effects which span from the transistor all the way out to the antenna far field radiation pattern.
- They need to assemble circuit, EM, and electrothermal analyses together across technology boundaries.
- It is not trivial to assemble IC's with packages in the design tools in the first place, but to do that in a way which facilitates EM and circuit envelope analysis to understand the effects of modulated waveforms in a multi-technology 3D structure is nearly impossible using existing EDA tools.

After witnessing how RFIC, RF module, and RF PCB designers struggle to correctly assemble and setup ICs, packages, and interconnects for 3D EM-circuit co-simulation to meet 5G and automotive-military radar modulated signal specs, Keysight significantly enhanced PathWave ADS by deploying its expertise across measurement and simulation domains to uniquely address these extreme difficulties.

Assembly of 3D Multi-Technology RF Modules

PathWave ADS is an open EDA platform based on the Open Access (OA) database architecture for efficient assembly and routing of 3D integrated RF module structures consisting of

- RFIC and chip scale antenna layouts based on OA (e.g. Virtuoso, PathWave EM Design)
- PCB and laminate layouts based on ODB++ (e.g. Allegro, Expedition, Zuken)
- ADS native MMIC and RF layouts

A unique assembly technology called SmartMount automatically handles different units (e.g., um and nm for ICs; mm, mils and inches for PCBs/laminates), orientation (top/bottom mount, flip chip, etc.), and adjacent technology layer stack up definitions.

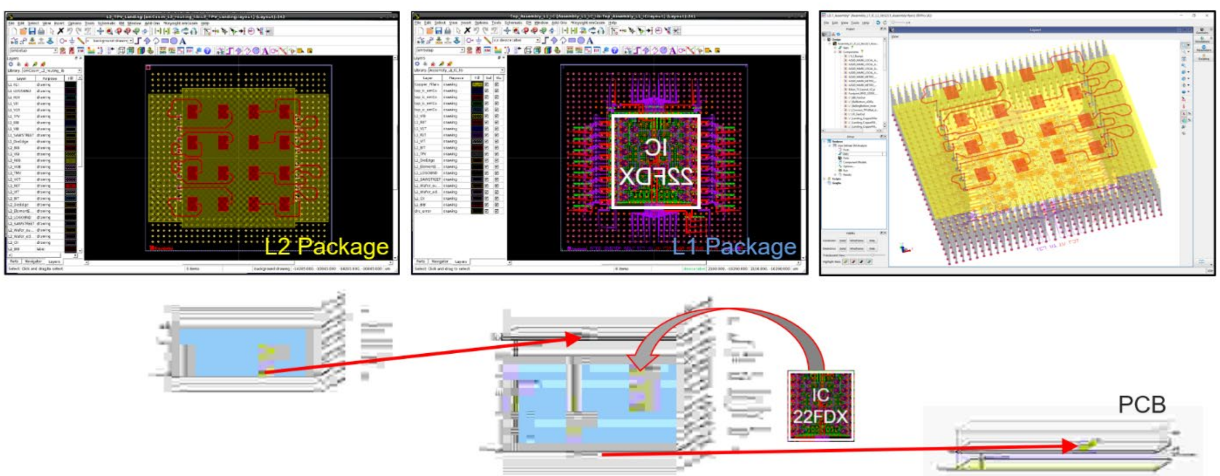

Figure 3. PathWave ADS unique SmartMount and Module Level DRC-LVS ensure efficient and correct assembly of densely integrated RF modules for subsequent EM-Circuit co-simulation and hardware realization.

Credits: Design from GLOBALFOUNDRIES and Fraunhofer IIS/EAS/IZM

After assembly, PathWave ADS layout behaves as both an IC layout and package design tool, enabling you to build hierarchical sub-structures as an IC tool; and avoidance route 3D interconnects as a package tool. This makes building and assembling packages easy for IC designers who need to account for package effects on their IC performance.

Unlike other single-technology DRC and LVS tools, only PathWave ADS has **Module level DRC and LVS** that ensures error-free integration of multi-technology RF modules for hardware realization.

3D EM-Circuit Co-simulation

RFPro in PathWave ADS is an industry-first breakthrough 3D EM-circuit co-simulation capability that enables RF circuit designers to "EM" analyze any portion of their design interactively without layout cookie cutting and tedious setup of ports, ground references, and 3D EM simulation parameters.

Since no modification of the layout is needed for EM simulation, the integrity of the original design is always preserved to avoid introducing manual modification errors like in using other 3DEM simulators.

