Vol.16.1

AWR Design Magazine

The Latest Design Software from NI

Customer Successes MaXentric and Infineon

Antenna Synthesis and Optimization Technology

Design of Base Station Power Amplifiers From Load-Pull Measurements

ni.com/awr

NATIONAL INSTRUMENTS

The Latest Design Software from NI

Performance of high-frequency electronics is continually advancing to meet increasing global demands for information. And while the cellphone has been around for over 40 years and the smartphone for over a decade, wireless communication systems are still evolving. As such, looking beyond cellular has become the central theme of this year's IMS keynote talks:

- Dr. Martin Cooper, father of the cellphone, "Birth and Death of the Cell Phone"
- Dr. James Truchard, NI president, CEO and cofounder, "Software's Role in Next-Generation 5G RF and Microwave Systems "
- Prof. Jan M. Rabaey, UC Berkeley, "The Human Intranet - Where Swarms and Humans Meet"

From the inner body to outer space, how will the hardware that connects more people and things to data continue to advance? Through collaborative innovation and continued advances in engineering tools.

During IMS, more detail on the state of smart RF/microwave design and test solutions from NI will be presented in MicroApp presentations and in-booth product demonstrations. Read on to learn more.

Designing Better PAs … Better

If your focus is on designing RF power amplifiers with higher linearity and power added efficiency (PAE), the latest load-pull capabilities in NI AWR Design Environment™ offer an unprecedented level of support and data management. Today's PAs must achieve multiple performance metrics that are difficult to achieve simultaneously. In addition, higher PAE levels can often only be achieved through harmonically tuned devices that employ output waveform shaping techniques. Combined, these requirements force many designers not using the NI AWR Design Environment to iterate their optimization efforts between different impedance matching scenarios until a reasonable trade-off is achieved. Optimum PA performance is extremely difficult and time consuming with this back-and-forth approach.

With the load-pull capabilities within NI AWR Design Environment, engineers can dynamically explore the impact of fundamental and harmonic terminations and directly observe the impact (simultaneously) on any number of power amplifier (PA) responses, including gain compression versus power, PAE, error vector magnitude (EVM), adjacent channel power ratio (ACPR), and more.

Integration Made Possible Through EM Analysis

Many of today's PAs are integrated into radio front-end modules that contain the filtering and switching necessary for multi-mode, multi-band mobile devices. Such modules include high-density components, embedded passives, and complex interconnects that require planar and/or 3D electromagnetic characterization. The latest chip-package-board design and validation solutions from NI are based on the powerful integration of AXIEM (3D planar) and Analyst™ (arbitrary 3D finite element) electromagnetic (EM) solvers within NI AWR Design Environment.

Complementing these EM modeling tools, bi-directional interoperability has been developed between Microwave Office circuit simulator and third-party EM simulators such as ANSYS HFSS. This integration supports unrestricted planar structures, as well as commonly used 3D circuit interconnect structures such as wire bonds and ball-grid arrays. Structures defined in NI AWR Design Environment are then automatically solved by HFSS during the overall network analysis, with the results embedded directly into the circuit hierarchy without leaving the circuit design environment or requiring manual steps on the part of the designer.

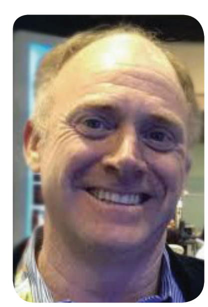
A New Starting Point for Antenna Designers

EM simulation and EM optimization have been the tools of choice for modern antenna design, with designers modifying the physical dimensions of antenna structures they already know or can find in reference materials. While tweaking physical dimensions will allow designers to shift antenna behavior to operate in the band of interest, there is no guarantee that the optimum performance has been achieved. To address the challenge of finding the optimum antenna structure and dimensions for a desired set of electrical characteristics, AntSyn™ antenna synthesis and optimization software was recently added to the NI AWR software portfolio.

Based on evolutionary algorithms (EAs), a programmatic method for exploring the design space and automatically locating novel antenna designs combined with EM simulation, AntSyn is proving to be more effective at generating antenna structures with greater performance than would otherwise be developed by traditional methods.

To learn more about NI AWR software and its fit for your microwave/RF design needs, visit Booth #1529 to speak with the NI AWR software experts.

