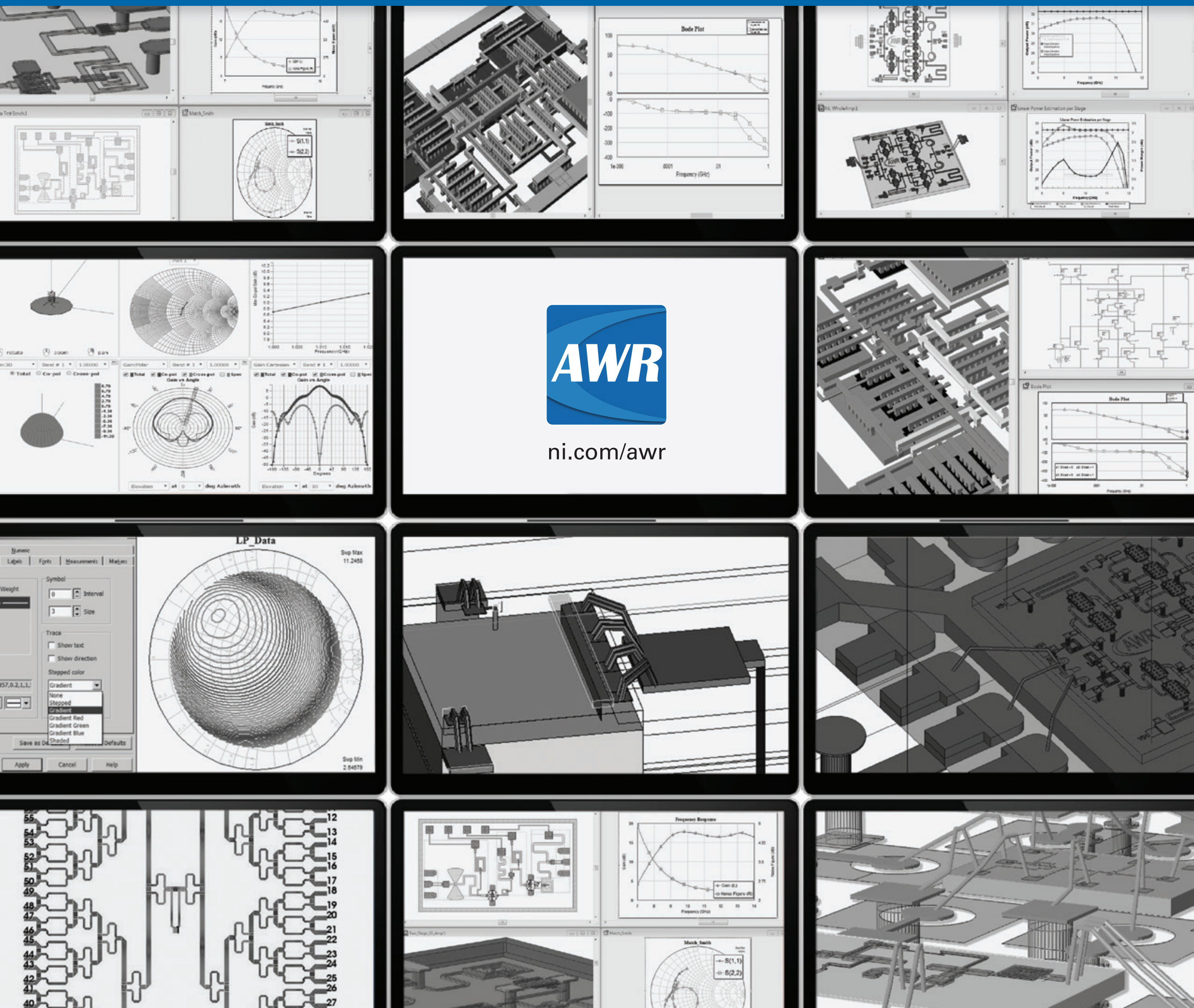
Vol.17

AWR Design Magazine



ni.com/awr

NATIONAL INSTRUMENTS

NI AWR Design Environment Drives Next-Generation Communications

Next-generation communication systems are driving developments in the RF/microwave industry. The big umbrella of technologies known as 5G actually focuses on supporting three main applications:

- Enhanced mobile broadband (EMB), a natural development of LTE
- Massive machine-type communications, also known as the Industrial Internet of Things (IIoT)
- Ultra-reliable, low-latency communications (URLLC), providing mission-critical infrastructure for services such as transportation, public safety, and medical.

NI AWR Design Environment, with its latest V13 release, introduces a host of innovative features and capabilities that accelerate the successful development of complex, high-frequency electronics — achieving performance targets, while reducing component size, cost and design cycles — allowing system integrators to meet future 5G goals.

As wireless communications systems evolve, the adoption of multi-technology-based module designs with diverse, best-in-class IC and PCB process technologies will allow designers to deliver higher performance and more functionality in a smaller footprint. V13 addresses multi-technology module design with enhanced support for multiple PDKs within a single project, thereby making it easier to combine designs built from devices using different manufacturing processes and different layer stackups. Support for Cadence Spectre netlist co-simulation with the APLAC harmonic balance simulator in Microwave Office, as well as support for OpenAccess, eliminates manual design entry for schematic import and export of silicon designs created in Cadence Virtuoso. In addition, engineers are now able to combine Cadence RFIC blocks with MMIC and PCB designs simulated in Microwave Office with EM modeling from AXIEM 3D planar and/or Analyst™ 3D finite element method EM simulators, as well as third-party EM simulators.

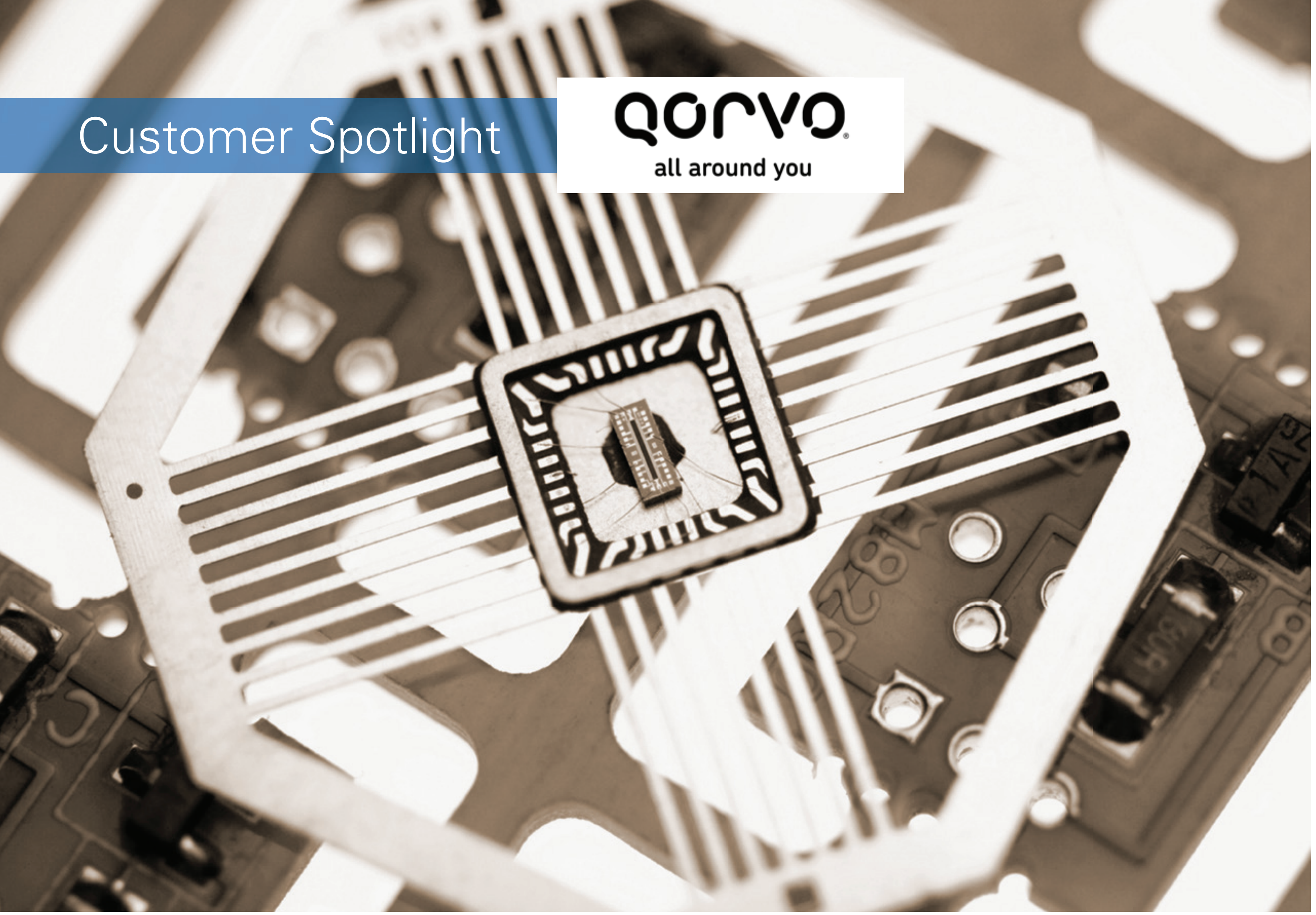
As 5G pushes into the millimeter-wave spectrum, MIMO and beam-steering antennas will be required to direct radiated energy from the base-station antenna array to the end user and overcome the higher path losses that occur at these frequencies. Fortunately, the shorter wavelength translates into smaller antennas, which in turn leads to more IC-based antenna array solutions. MMIC and RFIC design will play an important role in future MIMO and beam-steering technologies for 5G systems operating at millimeter-wave frequencies. V13 anticipates this migration toward integrated solutions with improvements in MMIC/RFIC design flows, advanced phase array modeling, and 5G waveform and test bench support.