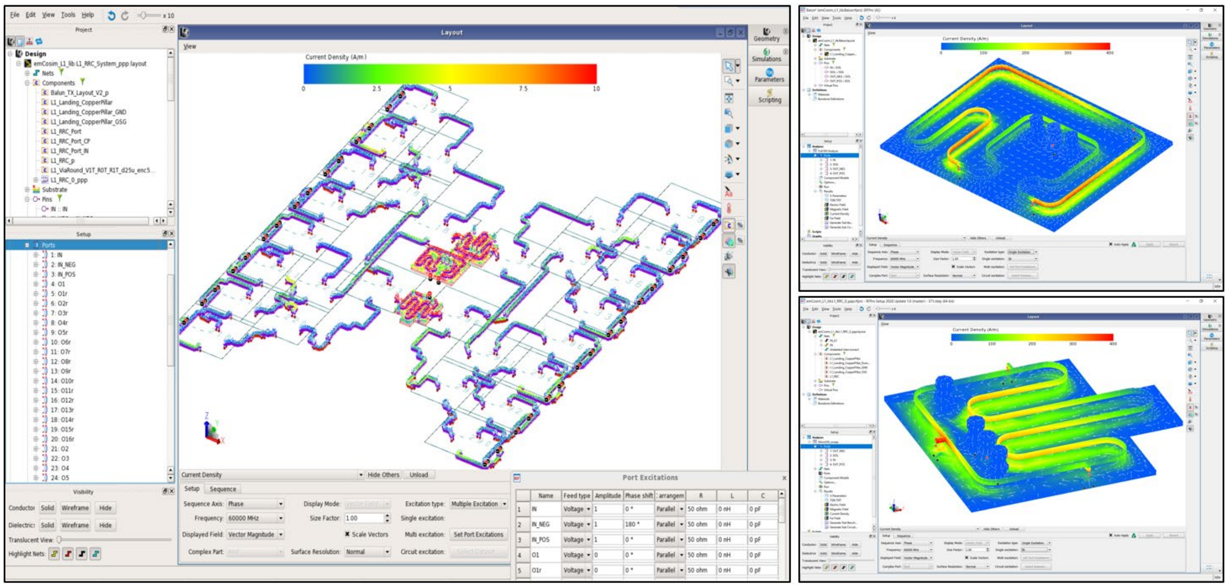

Figure 4. RFPro in PathWave ADS enables 3D EM analysis on any selected portion of your design through automatic net and component extractions without tedious cookie cutting or layout modifications. Connection of EM results to circuits is automatic for immediate tuning and optimization to account for EM effects on circuit performance.

Credits: Baluns, Splitters and Phased Array Feed Network of 60 GHz WiGig module designed by GLOBALFOUNDRIES and Fraunhofer IIS/EAS/IZM.

The 3D EM results are automatically combined with circuit simulation for immediate analysis of EM effects of packaging, interconnect, and coupling on circuit performance. This frees the RF circuit designer to do 3D EM analysis and EM-circuit co-simulation spontaneously without manual setup errors or waiting for the scarce EM experts to perform only the EM analysis.

The result is orders of magnitude faster EM-circuit co-simulation setup from weeks and months to seconds and minutes. It enables companies to buy precious time for early product entry into a tight market window to compete for 5G design wins.

Designing for Modulated Signals - EVM Distortion Simulation at Circuit Level

5G, automotive-military radars, WiFi 6E, IoT…, almost all modern wireless and aerospace/defense applications employ digitally modulated signals. EVM (Error Vector Magnitude) is now the common figure of merit for measuring the performance of a circuit or system under digital modulation stimulus. With increasing signal bandwidth and modulation density, the traditional rule of thumb such as P1dB or IP3 as an indicator of EVM performance is obsolete.

PathWave ADS offers the industry-first EVM simulation at the circuit level. By leveraging the fast EVM measurement algorithms and compact test signal stimulus from Keysight instrument groups, this unprecedented simulation capability enables RF circuit designers to directly tune and optimize for EVM.

This completely removes the guesswork in designing components for 5G or any other digitally modulated signals. Because there are no competing EDA tools on the market that currently offer this circuit EVM simulation capability, PathWave ADS provides a distinct advantage to companies competing for 5G and mmWave component market share.