Best regards,



David Vye
Director of
Technical Marketing
AWR Group, NI

AWR Design Forum 2016

Celebrating its sixth year, the AWR Design Forum (ADF) is an open forum that brings together NI AWR software customers, partners, and microwave/RF engineering professionals to learn, network, and collaborate on the design of today's microwave and RF circuits and systems.

This free-to-attend event travels the globe to bring NI AWR software experts to demonstrate the latest design technologies and encourage dialogue and the exchange of technical ideas around the design challenges you face.

Highlights

- Technical presentations featuring NI AWR Design Environment
- Select customer and keynote presentations
- Live demo exhibition area

Locations

Asia

- Tokyo, Japan - July 8
- Shanghai, China - August 16
- Shenzhen, China - August 19
- Taipei, Taiwan - August 22
- Hsinchu, Taiwan - August 23
- Seoul, Korea - September 6

North America

- Boston, MA (EDICON) - September 20 - 22

Europe

- London, UK (EuMW) - October 4

Visit awrcorp.com/adf for more information

Hands-On Practical Workshop

From Bits to Waves: Building a Modern Digital Radio in One Day

Hosted by: NCSU Professor David Ricketts
Date: Wed, May 25
Time: 9 a.m. - 3 p.m.
Location: Exhibition Area
Fee: $100

In this fun and interactive workshop that features the use of NI AWR software, participants will learn the basic theory of modern digital radios, as well as the RF circuits and systems used to build them.

- Participants need only a basic background in RF circuits, such as S-parameters and basic transmission line theory.
- Example designs will be available to ensure that everyone, from the most advanced RF designer to the student, will be successful.
- You only need to bring your laptop. All other materials and equipment (PC in a bag) will be provided.

To learn more, visit ims2016.org/technical-program/practical-workshop

MaXentric Designs and Optimizes Envelope Tracking Power Amplifiers for 5G LTE

MaXentric Technologies LLC

The Design Challenge

PAs are an integral part of all cellular phones, base stations, and radio systems and represent one of the most expensive component sub-assemblies in modern wireless infrastructure equipment. Both performance and cost are important drivers in system design and efficiency, making physical size, linearity, and reliability among the principal challenges. As systems and their waveforms get more complicated, new and innovative techniques and materials must be used to provide the required performance.

The increasing demand for higher data rates and larger signal bandwidth, while maintaining signal integrity, has led to the use of signals with non-constant envelope and high peak-to-average power ratio (PAPR). In conventional fixed-bias PAs, the maximum efficiency occurs at saturation, with a single-tone signal. As the PA operates at power levels away from saturation, the efficiency degrades. This creates an issue in the presence of high PAPR signals (such as orthogonal frequency-division multiplexing [OFDM]), where the average power is well below saturation.

"NI AWR Design Environment enhances the designer's experience by significantly reducing optimization time. In addition, in envelope tracking, the ability to simultaneously simulate one's design at the chip, board, and system level has become paramount in enabling next generation wideband high efficiency PA design."

Johana Yan, Lead Engineer, MaXentric Technologies, LLC , maxentric.com

Various techniques have been explored to increase the efficiency of PAs for high PAPR signals. One area of research is the ET technique. The drain voltage of the RFPA is varied dynamically to track the envelope of the signal, providing the appropriate DC supply signal and keeping the RF transistor operating continuously in its saturation region. Since the DC supply power is changing with the input envelope signal, the overall transmitter will not consume excessive DC power in a low-output power region. This results in a dramatic increase in PA efficiency.

The platform development of the ETPA is very important because the ETPA transmitter architecture is different from the conventional transmitter. Figure 1 shows the MaXentric ETPA.

The bandwidth of the RF signal from the up-converter is the same as that of the signal at the antenna. The bandwidths of both the RF and envelope signals are five times wider than that of the conventional transmitter. Many of the available evaluation platform/testbeds today are limited in bandwidth to ~200 MHz. This limits the bandwidth of the supported signal to ~40 MHz. In addition, the feedback path is needed for the digital pre-distortion (DPD) linearization. The transmitter for the conventional PA is simple, but the efficiency of the PA is relatively low. On the other hand, the efficiency of the ETPA is quite high thanks to the dynamic modulator design. To simplify ETPA development, it is important to establish the ETPA design platform.