For more information on V13, visit awrcorp.com/whats-new, as it provides further documentation covering the hundred plus enhancements/additions to this latest release.

Best regards,

David Vye
Director of Technical Marketing
AWR Group, NI

Table of Contents



Designing a Broadband GaN PA MMIC

The Design Challenge

Many modern microwave electronic systems specify amplifiers with high output power, wide bandwidth, and high efficiency. Until recently, most wideband high-power amplifier (PA) solutions have relied on vacuum electronics-based technologies. Recent work, however, shows steady progress in realizing high-power, high-frequency, wideband amplifiers utilizing GaN MMIC technology that operates from near DC up to 7 GHz. Qorvo designers were challenged to meet the requirements for an amplifier with high output power, wide bandwidth, and high efficiency by designing a 1-8 GHz PA MMIC fabricated with a 0.15 µm GaN process technology. The process featured a 100 µm thick silicon carbide (SiC) substrate and compact transistor layouts with individual source grounding vias (ISVs). The design utilized a non-uniform distributed power amplifier (NDPA) topology with a novel trifilar connected output transformer (Figure 1).

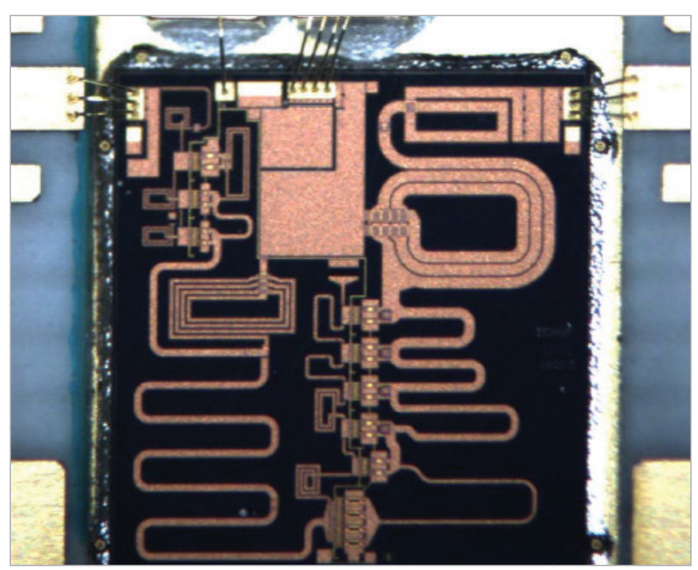


Figure 1: Photograph of the manufactured MMIC mounted to a test fixture. Die dimensions are 3.25 x 3.50 mm².

Design goals for PA MMIC were: 1-8 GHz bandwidth, > 25 dB small signal gain, 10 W saturated output power, and power-added efficiency (PAE) exceeding 30 percent. A small-signal gain goal in excess of 25 dB required at least two amplification stages. To meet the bandwidth requirement, the NDPA topology was adopted. The output power realized with the NDPA approach was proportional to Vd^2/RL where Vd is the power supply voltage and RL is the load impedance that the amplifier was driving.

Output power could be increased by designing the amplifier to operate with a higher power supply voltage and/or a lower load impedance. Increasing the supply voltage could be problematic as the transistor technology might not be able to operate reliably at higher voltage and the drain transmission line impedances could become unrealizably high. Therefore, to increase output power a novel monolithic trifilar coupled-line transformer design (patent pending) was used to reduce the 50 Ω load impedance to about 25 Ω. An idealized schematic for the transformer connected in the "bootstrap" configuration is shown in Figure 2.

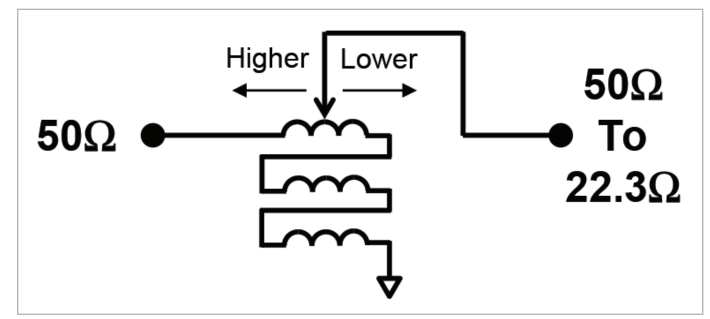


Figure 2: Triflar transformer for up to a 2.25:1 transformation ratio.

The Solution

The Qorvo design team chose NI AWR Design Environment, specifically Microwave Office circuit design software, for this complex task. The two-stage amplifier demonstrated 9.3-13.1 W of output power over a 1-8 GHz bandwidth with greater than 29 percent associated PAE. Theoretically transformation ratios up to 2.25:1 are possible depending on the location of the output tap. Due to physical limitations regarding the location of the low impedance side tap, the microstrip implementation produced a ratio closer to 2:1.

EM simulations performed on the transformer using AXIEM 3D planar EM simulator within Microwave Office suggested that an 8:1 bandwidth could be supported with this approach. For the NDPA application the ground connection was replaced by a bypass capacitor providing a drain bias injection port. This mitigated the need for a wideband high current drain bias choke, which could negatively impact the performance and bandwidth of the amplifier.

The layout and EM simulation results are shown in Figure 3. The predicted loss varies between 0.28 dB and 1.26 dB over the 1-8 GHz operating band.

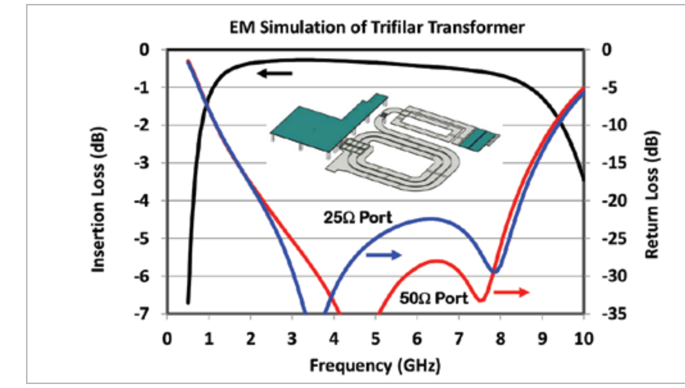


Figure 3: AXIEM EM simulation results for the trifilar transformer.

