Ansys

Engineering What's Ahead:

5G Intelligent Connectivity

e-book

Winning the Race to Intelligent Connectivity

The Critical Role of Engineering Simulation

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Speed to Market Will Determine 5G Winners.

Next-generation connectivity – powered by communications systems like 5G – will radically transform all industry sectors. The impact could boost global GDP by more than $2 trillion by 2030.[1]

The 5G opportunity is truly game changing. Advanced communications systems will deliver a new entertainment experience, serve as the backbone of intelligent autonomous mobility, revolutionize healthcare, and propel manufacturing into a new era of smart connected factories and products. Within a decade, people worldwide are expected to be consuming 20 times more data than today.

As a result, the pressure is on to be first to market with reliable, safe and affordable 5G-enabled technology that delivers the highest level quality of service.

58%

of consumers fully expect 5G to be available within a year's time.

Companies – established players and startups – are racing to capture the 5G market opportunity and they know that their future success depends on the critical technology decisions they make today. Engineering teams are the key to unlocking this enormous potential.

This e-book details the technical challenges they face, identifies simulation as a common best practice adopted by 5G leaders to tackle these challenges, highlights the resulting benefits, and details the critical simulation capabilities required to realize them.

[1] https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/connected-world-an-evolution-in-connectivity-beyond-the-5g-revolution

For 5G to Succeed, These Issues Must Be Addressed.

The opportunity before 5G innovators is almost unlimited, but critical market demands must be overcome by those who want to win the race to market.

10x
Decrease in latency
as low as 1ms

10x
Connection density
More efficient signaling for IoT connectivity

10x
Experieced throughput
More uniform, multi-Gbps peak rates

100x
Traffic capacity
Network hyper-densification with more small cells everywhere

100x
Network efficiency
Optimized network energy consumption with more efficient processing

3x
Spectrum efficiency
More bits per Hz with advanced antenna techniques

SCALABILITY AND USER DENSITY

It is anticipated that a 5G network must be capable of serving billions of users through trillions of terminals. This will push electronics complexity to unprecedented levels, driven by: new frequency bands, including mm-wave, thermal and power management, carrier aggregation leading to more electronics in RF front-end (RFFE); base station and handheld antennas need beamforming technologies to create directional radiation pattern gains; and systems must safely overcome human body interactions and serve many moving subscribers. The dense packaging of electronics must handle signal integrity, power integrity, thermal management, electronics reliability and consistent radio frequency (RF) performance, all potentially making maintenance more costly and more difficult.

LATENCY

Delivering an order of magnitude improvement with the drive to 1ms.

BROADBAND USER EXPERIENCE

5G is expected to deliver a 10 times improvement in speeds over 4G, with peak speeds anticipated to exceed 1Gbps.

RELIABILITY AND SECURITY

5G will need to meet industry standards, such as 3GPP, and "always on" connectivity for critical use case applications. These new technologies carry significant engineering implications to ensure that signal integrity, power integrity, electromagnetic interference (EMI), electromagnetic compatibility (EMC), cost and performance requirements are met, to offer low-cost, low-power high-reliability systems and components.

CELL-EDGE CAPABILITIES

In order for 5G networks to obtain the 1ms latency target for critical applications such as AI operations at the cell site, AR/VR, Autonomous Vehicles, Smart Cities, and emergency response systems, the compute capabilities previously provided by distant datacenters need to be pushed closer to the user. To do this, Edge network applications are being designed into 5G networks. These mini servers can be designed into micro and picocells placed around urban environments or larger edge systems placed directly at the cell site. These edge enabled small cell systems, combined with a large network capacity increase via implementation of Massive MIMO (Multiple Input Multiple Output) at large base stations, will allow for enormous amounts of data to be passed quickly between the Edge Cells, thereby helping to bring heavy data processing and rapid data response times to the user.

SPECTRAL EFFICIENCY

Driving towards >30 bits/s/Hz to maximize use of bandwidth availability within new frequency bands.

Core Systems Complexity Adds to the Engineering Task.