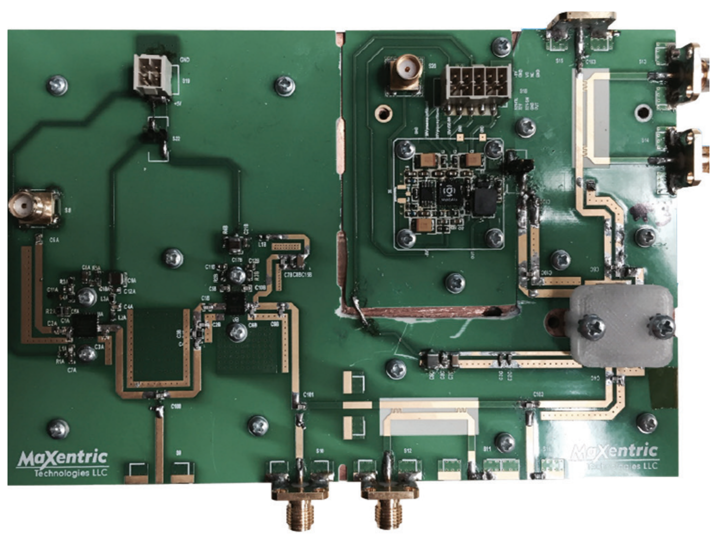


Figure 1: MaXentric ETPA.

The challenge for the MaXentric design team was to develop an ETPA using real-time efficiency and linearity measurements for optimizing ETPA design, with flexibility to accommodate different 5G signals. As talk of future 5G LTE systems calls for signal bandwidths of greater than 100 MHz, the need for an evaluation platform with 500 MHz was crucial.

The Solution

MaXentric designers chose NI AWR Design Environment, specifically Microwave Office circuit design software, to design and optimize their ETPA, as well as the NI vector signal transceiver (VST) for RF signal generation and the NI arbitrary waveform generator (AWG) for envelope signal generation. On-board tuning and final optimization of the PA impedance matching network was performed with Microwave Office software, which provided nonlinear harmonic balance circuit simulation in conjunction with design features such as load-pull analysis, transient analysis, circuit envelope, and verification through circuit/electromagnetic (EM) co-simulation via NI AWR Design Environment's AXIEM 3D planar EM simulator.

Results of Envelope Tracking using PXI and VST

The VST and PXI were used to optimize the LTE Band 1 (2.14 GHz) access point (AP) using MaXentric's MaXEA 1.0 modulator. The MaXEA 1.0 is a 30 V integrated envelope modulator with greater than 70 percent modulator efficiency, capable of outputting up to 7 W of average envelope power. It is designed to support signals with high PAPRs, such as those used in 5G LTE. It is compatible with various semiconductor technologies, such as laterally diffused metal oxide semiconductor (LDMOS), gallium nitride (GaN), gallium arsenide (GaAs), and more. In this application, a GaN device was used for the PA design. The PA was tuned and optimized for envelope tracking operation using the NI PXI system.

Initially, output and input external tuners were used to optimize the efficiency, gain, and output power of the ETPA. The desired input and output impedances were measured using a vector network analyzer (VNA) and the impedance tuning measurements were de-embedded via simulations performed using Microwave Office software in order to derive the required matching structures at the input/output of the power transistor. The retuned ETPA was then measured again using the PXI, VST, and LabVIEW ET setup to confirm its performance. Time alignment between the RF (VST) and the envelope (AWG) paths was performed digitally in LabVIEW for best efficiency and linearity.

The use of Microwave Office software enabled the designers to significantly reduce PA optimization time without sacrificing measurement accuracy. The close correlation between simulation and measurement enabled them to perform most of the optimizing in software before physically implementing it on the board, thus reducing the number of iterations that had to be performed. Figure 2 shows the retuning of the ETPA using Microwave Office.