Taking into consideration the frequency range, available transistor cells, transmission line current handling, and realizable characteristic impedances, a six-cell NDPA driving a 25 Ω load was selected for the output stage of the amplifier. The output stage also utilized non-uniform transistor cell sizes such that the optimum transmission line impedances were realizable on a 100 µm thick SiC substrate. The driver stage topology was a three-cell NDPA driving a 50 Ω load. Both stages operated at equal Vd and current density such that the first- and second- stage gate could be connected together, as were the first- and second-stage drain bias taps.

The measured performance of the amplifier MMIC compared favorably with recently published results for bandwidth, gain, die size, and efficiency.

Why NI AWR Design Environment

The Qorvo design team chose NI AWR Design Environment for the design of this 1-8 GHz GaN distributed PA MMIC utilizing a novel trifilar transformer because of the powerful circuit design capabilities combined with integrated AXIEM EM simulation. The power of harmonic balance circuit simulation and integrated EM analysis provided the speed to fully explore the design space and the accuracy to ensure reliable simulation results for first pass success.

Special thanks to Charles F. Campbell, Michael D. Roberg, Jonathan Fain, and Sabyasachi Nayak, Qorvo, for their contributions to this success story.

AntSyn Accelerates High-Efficiency Antennas for Wearables

The Design Challenge

Striiv needed to develop an integrated, high-performance antenna that would enhance the Bluetooth wireless performance and provide longer battery life for its next-generation Fusion 2 and Fusion Bio 2 wearable tracker devices. The antenna had to be small enough to fit into the device's housing and inexpensive enough for high-volume production. The design also had to be completed quickly to fit within a tight prototyping and production schedule.

The Solution

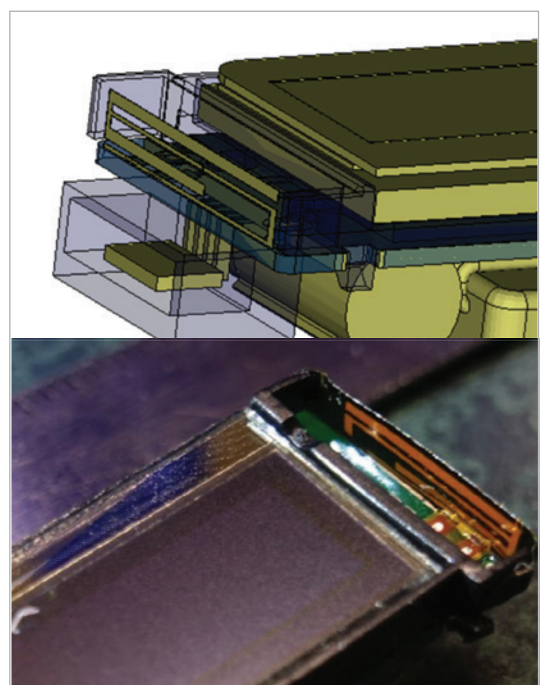
The Striiv design team chose AntSyn™ antenna design, synthesis, and optimization software for the design of a high-efficiency yet inexpensive Bluetooth antenna for these new devices. The initial designs were created using AntSyn in only a matter of days and the final synthesized design was complete in less than two weeks. The synthesized design was imported into Analyst 3D finite element method EM analysis software, along with the CAD model of the tracker components so the integrated antenna performance could be simulated. The design was then scaled and tuned to accommodate the effect of the packaging on the antenna assembly.

Testing of the first prototype showed excellent performance and no further design cycles were required. Using the AntSyn synthesized design approach allowed Striiv to develop their initial product in just a matter of days, drastically cutting design time.

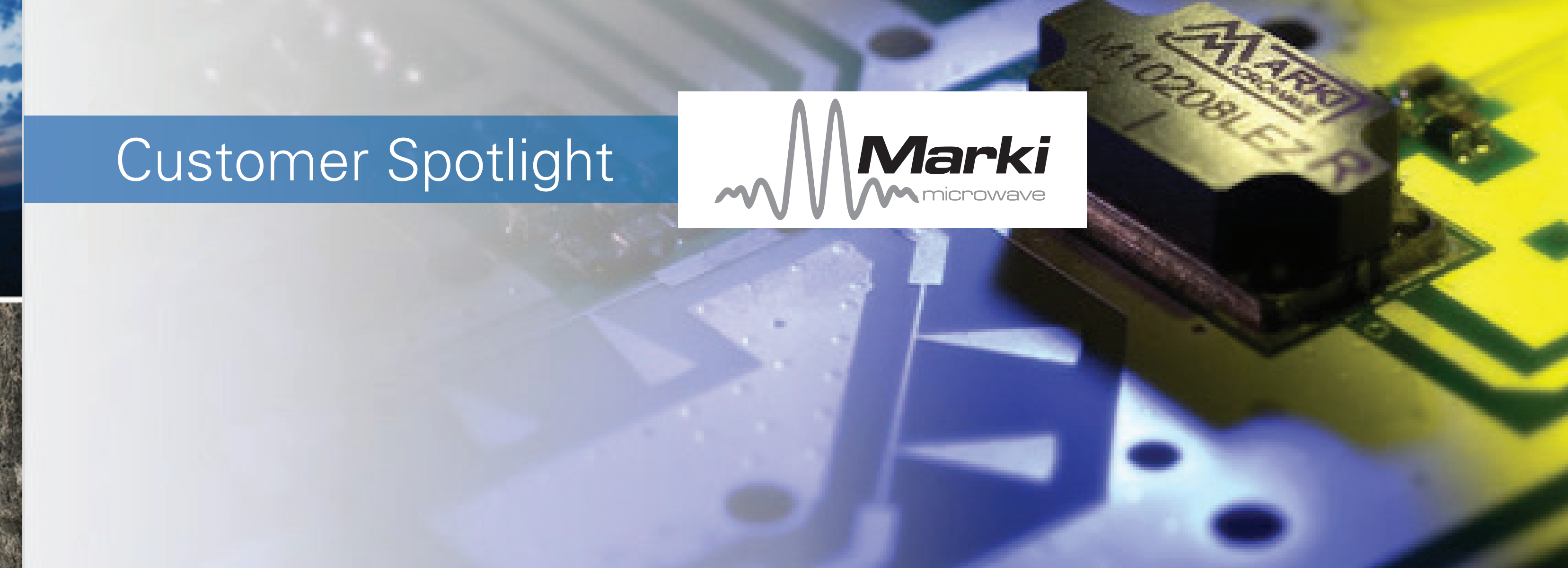
Why NI AWR Design Environment

The Striiv team chose AntSyn and Analyst as their design tools due to NI AWR software's proven prior successes. The AntSyn antenna synthesis tool, Analyst 3D EM, and related support expertise allowed Striiv to shorten and simplify the design process and reduce risk, enabling the company to meet its very aggressive development schedule and successfully launch the company's new Fusion Bio Activity Tracker.

> *"We chose NI AWR software because of the proven success of AntSyn and Analyst. The resulting designs worked from the very start and removed the iteration and experimentation usually required in antenna design efforts."*
>
> *Mark Ross, VP Engineering*
> *Striiv*



Antenna design as shown within NI AWR software (top) and final shipping product's integrated antenna (bottom).