Chip, Package System Design and Analysis

Critical engineering challenges:

- *Power efficiency*
- *Thermal and mechanical integrity: temperature dependent performance and thermally induced warpage*
- *Emissions compliance*
- *System-on-chip (SoC) designs for very high frequencies*
- *Integration and layout density*
- *Technology-level scaling (FinFet uneven scaling)*
- *Advanced packaging including InFO, WoW, CoWoS, etc.*
- *Lifetime reliability prediction (especially for safety critical applications)*
- *Die level crosstalk/coupling noise*
- *Side channel emissions*

Signal, Power and Optical Integrity of High Bit Rate Systems

Critical engineering challenges:

- *Verify performance of extremely high data rate signals such as SERDES, DDR and HBM*
- *Suppress impedance discontinuities seen by fast signals due to connectors and cables*
- *Suppress power noise and voltage fluctuations seen by ever more sensitive chip applications*
- *Optimize decoupling*
- *Reduce EMI and noise*
- *Perform thermal analysis*
- *Non-linearity in optical fiber simulation*

End Use Equipment Antenna System Design and Integration

Critical engineering challenges:

- *Design of multi-band/multi-antenna elements with beamforming and massive MIMO implementations in a compact & loaded platform*
- *Optimization of the individual components down to the chip-level floor plan*
- *Support of 10x higher data rates*
- *Radiated emissions compliance and human body interaction certification*

Full Communication Analysis in Electrically Large and Complex Environments

Critical engineering challenges:

- *Electrical size, dynamic nature and complexity of the operating environment*
- *Environmental effects on performance: wind loading, solar loading, etc.*
- *Antenna platform affected by platform and installation environment*
- *Physical channel and propagation modeling*
- *SNR degradation due to interference*

RFI, EMI, Cable Radiated Susceptibility Effect and Desense Mitigation

Critical engineering challenges:

- *EMI, RFI, coexistence & desense on digital signals*
- *Co-site antenna interference*
- *Multi-antenna placement*
- *Interference between antennas and circuitry*
- *Cable susceptibility to environment*

Simulation is *the* 5G Solution.

Simulation can address the myriad challenges faced by those engineering the future of 5G, delivering a significant competitive advantage.

60%
cost reduction compared with competitive offering[1]

3x
speed development time (acceleration compared with physical tests)[2]

70%
reduction in idle power[3]

80%
reduction in antenna weight through additive manufacturing[4]

1. https://www.ansys.com/about-ansys/advantage-magazine/volume-xi-issue-3-2017/crossed-signals
2. https://www.ansys.com/about-ansys/advantage-magazine/volume-xii-issue-2-2018/cutting-the-cords
3. https://www.ansys.com/about-ansys/advantage-magazine/volume-x-issue-3-2016/power-retooling-for-chips
4. https://www.ansys.com/about-ansys/advantage-magazine/volume-xi-issue-3-2017/tuning-in-to-antenna-design

Going Behind the Statistics.

The real story of 5G simulation success can be found behind the statistics. These case studies highlight the impact of simulation in real-world 5G breakthrough situations.

AMD:
Power Retooling for Chips

Device temperature affects performance significantly. Hotter chips run slower, become unreliable, and can fail prematurely. The inability of the chip package to dissipate heat can become a major bottleneck, limiting the chip's ability to run at higher frequencies and restricting the number of transistors per device. Reducing chip power consumption often increases performance while reducing the cost of powering and cooling servers. AMD engineers used Ansys simulation software to identify design elements continuously supplied by a clock signal as a means of improving performance. By evaluating power consumption earlier in the design flow with Ansys tools, AMD achieved an extraordinarily high level of power efficiency.

Qualcomm:
Cool Smartphones

As smartphones continue to add features like high-end cameras, antennas, and multi-tasking capabilities, the additional processing power needed to control these features generates more heat, reduces battery life, and increases power consumption. Keeping smartphones from heating becomes even more daunting as more transistors and devices must fit into smaller, sleeker designs. Qualcomm engineers teamed with Ansys simulation solutions to create a smaller model of the power sources in a smartphone. This model can be solved in a fraction of the time of a full thermal analysis, opening the door to more operating scenarios. Ansys has helped Qualcomm create a dynamic power management strategy to selectively direct power where it's needed while keeping the temperature down.