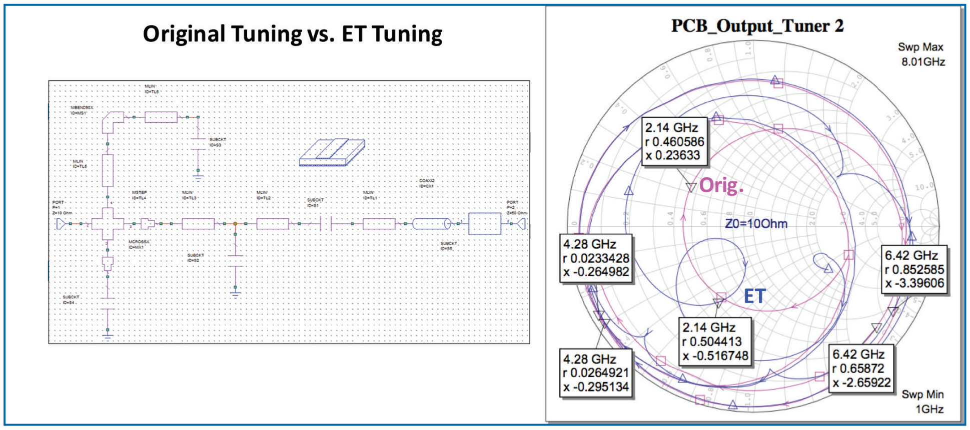


Figure 2: Retuning of the ETPA using Microwave Office software.

Why NI AWR Design Environment

NI AWR Design Environment delivered faster simulation speed, particularly the AXIEM 3D planar EM simulator, which provided excellent correlation between the simulations and measurements. The MaXentric team also noted that compared to competitive products, the NI AWR Design Environment demonstrated better convergence and faster simulation times, enabling designers to perform most of their optimization in the software. As a result, design time was cut in half over that of previous methods.

Infineon Supports LTE-A LNA Customers With Band-Specific Application Notes

"Generating the application notes and technical reports for the hundreds of circuits we developed from our LNA model was very time consuming, however, we wrote a custom script for the application note generator add-on tool in Microwave Office software that automated the whole operation, reducing the time and effort considerably."

Moakhkhrul Islam, Technical Marketing and Application Engineering, RF and Sensors, Infineon Technologies AG, infineon.com

The Design Challenge

To deliver best-in-class linearity and noise-figure performance, Infineon designers rely on the robust, accurate circuit simulation and precise modeling of all the components used in their MMIC and module designs, including printed-circuit board (PCB) test boards. Precise linear models enable faster verification of system-level performance for the application circuits supporting different bands of 4G LTE-A, currently numbering more than 44 LTE bands worldwide. By using powerful scripting capabilities built into NI AWR Design Environment, the time for designing and documenting new application circuits has been reduced from days to hours.

The Solution

Infineon chose NI AWR software for its exacting device modeling needs. The LNA and LNA/multiplexer PCB test structure include an RF input and output transmission line of predefined length and width. S-parameter and noise figure measurements of any device at the calibrated test equipment port will include this transmission line, as well as the SMA connector launches on the test boards input/output. The response of the test structure can be removed from the measurement through de-embedding, resulting in a more accurate measurement of the isolated device response. The test structure can be characterized through a variety of measurement-based methods or rigorous electromagnetic (EM) simulation. In this case, engineers used the closed-form transmission line and SMA models in NI AWR Design Environment, specifically Microwave Office circuit design software, to compare to three different calibration standards: namely a short, open, and through transmission line, as shown in Figure 1.

Simulating the device, application circuit, and test fixture together enabled the engineers to make a direct comparison to the application circuit's measured results (in the test fixture). If the simulation and measurement results showed equivalent responses, then the model was accepted.

As the simulation and measurement results of the application boards demonstrated an acceptable level of agreement, the LNA model was used in hundreds of simulation circuits for different wireless applications, especially for different LTE bands. Generating the documentation (datasheets and application notes) for the hundreds of application circuits is very time consuming, however, the Infineon RF & Sensors Business Unit was able to develop an application note generator add-on tool for Microwave Office software. Using this tool, the documentation for each application circuit was completed in a few minutes.

The generator tool is based on a custom script file that automates the entire operation, reducing the time and effort considerably. By running the script file first, all the necessary graphs were generated with proper annotations, axis definition, title, and markers. Then all the graphs were verified by the applications engineers. If the graphs were approved, the script was used again and all the graphs were copied from Microwave Office software to the appointed document file. The script was also used to complete the table in the document file by finding the proper values from the generated graphs.