Exceeding Performance Goals with MMIC T3 Mixer

The Design Challenge

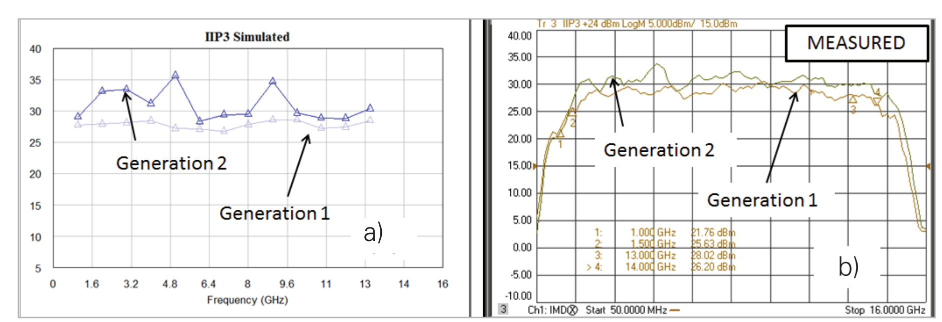
Marki Microwave's high-performance mixers are designed for applications where intermodulation distortion and input power compression are system limitations. When provided with a square wave LO drive, generated by the integrated LO amplifier (T3A units), they provide excellent IP3, 1-dB compression, and spurious product prevention, particularly at frequencies below 10 GHz. The challenge was to re-design the device to offer customers a significant improvement in performance while simplifying the manufacturing process to address the needs of the mass volume market.

The Solution

The accuracy of Microwave Office enabled the engineers to successfully develop an initial design on their first try. "The parts looked great, very similar to simulation, and they were ready to go to market that summer," commented Christopher Marki, CEO. Then, the design team had an idea and decided to make some tweaks to the design in Microwave Office, improving the nominal IP3 of +28 dBm across the band to nominal values of +31 dBm across the band. Due to its confidence in the simulation results from the first design, the design team made a new mask set at significant expense. The new design worked perfectly, resulting in the higher IP3 that the designers were looking for.

Why NI AWR Design Environment

Christopher Marki and his team have been using Microwave Office for many years to design the highest quality mixers for customers who demand the best performance possible and his confidence in the software paid off. The new design is superior to the old parts by a noticeable margin in almost every spec and can be manufactured with high-volume processes. With the help of Microwave Office, Marki has unleashed the best mixer technology onto an IC platform and this will revolutionize what customers will come to expect out of high performance mixers for years to come.



IIP3 for the MT3-0113H mixer with a +20 dBm LO drive. a) Simulated. b) Measured.
NOTE: Measurements include additional fixturing not included in simulation.

> *"Every designer faces a choice during the design cycle: do I believe the simulation results displayed by the software, or not? I trusted the predictions, and thanks to Microwave Office the new design worked perfectly. The performance we have achieved is unlike any other MMIC ever produced."*
>
> *Christopher Marki, CEO*
> *Marki Microwave*

Commercial Applications Adopt Phased-Array Technology

The millimeter-wave (mmWave) spectrum and advances in new antenna-array technology converge in various communication and radar applications such as 5G and advanced driver assistance systems (ADAS). The available spectrum at mmWave supports the bandwidth required for these applications and phased-array (also known as electronically-steered) antennas provide efficient over-the-air transmission either through beam steering or MIMO technologies.

While an antenna array shrinks in size with frequency, benefiting system integration, there remain many challenges to engineering robust and reliable antenna solutions for the multitude of applications, operational requirements, and environments. Fortunately, the complexity and related development costs are being addressed through new capabilities in EDA software, providing designers with a step-by-step methodology for defining the optimum array configuration, designing and integrating the antenna element, developing the feed network, and simulating the entire structure, inclusive of the RF front-end components.

Arrays offer higher gain and directivity than antennas of equivalent aperture. By controlling the phase and amplitude of the input signal to each array element, they provide steerable directivity of the antenna beam over both azimuth and elevation without the need to physically move the antenna.

This supports extremely fast re-direction of the beam for superior radar tracking and can produce a pattern of multiple beams to support multiple mobile devices.

Design Considerations

Design considerations focus on the performance of the individual radiating elements, the RF-link budget of the feed network that is tied directly to component performance and network design (accounting for insertion losses and impedance mismatches), and the array itself. While the task of designing phased-array antennas is complex, it can be broken down into manageable steps supported throughout with simulation.

NI AWR Design Environment provides a start-to-finish, front-end design flow for phased-array systems. A proprietary array model delivers rapid configuration and array analysis combined with EM simulation for antenna and feed network analysis and co-simulation of detailed RF/microwave circuits, and RF and signal-processing behavioral models. Together these simulation technologies enable design teams to move seamlessly from early concept through physical implementation.

Visual System Simulator™ (VSS) system design software provides full system analysis as a function of steered-beam direction, inclusive of the antenna design and the active and passive circuit elements used to implement the electronic-beam steering. System components can be modeled in greater detail using Microwave Office circuit simulation, inclusive of EM analysis for antenna design and passive device modeling using AXIEM 3D planar and/or Analyst 3D finite element method simulators. Furthermore, individual antenna designs can be generated from performance specifications using the AntSyn antenna synthesis and optimization module, with resulting geometries imported into AXIEM or Analyst.

Highlights of Phased-Array Analysis:

- Configure phased-array antennas
- Implement beamforming algorithms
- Study performance vs user-specified parameters
- Simulate array impedance vs beam angle
- Simulate impedance mismatch and gain compression
- RF link-budget analysis
- Sensitivity analysis
- End-to-end system simulations

These simulators also work together to address the design challenges associated with the feed network. For instance, gain tapers are commonly used in phased arrays; however, when identical RF links are used for all antenna elements, elements with higher gains may operate well into compression while others operate in a purely linear region, causing undesired array performance. To avoid this problem, designers often use different RF-link designs for different elements. VSS phased-array modeling includes the capability to automatically generate the characteristics of the phased-array element link with circuit-level design details (nonlinearities) via Microwave Office co-simulation.

An accurate simulation must also account for the interactions that occur between the antenna elements and the driving feed network. The problem for simulation software is that the antenna and the driving feed network influence each other. The antenna's pattern is changed by setting the input power and relative phasing at its various ports. At the same time, the input impedances at the ports change with the antenna pattern. Since input impedance affects the performance of the nonlinear driving circuit, the changing antenna pattern affects overall system performance. AXIEM and Microwave Office co-simulation allows engineers to study this interaction and implement any corrective impedance matching.

Automotive Radar

Ongoing developments in ADAS are expanding the capabilities and affordability of vehicles that can alert and assist drivers using radar technology mostly over the 76-81 GHz spectrum. These systems must perform over a variety of operating conditions, and object detection challenges in order to provide reliable coverage over the range (distance) and field of view (angle) as dictated by the particular driver assist function.

Long-range radar (LRR) supports multiple functions, comfortably handling distances between 30 and 200 meters, while short-range radar (SRR) can detect objects below 30-meter distances. The 24-GHz frequency band that addresses SRR detection is commonly found today in hybrid architectures but is slated to be phased out of new vehicles by 2022. The 77-GHz band supporting LRR is expected to provide both short- and long-range detection for all future automotive radars.

Important requirements for automotive radar systems include the maximum range of approximately 200 m for adaptive cruise control (ACC), a range resolution of about 1 m, and a velocity resolution of 2.5 km/h. To meet all these system requirements, various waveform modulation techniques and architectures have been implemented, including a continuous wave (CW) transmit signal or a classical pulsed waveform with ultra-short pulse length.