Samsung: Enabling New 3D-IC Reference Flows

In a press release, Samsung notes that is has certified Ansys simulation software for multiple applications. One example is an Ansys multiphysics simulation for Samsung's latest multi-die integration advanced 2.5/3-dimensional integrated circuit packaging technology. The certification empowers mutual customers to achieve higher performance and lower power within a smaller form factor when designing for artificial intelligence, automotive, networking, and high-performance computing. Another certification of Ansys simulation software allows for detailed modeling of silicon interposer, through silicon vias, microbumps, high-bandwidth memory, high-speed interfaces, and different dies – all critical for accurately simulating power, signal, and thermal integrity effects.

Simulation Solutions Explained in Detail.

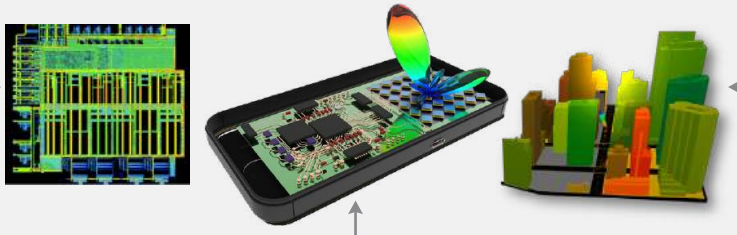
Ansys provides a multiphysics simulation solution leveraging high-fidelity physics, spanning a scale from silicon to the city, which includes:

- *Integrated chip package and system analysis.*
- *Signal, power and optical integrity.*
- *Antenna design, placement and integration.*
- *RFI, EMI/EMC and de-sense mitigation and full communication analysis in electrically large and complex environments.*
- *Open environment delivery for optimization, simulation data and process management, workflow customization, access to cloud and high-performance capacity (HPC).*
- *Support of third-party integration for deployment across the enterprise.*

All of these solutions are backed by the world's leading center of simulation expertise, providing customer enablement through technical support, services and training.

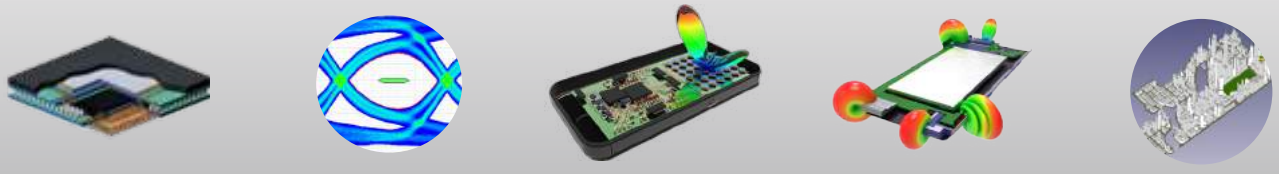
Ansys Comprehensive 5G Simulation Solution

Simulation from silicon to the city



Integration of high fidelity multiphysics and system level simulations

Chip Package System Simulation	*Signal, Power & Optical Integrity Simulation*	*Antenna System Design & Integration Simulation*	*RFI, EMI/EMC & Cable Simulation*	*Electrically Large Environment Simulation*



Optimization | *Simulation & Process Data Management* | *Cloud & High-Performance Capacity (HPC)* | *Workflow Customization* | *Third-Party Tool Integration* | *Customer Enablement*

Making It Real: Peraso Technologies

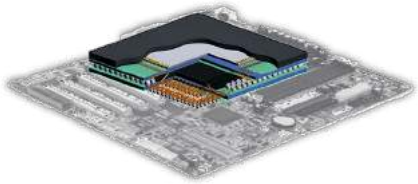
Ansys Comprehensive Simulation Solution:
Chip Package System

Critical engineering challenges:

- *Comprehensive thermal analysis*
- *Optimizing shape for efficient and effective thermal cooling*

By 2021, two-thirds of all internet traffic will be used for high-throughput services such as wireless docking, video streaming, cloud backup, and virtual reality. Peraso Technologies lets users go wireless through chipsets based on the emerging 802.11ad (WiGig) standard that delivers high-speed wireless throughout in a USB 3.0 stick. By using Ansys simulation software, Peraso engineers solved thermal issues associated with packing high-power transmitters into a tiny enclosure. Ansys multiphysics simulation accurately predicts temperature and heat flow at every point in the adapter as the design process moves along, reducing the time needed for thermal design by two-thirds.

Chip Package System Simulation



Co-simulation for Power, Power-Integrity, Reliability, SI, EM, Solutions across chip-package-system (CPS).