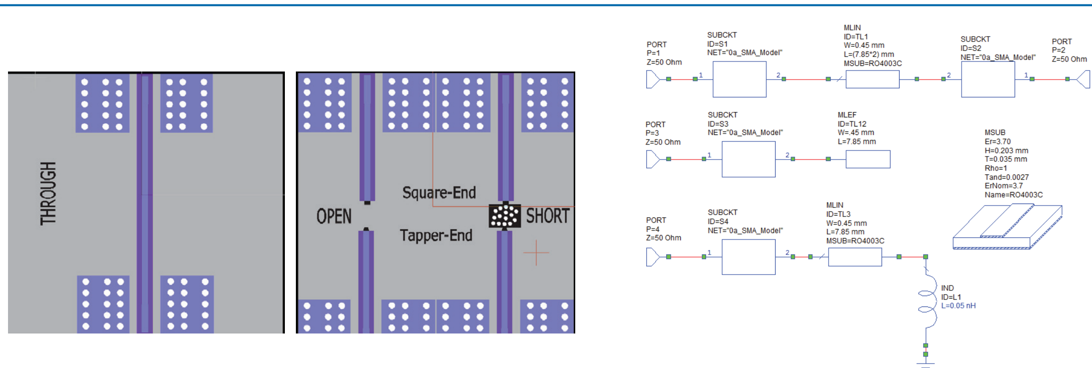


Figure 1: Actual layout of the PCB (left) and Microwave Office schematic diagram for PCB characterization (right).

Technion Students Design Synthetic Aperture Radar (SAR) Simulator

The Design Challenge

The design challenge for Technion SAMPL Lab students was to build an efficient, easy-to-use synthetic aperture radar (SAR) simulator that connects to MATLAB for signal processing. SAR is a type of radar used to create two and three dimensional representations of an object. SAR uses the motion of the radar antenna over a targeted region to provide finer spatial resolution than is possible with conventional beam-scanning radars. The SAMPL Lab design focuses on sub-Nyquist sampling of the received signal and full reconstruction of the image.

The students, supervised by Kfir Aberman and Prof. Yonina Eldar, wanted to create a SAR simulator that could handle many targets on the surface and then use MATLAB to calculate the object shapes. The SAR simulator had to perform as quickly as possible.

The Solution

The SAMPL Lab students used NI AWR Design Environment, inclusive of Visual System Simulator™ (VSS) system design software, for this SAR simulator research project because it provides an intuitive, accurate and flexible environment. The software gave the students a simple yet accurate look at the architecture and design phases of the SAR simulator. They were able to examine many related examples that were provided, which helped them in learning the software, its capabilities, and its usefulness for the SAR simulator project.

"We found the e-learning tools and software documentation very helpful. The vast simulation options within NI AWR Design Environment makes radar design a very easy and straightforward process."

Yoav Chachamovitz, Student
SAMPL Lab Technion
technion.ac.il

NUPT Students Design Novel Broadband Substrate Interconnection Structure

The Design Challenge

Substrate-to-substrate interconnection is important in order to achieve a higher isolation among the parts of a transceiver. Each part must be designed on a separate circuit substrate to avoid signal leakage through the shared substrate, especially the high-power LO leakage to other parts. Additionally, it is not possible in every case to place all components on one circuit substrate so they must be placed on different substrates for a complex circuit. To solve these challenges, engineers at Nanjing University of Posts and Telecommunications wanted to design a novel broadband substrate-to-substrate interconnection structure.

The Solution

The designers developed a broadband interconnection using double bond wires with square-shaped defected ground structure (DGS) under open stubs. The square-shaped DGS etched under compensated microstrip open stubs not only expanded its operating bandwidth, but also increased the characteristic impedance of the microstrip line without narrowing its width, which overcame the PCB fabrication limitation of narrow stubs.