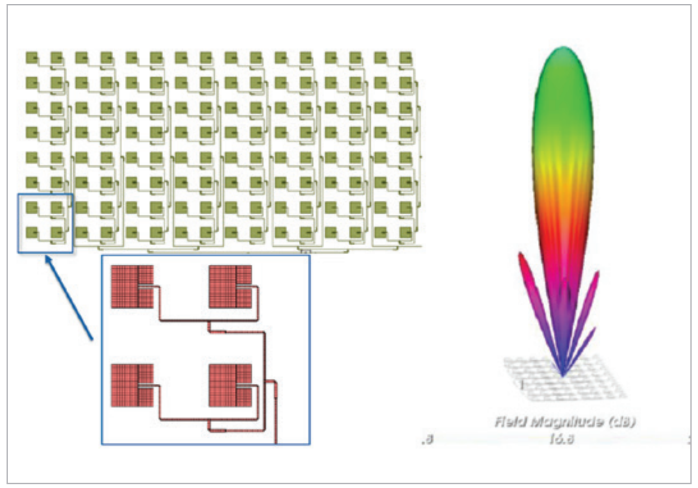
To support multiple ranges and scan angles, module manufacturers such as Bosch, DENSO, and Delphi have designed multi-range, multi-detection functionality into increasingly capable and cost-sensitive sensors using multi-channel transmitter (TX) and receiver (RX) architectures. These different ranges can be addressed with multi-beam/multi-range radar by employing radar technology such as frequency-modulated CW (FMCW) and digital beamforming with antenna-array design.

Radar performance is greatly influenced by the antenna technology, which must consider electrical performance such as gain, beam width, range, and physical size for the particular application. Multiple, fixed TR/RX antenna arrays are typically optimized for range, angle, and side-lobe suppression. A patch antenna is relatively easy to design and manufacture and will perform quite well when configured into an array, which results in an increase of overall gain and directivity.

Designing a single patch antenna or array is made possible using design software that utilizes EM analysis to accurately simulate and optimize performance. AXIEM and Analyst EM simulators take the user-defined physical attributes of the antenna such as patch width and length, as well as the dielectric properties and substrate height, to simulate antenna performance. AXIEM is ideal for patch antenna analysis, whereas Analyst is best suited for 3D structures such as modeling of a coaxial feed structure or finite dielectric (when proximity to the edge of a PCB would impact antenna performance).

To determine the physical attributes that will yield the desired electrical response, antenna designers can use the AntSyn antenna synthesis tool. AntSyn users specify the electrical requirements and physical size constraints of the antenna and the software explores a set of design configurations and determines the optimum structure based on proprietary genetic optimization and EM analysis. The resulting antenna geometry can then be imported into AXIEM or Analyst for verification or further analysis/optimization.

Learn more about NI AWR software for phased array design at awrcorp.com/radar.



Feature Story: NI AWR Design Environment

V13: Focus on RF and Microwave Design Engineering Productivity

NI AWR Design Environment V13 addresses design challenges associated with highly-integrated RF/microwave devices commonly found in communications and radar systems. Emphasis in the V13 release is placed on user productivity through greater simulation speed and capability as well as design automation. The design environment now offers enhancements to the user interface (UI) and new additions to design flow automation, inclusive of synthesis, import/export of file format standards, and links to third-party tools. Improvements have been made to the harmonic balance (HB) and system-level simulation engines, as well as the planar and arbitrary 3D EM solvers. Support for physical design has been enhanced with a powerful new PCB import wizard for streamlining design flows across various vendor tools in addition to new, advanced layout editing commands. Lastly, user support has been expanded to bring new insight to the software with interactive guided help and knowledge base content.

V13 New and Enhanced Features at a Glance

Design Environment and Automation
- Multi-technology enhancements
- New optimization methods
- Transmission zeros now in iFilter
- OpenAccess schematic import/export
- Graph marker improvements
- Real-time marching waveforms
- Additional synthesis wizards

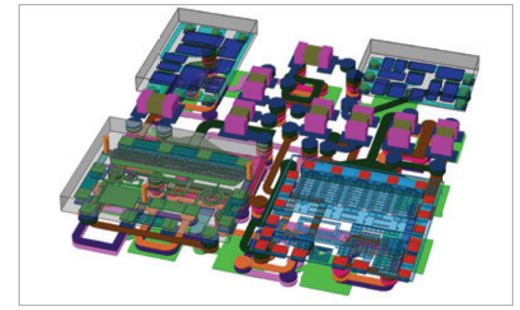
EM Simulation and Modeling
- Simulation speed improvements
- Solver enhancements
- Enhanced EM ports
- Analyst surface roughness model
- New 3D editor commands
- Enhanced EM Socket bi-directional links

Circuit/System Simulation and Models/Libraries
- Enhanced APLAC transient analysis
- Expanded circuit envelope simulation
- Passive model enhancements
- Spectre netlist co-simulation
- Load pull supports digital modulation
- New nested source/load pull
- New LTE-A and 5G libraries
- Enhanced Radar Libraries
- Expanded phased-array models

Physical Design and Layout
- PCB layout import (ODB++, IPC2851)
- Expanded shape preprocessor modifier
- Enhanced layout editing

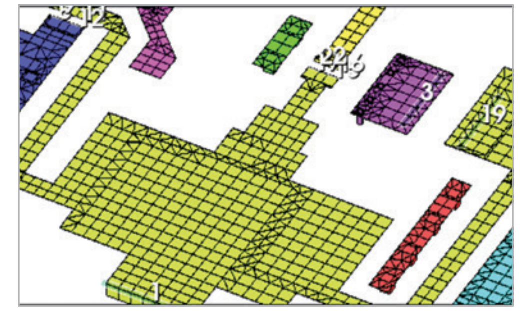
Learn more at awrcorp.com/whats-new

Key Technology and Application Highlights



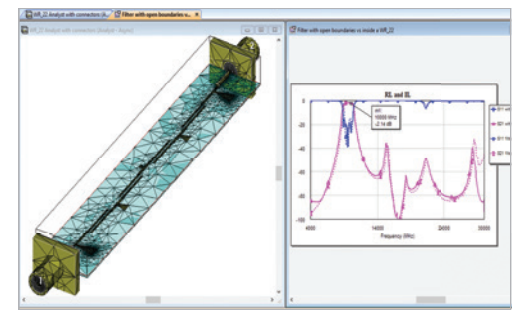
MMIC/Modules

New features enhance MMIC and integrated multi-technology module development with EM analysis, speed/capacity improvements, EM hierarchical simulation, Spectre netlist conversion and co-simulation with APLAC for RFICs, support for different IC (PDK) and PCB processes within a single project, and on-going PDK development.



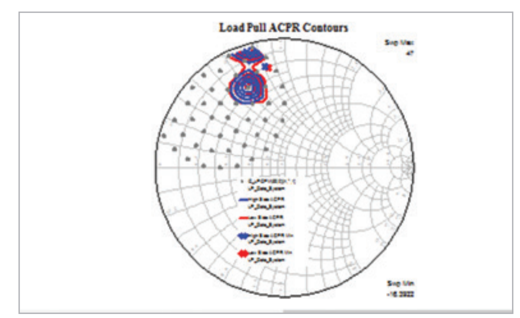
PCB Design

New PCB design features include a PCB import wizard for IPC-2581 (A and B) and ODB++ (V7 and V8) file formats produced by leading enterprise board tools, enhanced general shape modifiers to de-feature PCB layout for faster, more robust EM simulation, and automation to manage and simplify PCB analysis.



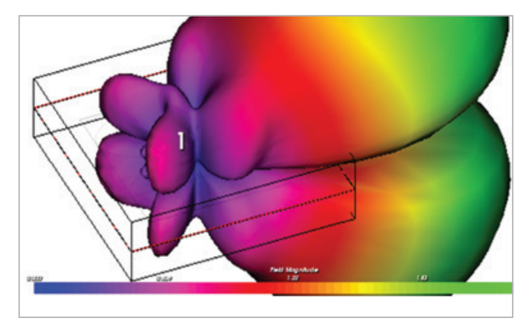
Filters

Accelerate filter design with iFilter synthesis, which offers automatic, semiautomatic, or manual extraction and transformation of transmission zeros (TZ) such as DC, INF, and finite, as well as application of transformations from over 80 filter types.