Solution Capabilities

- Process and analyze all advance silicon nm nodes with multiple EM solvers
- Access all foundry requirements for tech file encryption standards
- Perform 3DIC analysis
- Accurately analyze design of power delivery network (PDN) including chip-level models
- Analyze CPS-level thermal and ESD
- Synthesize IP Compiler for passive on-chip devices for floor planning
- Analyze EM crosstalk risk
- Analyze block-to-block EM coupling in nm SoCs
- Perform transistor-level power noise simulations for mixed-signal custom chips
- Utilize RTL design-for-power platform to analyze, debug and reduce power levels early in the design
- Perform RLCk extraction

Key Outputs & Benefits

Technical Outputs

- S-parameters
- SPICE models
- Chip thermal models
- Chip power models
- ESD models
- IBIS models
- DC, transient and frequency domain analysis
- Color plots displaying problem areas

Technical Benefits

- Accuracy by characterizing chip, SoC and complex packages
- Scalability of simulation from the chip to the system
- Improved reliability
- Improved security

Making It Real: Samtec

Ansys Comprehensive Simulation Solution:
Signal, Power & Optical Integrity

Critical engineering challenges:

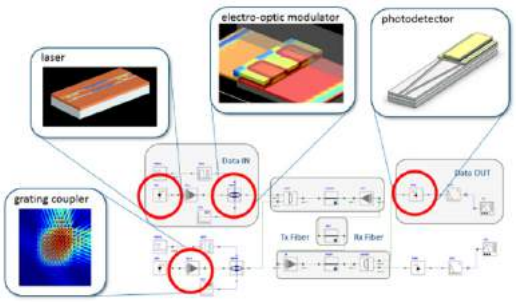
- *Analyzing and optimizing 3D structures with high-frequency electromagnetic fields*
- *Performing full-channel simulations of a high-speed interconnect*

Data center servers, storage and networking equipment communicate over copper and optical cable assemblies joined together by ever-faster connectors. Samtec uses a suite of simulation software from Ansys to design and optimize next-generation, high-performance interconnect solutions across the entire signal channel.

Samtec's engineers port the mechanical models into Ansys software to optimize channel component structures, target subcomponent modeling, and improve improve channel optimization. Next, Samtec uses Ansys software to model and analyze large planar printed circuit board and integrated circuit package high-speed channels, and complete power delivery networks. Samtec also uses Ansys time-domain circuit simulation engines to perform full-channel simulations of a high-speed interconnect.

Signal, Power & Optical Integrity Simulation

Co-simulation for Power, Power-Integrity, Reliability, SI, EM, Solutions across Chip Package System.



Ansys provides basic building blocks for a complete optical system transmission link; from transmitter to transmission channel to a receiver.

Solution Capabilities

- Power analysis of the chip and the creation of a chip power model (CPM).
- CPM integrated system analysis to verify the electrical operational integrity CPS
- Analysis of extremely fast signals using full wave solvers
- Use of MCAD geometries in an ECAD environment to create full-system analysis
- Ability to mix different full wave solvers to help speed up analysis without losing accuracy
- Thermal analysis of the chip and the creation of chip thermal models (CTM) followed by Integration of the CTM into the system thermal analysis
- Design of thermal distribution structures for heat dissipation
- Automated EPDA design flow
- Foundry-supported PDKs & CMLs
- Use of S-parameter simulator and transient simulator in one circuit with converters to speed up simulation on solving nonlinearity

Key Outputs & Benefits

Technical Outputs

- Crosstalk and impedance scans
- EMI scans
- Decoupling optimization
- S,Y,Z parameters
- Transient analysis (TDR, eye diagrams)
- EM fields plotting
- Thermal analysis
- Standards sign-offs
- QPSK fiber communication system with foundry PDK
- SMF-28 communication system with linear & nonlinear dispersion

Technical Benefits

- Design and analysis time reduction
- Accuracy
- The ability to integrate chip and package models into the PCB models allows for a more accurate analysis of the PDN
- The use of foundry supported Compact Model Libraries (CMLs) guarantees the accuracy of the circuit simulation
- Scalability of simulation from the die to the server