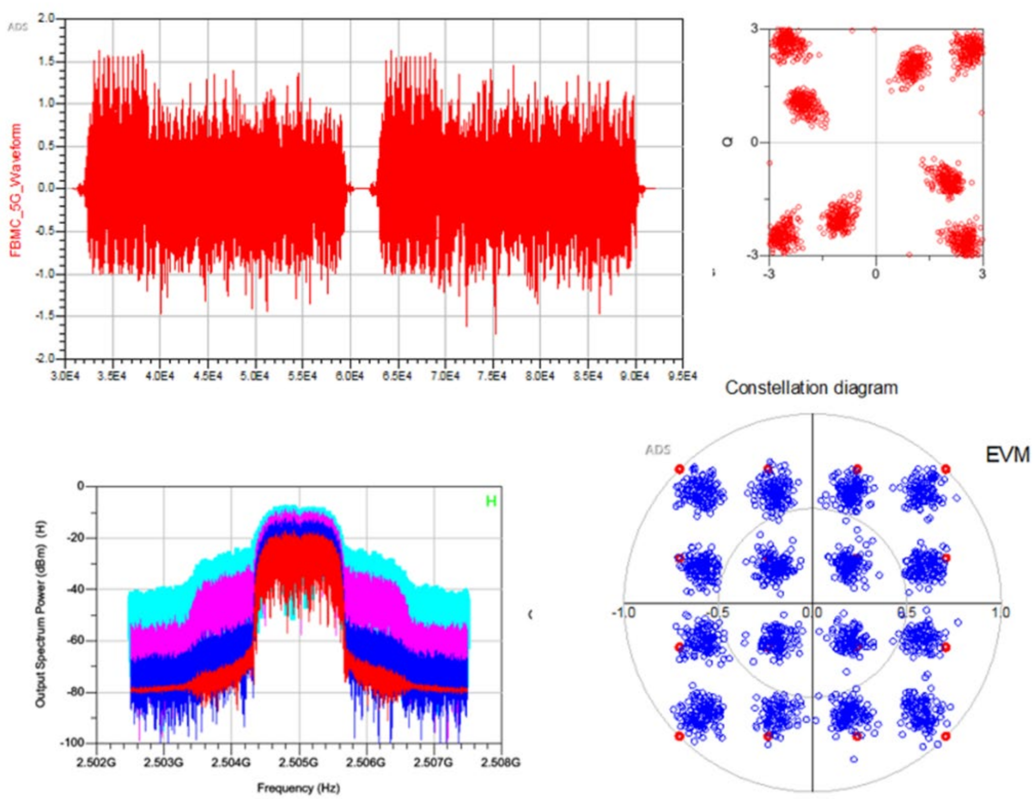

Figure 5. PathWave ADS enables industry's fastest circuit level EVM simulation for tuning and optimization under digitally modulated RF excitation by using Keysight instruments' compact test signal and distortion EVM measurement algorithms.

Verification Against True 5G Standards

PathWave ADS offers instrument grade 5G, radar and other standards-based wireless sources and demodulation algorithms from Keysight instrument groups in the form of preconfigured VTBs (Virtual Test Benches) so that RF designers don't have to deal with complicated setup of 5G and other compliance tests.

VTBs enable accurate verification of RF component designs for 5G, radar and other standards compliance just like using Keysight instruments on the bench, but before hardware is built.

These pre-hardware verifications are useful for 5G and mmWave component vendors to build confidence with their potential clients to secure contracts early.

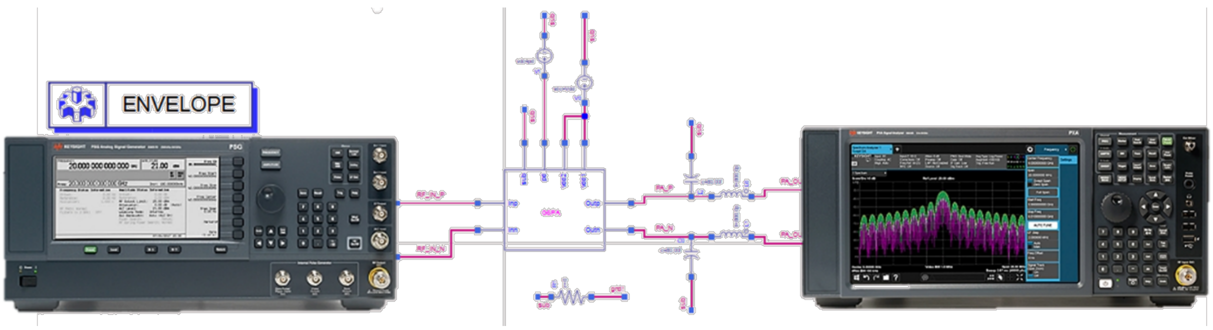

Figure 6. Virtual Test Bench (VTB) contains pre-configured source and measurement setups using the same algorithms as in Keysight instrumentations to verify your design for compliance with 5G, automotive-military radars, WIFI or other popular standards before building hardware.