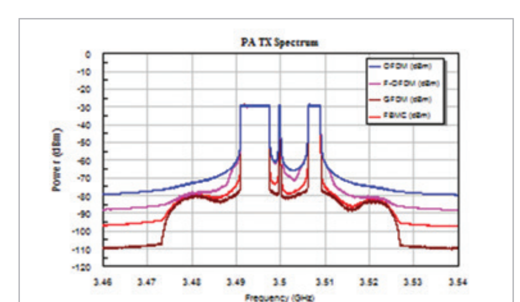
Power Amplifiers

Develop linear PAs for mobile devices and infrastructure with new load-pull analysis for digitally-modulated signals to develop matching networks to optimize ACPR and EVM performance. New load-pull capabilities also support synchronized source/load pull, expediting the design of input/output matching networks.



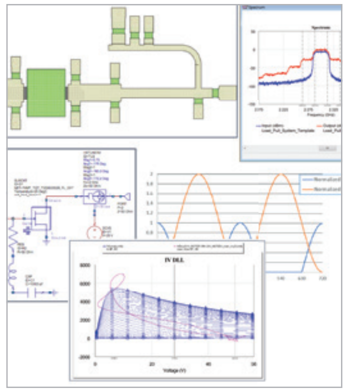
Phased Array

Rapidly define and analyze large phased-array antennas for the development of beam-forming algorithms, evaluation of hardware impairments, and RF link analysis. The enhanced model, which also accounts for mutual coupling between radiating elements for greater accuracy, can also be configured as a MIMO antenna assembly.



5G

V13 offers a new library of 5G candidate modulated waveforms such as FBMC, GFDM, and filtered-OFDM, as well as expanded support for LTE-Advanced (LTE-A) with carrier aggregation of intra-band and inter-band component carriers. New pre-configured test benches include signal generation and demodulation to allow for full-system simulation and measurements such as BER, ACPR, and EVM.

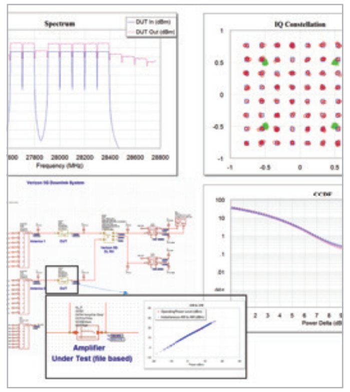


Expanded Load Pull for PAs

For amplifier designers, V13 now supports nested source/load-pull contours, enabling designers to directly observe changing source and load contours as a function of source and load impedance terminations.

This unique capability provides a new terminating impedance to either the source or load and allows direct observation of the change to the contours at the other port—without having to re-simulate the circuit.

The expanded load-pull capabilities in V13 can also generate performance contours for digitally-modulated power amplifiers, allowing designers to optimize linearity metrics such as ACPR and EVM.

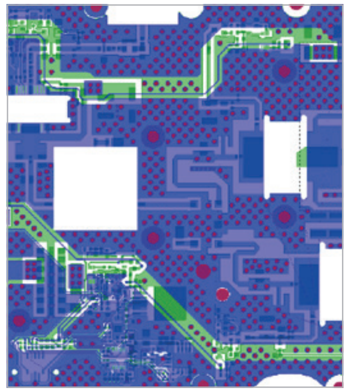


Wireless LTE-A/5G Support

The new 5G library option in V13, specifically for VSS, offers pre-configured test benches supporting the latest 5G signals and frameworks as proposed by various industry groups, including the Verizon 5G Technology Forum (http://www.5gtf.org/).

This VSS test bench implements the Verizon 5G signal generation and receiver functionality, and is pre-configured to perform a number of common measurements such as ACPR, EVM, spectral, and many other types of measurements.

Users can insert their 5G component or sub-system designs into the test benches and evaluate their performance under the requirements of 5G systems.



Streamlined PCB Flows

RF PCB designers increasingly rely on EM simulations to characterize their designs before the first component is placed, as well as throughout the design process.

Automation and EM analysis are critical as board designs become denser and new manufacturing processes allow engineers to squeeze more performance out of their PCB designs.

NI AWR Design Environment supports EM simulation with yield analysis, enabling engineers to design for manufacturing. V13 makes it easier to do to so with enterprise PCB design tools via a new PCB import wizard that streamlines the flow of layout data in Microwave Office and AXIEM.

Product Review

Learn more about NI AWR Design Environment V13. This product review highlights key features of this software release and can be accessed at awrcorp.com/whats-new.

NI AWR Software Ecosystem

AWR Connected Solutions

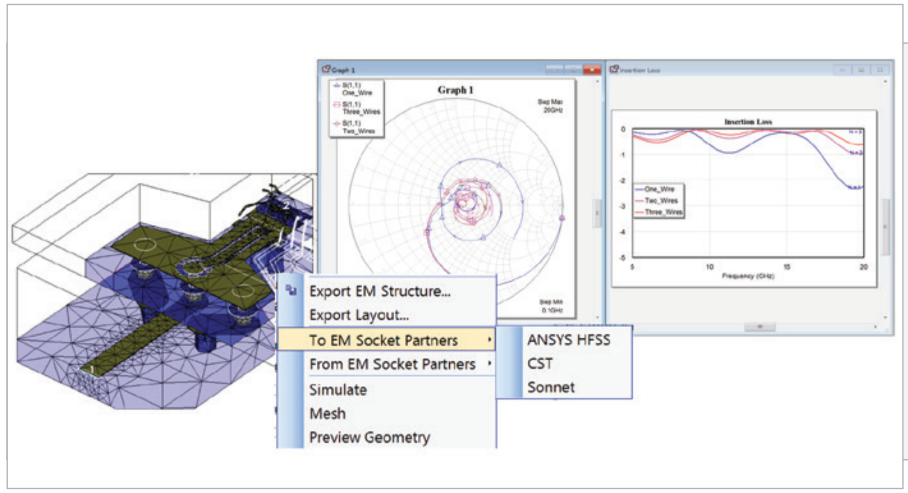
The AWR Connected™ product family integrates NI AWR Design Environment with third-party software/hardware products to provide a breadth and depth of solutions for the design of high-frequency products. AWR Connected offerings span application areas such as synthesis, PCB layout, verification, and EM/thermal, as well as test and measurement.

Synthesis
- AMCAD
- AMPSA
- Nuhertz
- Optenni Lab

PCB
- Cadence
- DWT
- Intercept
- Mentor Graphics
- Zuken

EM/Thermal
- ANSYS
- CapeSym
- CST
- Sonnet
- WIPL–D

T&M
- Anritsu
- Focus
- Maury Microwave
- National Instruments
- Rohde & Schwarz



EM Socket Partners

In V13, AWR Connected for third-party EM simulators, including ANSYS HFSS, Sonnet, and CST, is now more robust and fully bi-directional. After the layout is created in the Microwave Office layout editor, a third-party tool can be selected as the EM simulator and the resulting dataset is automatically read back into Microwave Office for further circuit tuning, optimization, yield analysis, and verification.

Recent Additions on ni.com/awr

White Papers
- Design Challenges of Next-Generation AESA Radar
- A Product Development Flow for 5G/LTE ETPA
- EM Simulation Technologies for RFIC Design

Application Notes
- Multi-Chip Module Design, Verification, and Yield Optimization
- Synthesizing UHF RFID Antennas on Dielectric Substrates
- Design of a Reduced Footprint Microwave Wilkinson Power Divider
- Coffee-Can Radar Optimization
- Five Tips for Successful 3D Electromagnetic Simulation

Success Stories
- Thales UK Designs GaN MMIC/Packaging for MAGNUS Program
- Oregon Tech Students Readily Learn RF/Wireless Design
- SARAS Technology Designs Broadband and Efficient RFPAs

Visit awrcorp.com/resource-library for the latest white papers, application notes, success stories and more.

E-Learning Portal
The NI AWR Design Environment E-Learning Portal gives current customers of NI AWR software the ability to learn more about the powerful tools, technologies, and applications of the software as their time and interest allows.