Making It Real: PHAZR

Ansys Comprehensive Simulation Solution:
Antenna System Design & Integration

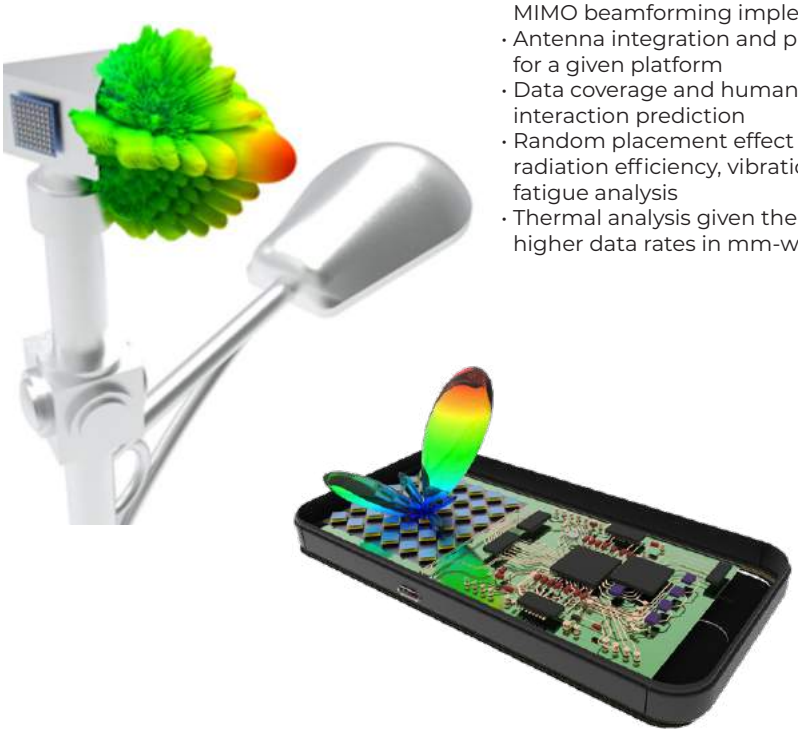
Critical engineering challenges:

- *Integrated simulation*
- *Detailed antenna analysis*
- *Device integration*
- *Environmental interaction*

PHAZR was formed to develop a unique 5G millimeter wireless network capable of providing a 128-times faster experience and 1,024-times more capacity, compared with 4G LTE for mobile and fixed-access applications. Since consistent, uninterrupted user access has not been achieved through 4G technology, PHAZR engineers have worked to significantly increase capacity and allow consumption of much higher data quantities per user.

To reach these aggressive goals, PHAZR leverages Ansys simulation software to both speed up its analysis capabilities and also provide design agility and flexibility for this cutting-edge technology. For example, Ansys tools enable the study of radio frequency propagation of various antenna and array designs at different frequencies across a variety of materials, enabling engineers to more quickly analyze data and arrive at solutions.

Antenna System Design & Integration Simulation



Solution Capabilities

- Antenna modeling and optimization
- Phased array antenna and massive MIMO beamforming implementation
- Antenna integration and placement for a given platform
- Data coverage and human-device interaction prediction
- Random placement effect on radiation efficiency, vibration and fatigue analysis
- Thermal analysis given the supported higher data rates in mm-wave band

Key Outputs & Benefits

Technical Outputs

- Robust design with multiband antenna placement and integration
- Optimized housing material characteristics and distance from radiation elements for best product performance
- Massive MIMO and antenna beamforming
- Data coverage with cumulative distribution function calculation
- Human-device interaction effect via power density (PD) evaluation

Technical Benefits

Proven

- Robust design of the complete end-user equipment platform with multiple antennas covering different frequency bands from low sub-6 GHz to mm-wave including placement and integration

Accurate

- Implementation of phased array antenna and massive MIMO beamforming while evaluating 5G data coverage efficiency and interference with other radios in the surroundings.

Predictive

- Both cumulative distribution function (CDF) and power density for human-device interaction as well as radio frequency interference and desense mitigation are key parameters in the usability of Ansys tools

Making It Real: STMicroelectronics

Ansys Comprehensive Simulation Solution:
RFI, EMI/EMC & Cable

Critical engineering challenges:

- *Setting industry standards*
- *Electromagnetic analysis*

The proliferation of wireless and wired channels has made compliance with electromagnetic interference and compatibility standards harder to achieve. These issues have traditionally been addressed using an electromagnetic simulator to extract an S-parameter model of those features anticipated to be problematic.