Stability Analysis of Nonlinear Large Signal Multi-Device Amplifiers

With 5G and automotive radar frequencies trending towards 40 GHz and 77 GHz respectively, transistor gain must also increase to offset high frequency gain roll off. High transistor gain amid densely integrated RF modules causes increased parasitic coupling which often results in unstable amplifiers.

PathWave ADS introduces a unique amplifier stability analysis called Winslow technique, that provides a single unified simulation to consolidate the results from potentially hundreds of separate traditional stability test benches.

Amplifier designers have often wished for a single all-encompassing stability analysis that can determine whether an amplifier is unstable or not under both large and small signal excitations.

The Winslow stability analysis in PathWave ADS has finally made that wish come true!

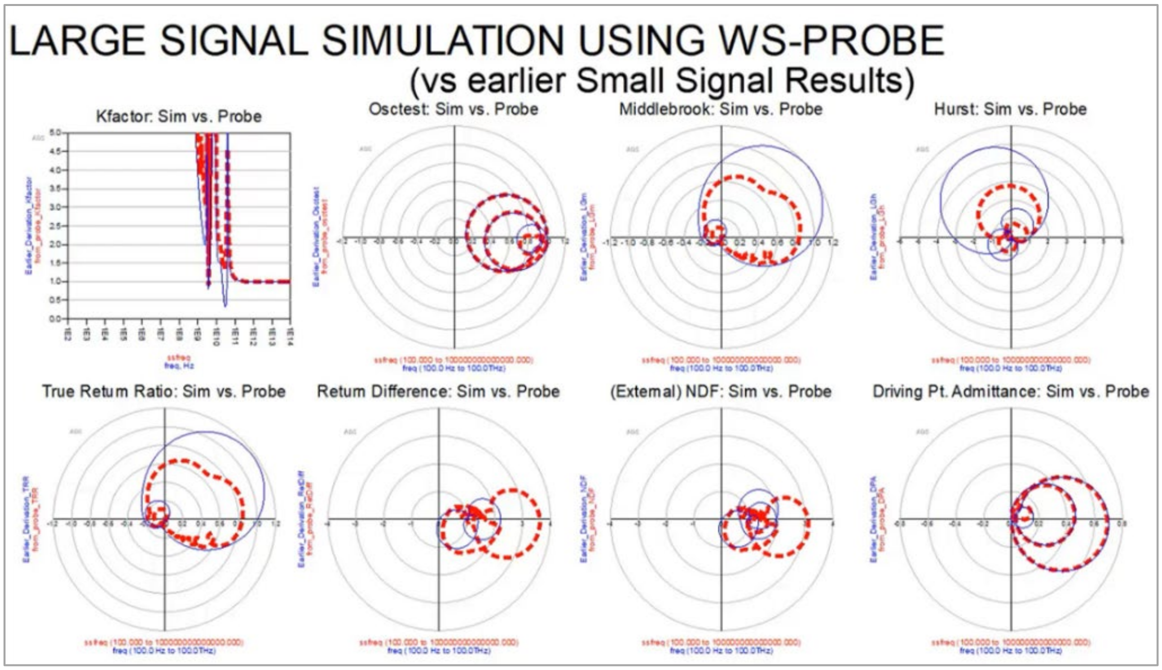

Figure 7. Winslow Stability analysis in PathWave ADS unifies all traditional stability results with a single simulation, enabling amplifier designers to confidently know if their design is stable under large and small signal excitations.

Summary

PathWave Advanced Design System enables the design, simulation, and verification of RFIC, MMIC, RF Modules, and RF PCB for 5G, automotive radar, aerospace/defense applications that no other competing EDA vendor offers:

- Assembly of multi-technology structures with module level DRC and LVS
- Automated 3D EM-circuit co-simulation of multi-technology modules with no layout modification
- EVM simulation and optimization of circuits with digitally modulated signals
- Instrument grade 5G virtual test bench for 5G and other standards compliance verification
- Comprehensive nonlinear amplifier stability analysis for large and small signal excitations

By deploying PathWave ADS in their design flows, companies can achieve early design wins. To learn more about Keysight PathWave Design tools, visit PathWave Design 2021.

Learn more at: www.keysight.com

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at:
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