The latest addition includes an antenna synthesis module featuring:

- Introduction to AntSyn
- An Example - Wi-Fi Antenna
- AntSyn Export to AXIEM
- AntSyn Export to Analyst

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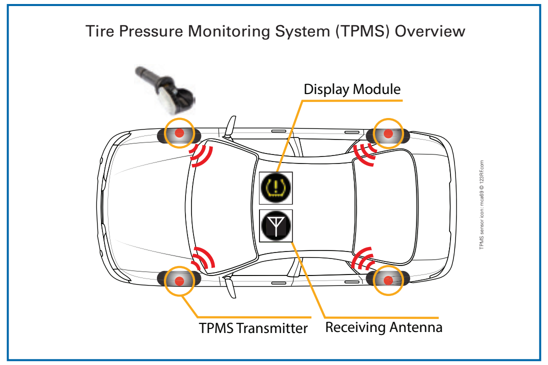
Design of a Wireless Tire Pressure Monitoring System

Automobile safety concerns are increasing worldwide and a variety of car safety features have been encouraged by legal mandates in many countries. One such system, the tire pressure monitoring system (TPMS), helps reduce single car accidents caused by insufficient tire pressure. TPMS systems not only actively measure actual tire pressure, but many also sense tire pressure and temperature and can wirelessly report this data to the automobile's computer. Sensata Technologies, a sensing and controls company, employed NI AWR Design Environment to meet the cutting-edge performance and optimization challenges for its TPMS. Using NI AWR software, Sensata was able to perform planar EM simulation, Monte-Carlo analysis using load-pull techniques, parametric optimization with component swapping, and EM environmental disturbance analysis, all within the integrated software environment.



TPMS Design Challenges

The latest active TPMS is a wireless device that can monitor several critical tire conditions and provide timely updates to the car's computer. Located on or within the tire, a TPMS will be subjected to adverse weather conditions, corrosion, physical obstructions, and dirt/grime from road and car conditions.

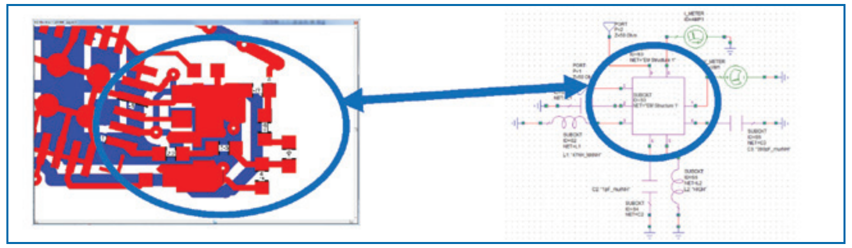
Therefore, a TPMS must be extremely rugged, reliable, and continue to operate for several years after installation, thereby requiring very low standby current drain and low power sensing/transmission to extend the battery life. The extremely wide temperature, pressure, and physical forces in which the TPMS must operate tend to significantly impact circuit behavior and performance.

With the constant rotation of the metallic wheel structure, electromagnetic interference (EMI), radio frequency interference (RFI), and a non-ideal antenna structure are all factors that will negatively impact the performance of an active TPMS. In order to meet worldwide RFI and EMI regulations, the TPMS must be designed to avoid any harmful or disturbing radiation. This requires complying with 30 RF regulations, which puts a burden on the harmonic filtering and circuit design.

These factors challenge TPMS circuit design, component choices, impedance matching, and optimization. Size, weight, power, and cost (SWAP-C) must all be very low to avoid impacting the wheel balance, and to reduce automobile production costs. As yield is a significant portion of mass-produced electronics cost, these devices must be designed to be extremely robust to production variations. As the component parasitics and electrical characteristics of the PCB and components are non-negligible in determining TPMS performance, the design tools used to select and optimize circuit components must be able to account for the EM behavior and circuit behavior under an expanse of conditions.

PCB Analysis

The size and weight constraints of a TPMS require a small PCB with limited use of custom technologies. Therefore, careful design of the sensing, control, and RF electronics is often implemented using standard surface mount technology (SMT) in highly compact layouts. However, the parasitics introduced by the close-knit PCB traces have an impact on the component parameter optimization and RF performance. Hence, the PCB trace leads must be carefully modeled and accounted for prior to selecting optimal inductor, capacitor, and resistor components. Sensata engineers imported a DXF file of the PCB traces into Microwave Office software, which was then simulated using AXIEM 3D planar EM solver.



With AXIEM, designers were able to visually analyze current densities within the EM structure. Additionally, edge ports in AXIEM revealed voltages between different circuit sections, currents along specified PCB tracks, and component locations that would later require optimization. Along with the TPMS PCB optimization, AXIEM was pivotal in the design optimization of the TPMS antenna. The antenna size, weight, and efficiency were an extremely delicate balance in this design. Using shape modifiers and optimization routines, Sensata was able to design the optimum structure for the antenna while still meeting impedance, radiation pattern, and efficiency goals.

Components added to the appropriate ports of the PCB trace structure were modeled/manipulated to meet the design specifications. As Sensata desired a detailed Monte Carlo analysis, each component was enabled for statistical analysis. The reliability and robustness of a TPMS sensor in an automotive environment demands a design that can perform in a wide range of environmental factors and up to 10 years on a single battery. Therefore, multi-level component selection, optimization, and analysis phases were necessary to meet quality and reliability standards. Sensata leveraged the optimization features in Microwave Office to swap components among a full library containing detailed performance data for each component. In applications where very precise impedance matching, power transfer, or filtering are needed, this feature dramatically reduces design times and parts sourcing challenges during prototyping.

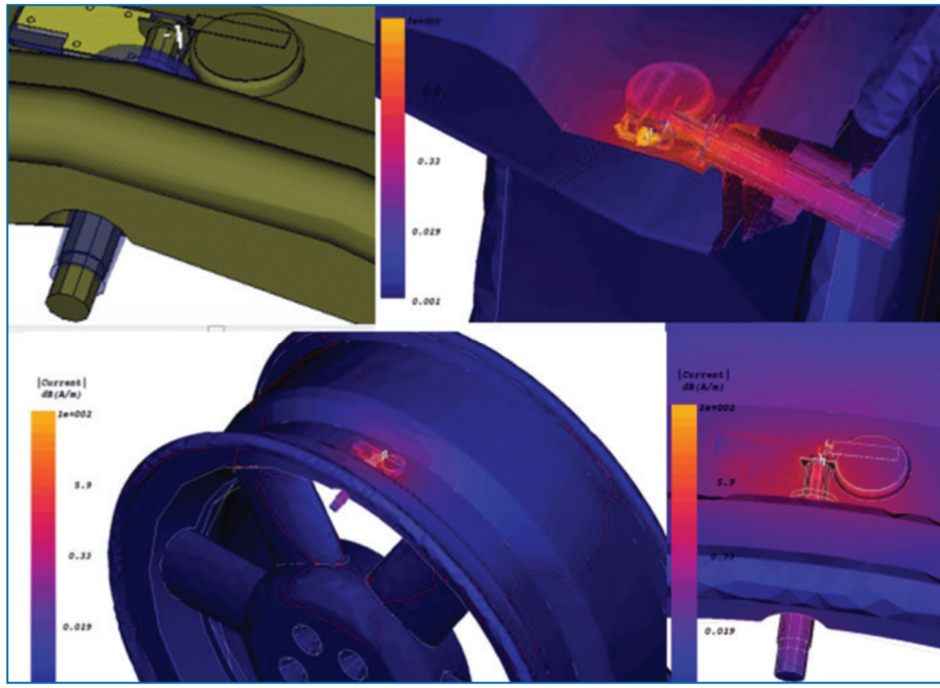
Monte Carlo Analysis

In such a critical application, understanding the full spread of the circuit's operational dynamics helps lead to a maximally-efficient end design. Most tire pressure monitoring systems have non-serviceable batteries and rely on highly-efficient designs to prevent the constant need to replace the component, making power consumption and transmitter efficiency among the utmost concerns in this design. Analysis of PAE and current consumption at various output power levels of the optimized impedance-matching circuit reduced the number of prototypes and tests needed to verify the design by performing a Monte Carlo analysis for spread and stability assessment and improvement using a load-pull measurement technique.