Engineers at STMicroelectronics have used Ansys simulation solutions to model the structure and calculate electromagnetic fields in the frequency domain. The resulting S-parameter model, embedded in the circuit model, provides a realistic excitation to accurately predict the magnetic and electrical emissions of the actual circuit. Results can be used with confidence to rapidly identify and correct electromagnetic interference issues.

RFI, EMI/EMC & Cable Simulation

The industry standard for electromagnetic analysis

Solution Capabilities

- Coupling effects and EMI scanner
- Reliability, EMI, RFI and desense mitigation
- Built-in EMC analysis templates
- Dynamic link between circuit and field solvers

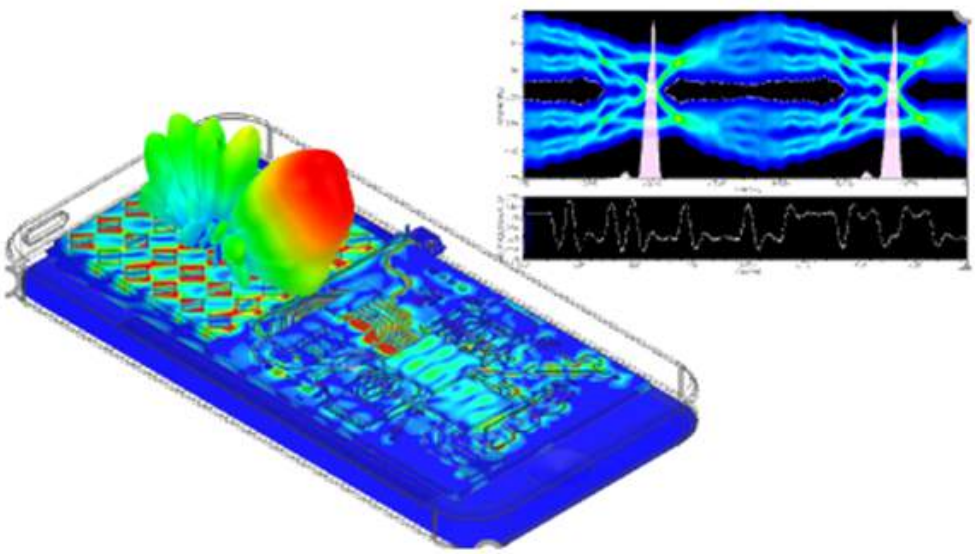
Key Outputs & Benefits

Technical Outputs

- Antenna-to antenna, antenna-to-digital signal coupling, RFI and EMI early design stage prediction
- Sign-off reports and verification data on channel performance or failure events
- Coexistence and desense mitigation high-fidelity workflows
- Radiation plots
- S-parameters

Technical Benefits

- **Coexistence:** Co-site simulation of radio-dense equipment accurately predicts coupling and interference between numerous channels
- **Immunity:** EMI margin and desense simulation can predict immunity of signal in complex RF environment
- **Reliability:** Full system simulation helps maintain reliable channel capacity through the dynamic interference
- **Certified:** Virtual test in simulation environment guarantees the products to pass rigorous certification tests



Making It Real: Pivotal Commware

Ansys Comprehensive Simulation Solution:
Electrically Large Environment

Critical engineering challenges:

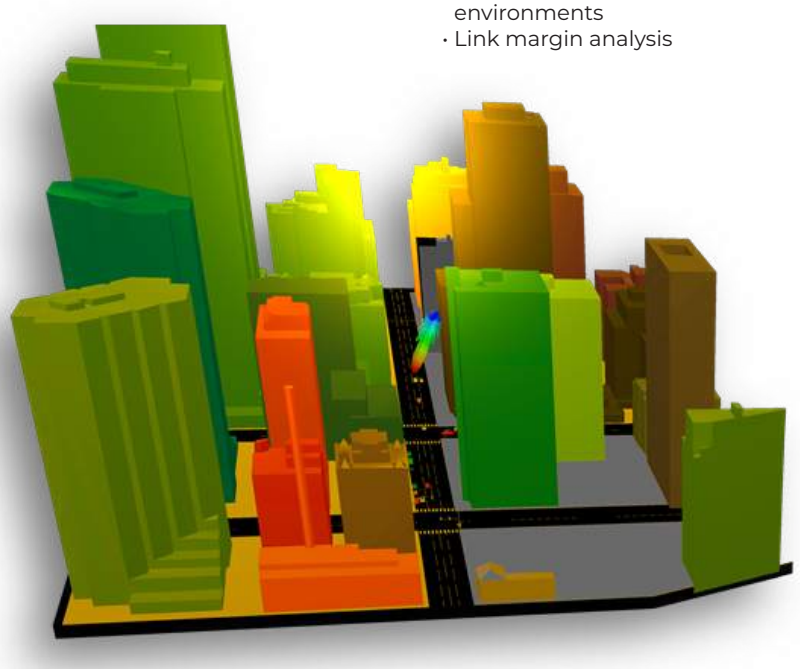
- *Setting industry standards*
- *Electromagnetic analysis*

The speed of communications bandwidth has been proven to far outpace the rate of growth in the existing radio frequency spectrum. 5G can solve this problem by leveraging beamforming antennas to send multiple simultaneous transmissions on the same frequency. Pivotal Commware designs the next generation of these antennas and cellular base stations.

Ansys simulation solutions assist Pivotal Commware engineers in creating antenna designs that meet these requirements on the first or second pass. Ansys models focus attention on element radiators, passive elements of the antenna responsible for the radiation pattern. Using simulation tools, Pivotal Commware can substantially reduce the time required to bring new antennas to market.

Electrically Large Environment Simulation

The industry standard for electromagnetic analysis



Solution Capabilities

- Full physics based SBR+ solver for:
  - Installed pattern
  - Dynamic environment
- Channel characterization
- Physics-accurate modeling of physical channel propagation for testing MIMO beamforming and dynamic environments
- Link margin analysis

Key Outputs & Benefits

Technical Outputs

- Adaptive beamforming of massive MIMO phased array in urban environment
- Accurate antenna pattern on base station platform
- Cell planning

Technical Benefits

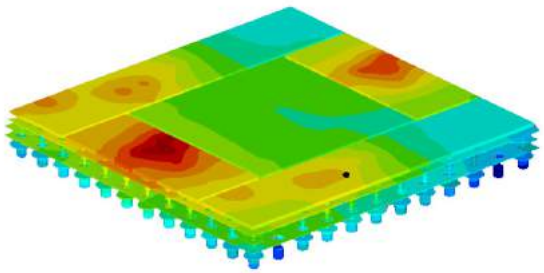
- **Faster Array Antenna Design:** With HFSS 3D component finite array decomposition, complex 5G and automotive radar sensor antenna systems can be modeled accurately using 2X less memory.
- **Virtual Site Testing:** HFSS and HFSS SBR+ enable high-fidelity physics testing of antennas and environment interactions. Bypass costly test installations and installation permits by testing BTS antennas virtually
- **Accurate:** Efficient high-fidelity physics simulation against accurate environment structures and materials to synthetically generate 5G physical channel response

Multiphysics: *The* Critical Capability

The 5G World is Multiphysics

Making 5G technology real requires an increased density of more complex electronic systems in ever smaller form factors. As 5G proliferates into safety critical systems and infrastructure, such as autonomous vehicles and healthcare, reliability is paramount.

Engineers must therefore be able to determine the performance and the lifetime of the systems they are designing and deploying. The increased density of components increases the interdependency of many design considerations, for example, the electromagnetic performance can no longer be considered in isolation of thermal and mechanical performance as they impact each other and are interdependent. Thermal issues are now one of the primary failure modes for electronic systems. And this interdependence occurs across scales from the chip to the package to the system.



Bi-Directional Chip Aware Multiphysics System Simulations

Ansys semiconductor specific tools can produce and export detailed electromagnetic and thermal chip models to be placed in board/package level simulations, leveraging integrated multiphysics workflows, yielding higher fidelity simulations at the system level.

For the highest fidelity thermal reliability simulations, the multiphysics data links between chip-level, package-level, and system level (board/assembly) can be made fully bi-directional. The system level simulation is “chip-aware” by leveraging chip thermal models, and the chip level is made “system-aware” by importing boundary conditions from the system level. An iterative process is applied to simulate at the chip and system level until convergence is reached for both electrical and thermal performance.