The statistical variation of the SMT component values could have led to non-optimal performance if the circuit design wasn't robust, and the Monte Carlo analysis might have revealed the need to redesign or identify component combinations that should be avoided in manufacturing. Ultimately, this approach increased the yield and overall reliability of the end product. Sensata performed this analysis both with and without an optimized network matching as a control experiment to justify the investment in enhancing the design processes with such a sophisticated optimization process. The end results of the optimized impedance matching were a decrease of roughly 1.5 dB in the ideal reflection loss and a reduction in current consumption. The Monte Carlo analysis greatly enhanced the overall power efficiency over statistical component variations, which directly impacts the lifetime of the TPMS.

Environmental Disturbances Analysis

A physical model of the complete TPMS assembly installed within a wheel was used to analyze the current distribution during TPMS transmitter operation. The simulation revealed significant current on the inside of the wheel rim that could impact the transmitter performance and radiation pattern of the valve antenna. The wheel body and rim's impact on the antenna radiation pattern is displayed as a 3D intensity map in Analyst, which shows that only a small portion of the wheel body and rim impact the TPMS sensor behavior. Therefore, a smaller parametric subsection of the wheel and TPMS assembly were used for more detailed simulations. Unpredicted current losses from parasitics could be identified and design measure were taken to prevent undesirable interference.



Conclusion

NI AWR Design Environment, inclusive of Microwave Office, AXIEM, and Analyst, was critical in streamlining the design flow and enhancing optimization of Sensata's TPMS. The software also provided a conducive platform for implementing customized scripts that enabled designers to tweak even greater optimization from the circuit components.

For more details on this design application visit ni.com/awr.

Customer Spotlight

RFμmicrotech www.rfmicrotech.com

Developing a Complex UWB Filter in Record Time

The Design Challenge

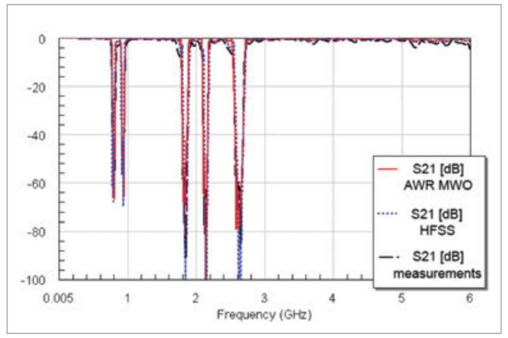
Prior to the opening of Expo Milano 2015, the side lobe of a mobile service antenna was found to be directly interfering with the communication signals of a critical security control base station. RF Microtech was asked to provide a validated full-wave EM simulation of an ultra-wideband (UWB) filter that could reject all five mobile service bands with greater than 35 dB of rejection to mitigate the problem. Furthermore, the filter had to ensure 80 MHz to 6 GHz wide-band transmission with insertion losses of less than 2 dB. The validated EM simulation had to be delivered within two weeks and the complete deployable device by the time the expo opened.

The Solution

The design team used Microwave Office to develop a circuit model of five independent notched-band filters (NBFs) cascaded along a transmission line. Each independent filter was designed as a fourth or fifth order NBF, composed of several cascaded stages of N shunt resonators. The individual filter specifications called for resonators with high unloaded Qs (> 1000) and no spurious modes under 6 GHz. After identifying the optimum filter geometries, the transmission line and filter sections were verified in ANSYS HFSS full-wave EM analysis tool. The results corresponded well with the initial circuit simulation.

Why NI AWR Design Environment

RF Microtech's design challenges were met with the speed and accuracy of Microwave Office and its compatibility with HFSS EM simulation. Designers were able to successfully develop a complex filter design in a fraction of the time by taking advantage of the circuit tool's tuning and optimization capabilities. Using Microwave Office software, RF Microtech cut simulation time by 90 percent compared to exclusively using a full-wave EM simulation flow.



Simulations and measurement results match very well.

"We chose Microwave Office because it could easily and quickly optimize the cascade of a series of full-wave component blocks of a very large and complex UWB filter structure. Using Microwave Office, we were able to reduce optimization and development time by 90 percent, a critical factor in delivering this project in a very short timeframe."

Roberto Sorrentino
Honorary President
RF Microtech Srl

Customer Spotlight

University of BRISTOL

University of Bristol Wins IMS2016 Student Design Contest

The Design Challenge

University of Bristol engineering students Paolo Enrico de Falco, James Birchall, and Laurence Smith, under the supervision of Dr. Souheil Ben Smida, designed a single-ended RF PA, which won first place at the 2016 IEEE Microwave Theory and Techniques Society (MTT-S) IMS High-Efficiency PA (HEPA) Student Design Competition.

The main challenge of the competition was to maximize the overall PAE of the PA while amplifying a time-varying envelope signal, without compromising the linearity performance. The competition required that the winning team achieve the highest PAE as measured for a two-tone input signal while not allowing the carrier-to-intermodulation ratio to exceed 30 dBc (in other words, the measured third-order intermodulation distortion [IMD3] level could not be lower than –30 dBc).

"Access to the complete high-frequency suite of tools in NI AWR Design Environment combined with the usability of the software enabled my students to successfully overcome the challenges of maximizing PA efficiency to win this prestigious design competition."

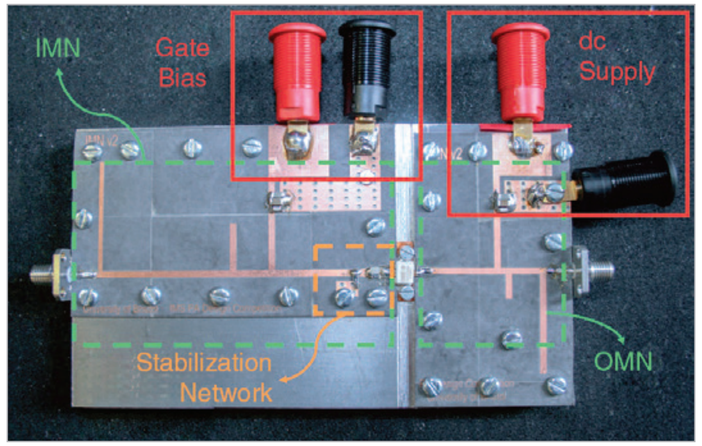
Dr. Souheil Ben Smida, Lecturer
University of Bristol

The Solution

The students chose NI AWR Design Environment to design their PA to the competition's exacting standards because they were very familiar with the software and were confident that the complete suite of high-frequency tools would deliver the design performance they needed for the task.

Why NI AWR Design Environment

NI AWR Design Environment was chosen because the University of Bristol is part of the NI AWR University Program, which provides software donations to member universities, so the students were already using the software. They knew that the software's capabilities would provide the powerful yet intuitive features needed to successfully carry out the design method they had formulated and would enable them to obtain the necessary good agreement between the simulation results and measured data.



Photograph of the PA showing the input matching network (IMN), the output matching network (OMN), and the stabilization network, as well as the V_{gs} and V_{ds} supply points.

NI AWR DESIGN ENVIRONMENT

SIMPLY SMARTER

5G WIRELESS

NI AWR Design Environment is one platform integrating system, circuit, and electromagnetic analysis for the design of 5G communications systems. Supporting wireless standards like 5G and proprietary waveforms, the software enables designers to quickly build virtual communications systems and evaluate benefits and drawbacks, as well as share IP from design through to test.

Simply smarter 5G design.

Learn more at awrcorp.com/5g

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