Scalability and Extensibility

The electro-thermal analysis can be scaled by linking multiple separate PCB power simulations, so that a system of multiple boards such as in a data center server, can be combined into one complete system thereby providing a realistic simulation of how the system will perform in the real world.

These electro-thermal simulations can also be extended to incorporate mechanical effects in an integrated workflow to determine thermal stress induced deformation at the PCB level or at the more detailed solder ball level. The analysis workflow is bi-directional, allowing the thermally induced mechanical deformation effects to be fed back into the electromagnetic analysis to determine the impact on electrical operations. The geometric complexity of PCBs and packages can make thermal and mechanical simulations computationally challenging without significant simplifications. Ansys trace mapping technology allows the layout to be solved with a relatively simple mesh while still accounting for the layer-by-layer metallization complexity by using a metal fraction mapping technique.

Additional mechanical analysis, such as model and random vibration, drop text and fatigue studies can also be completed.

Ansys dedicated electronics reliability solutions can then be used to make lifetime predictions by computing the cumulative damage index, time to failure and life curve.

From Silicon to the City

Combined, Ansys high fidelity multiphysics simulation capabilities can be scaled from the level of the silicon to the level of the city, delivering the comprehensive, simulation based solution engineers need to make 5G a reality.

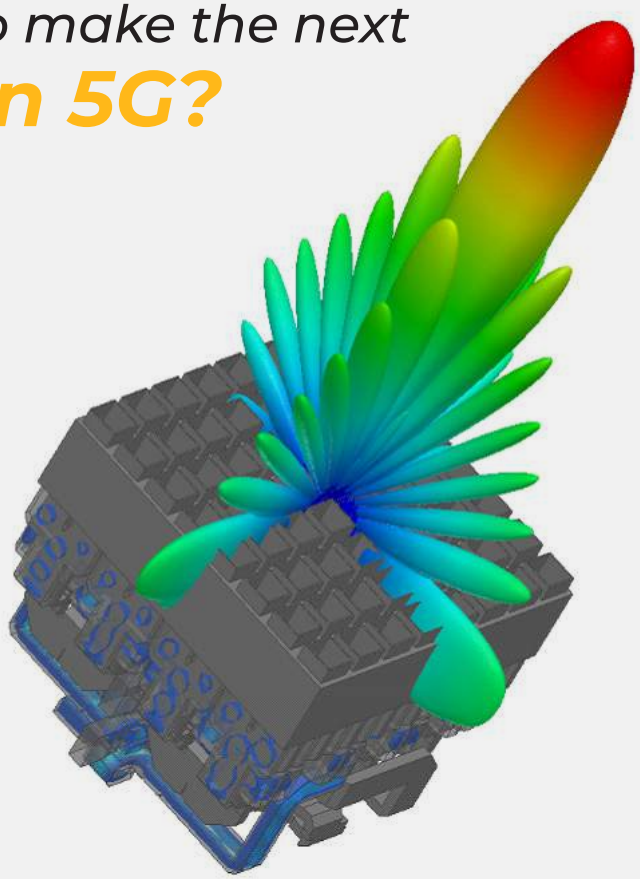
Contact us to learn more about
Ansys solutions for Electrification.

Ansys, Inc. / Southpointe / 2600 Ansys Drive / Canonsburg, PA 15217 / U.S.A. / 724-746-3304 / ansysinfo@ansys.com

Is your startup poised to make the next ***breakthrough in 5G?***

Startup firm Optisys, LLC uses engineering simulation from Ansys to achieve orders-of-magnitude reductions in antenna size and weight, while reducing development time. Through Ansys electromagnetic and structural simulation tools, Optisys engineers take full advantage of the design freedom offered by 3D printing to meet radio frequency performance requirements for an integrated array antenna.

Ansys has the simulation solution to help any startup prove and improve its innovative, disruptive, market-breakthrough idea.



Click here to see how Ansys supports startups like Optisys.

About Ansys

If you've ever seen a rocket launch, flown on an airplane, driven a car, used a computer, touched a mobile device, crossed a bridge or put on wearable technology, chances are you've used a product where Ansys software played a critical role in its creation. Ansys is the global leader in engineering simulation. We help the world's most innovative companies deliver radically better products to their customers. By offering the best and broadest portfolio of engineering simulation software, we help them solve the most complex design challenges and engineer products limited only by imagination.