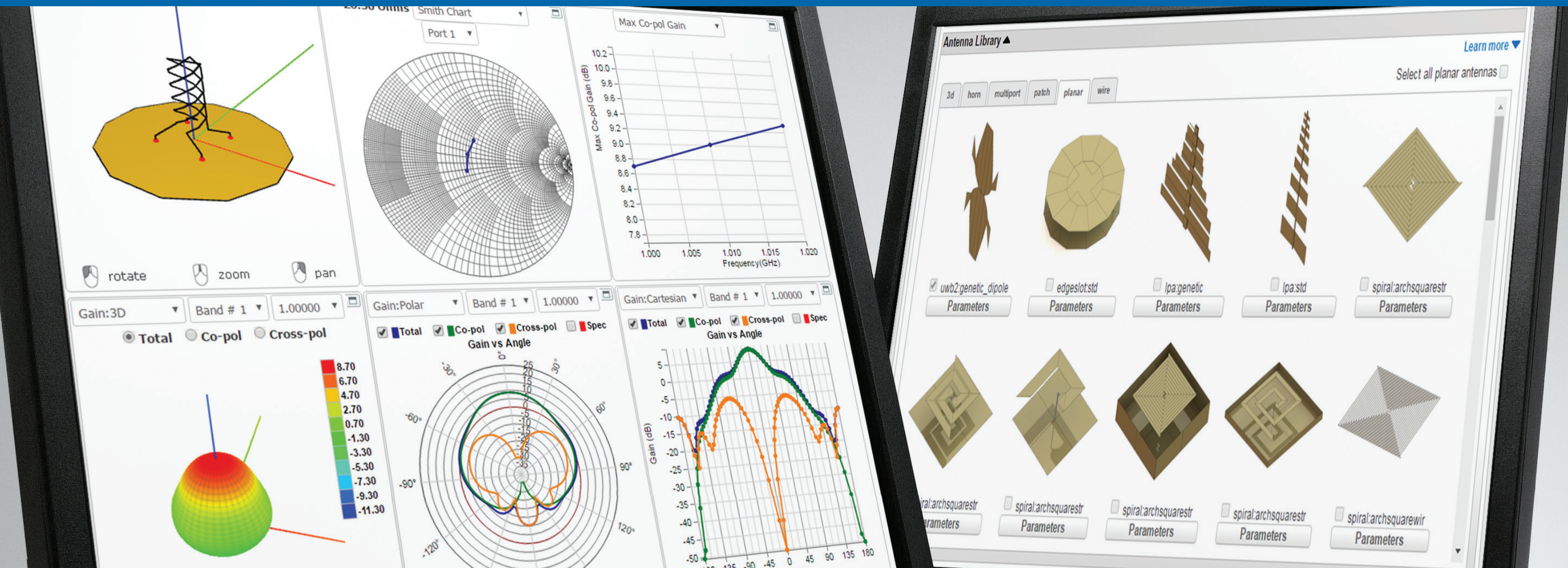
The advantage of using this structure was that it enabled the designers to increase the characteristic impedance of the microstrip line without narrowing its width. Electromagnetic simulation was accomplished using NI AWR Design Environment, specifically Microwave Office circuit design software and AXIEM 3D planar EM simulator. The novel structure provides more than 1200 percent bandwidth increment compared to a conventional structure.

"Using Microwave Office and AXIEM to simulate and optimize this novel broadband interconnection structure gave us the insight we needed to overcome the challenges and develop a successful design."

Dr. Zhou
Nanjing University of Posts and Telecommunications
njupt.edu.cn/en

AntSyn

Antenna Synthesis and Optimization Technology



Overview

The wireless revolution that brought smart phones and Wi-Fi enabled everything to consumers is largely thanks to our community of microwave/RF engineers, as well as NI AWR software. NI AWR Design Environment software – inclusive of Microwave Office, VSS, Analog Office, AXIEM, and Analyst, is what you—microwave and RF engineers—use to design wireless products that range from base stations to smart phones to satellite communications.

An Evolution in Antenna Design

Growing demand for wireless connectivity relies more and more on integrated antenna solutions customized for optimal system performance, cost, and size. Achieving multiple performance metrics such as impedance matching, gain, radiation efficiency, and operating bandwidth is a time consuming process involving numerous iterative simulations and a significant amount of design knowledge. With the demand for design experience greatly exceeding the current supply of antenna engineers, an alternative approach is needed.

Fortunately, research into the use of the evolutionary algorithms (EAs), a programmatic method to explore the design space and automatically locate superior antenna designs, offers a means to accelerate the overall design process. EA is proving to be highly effective at generating antenna structures with greater performance than would otherwise be developed by traditional methods. AntSyn, a combination of EA with RF/microwave simulation, which has been successful in the development of a variety of antenna types for aerospace applications, is now available as a commercial product from NI.

AntSyn is an automated antenna design, synthesis, and optimization tool that enables users to input antenna engineering requirements and output antenna designs. AntSyn was designed to be used by many types of designers, from experts to those who are relatively new to antenna design.

The Antenna Design Bottleneck

A properly designed antenna is typically characterized by a number of critical performance metrics driven by the target application. Chief concerns relate to the directional characteristics (as depicted in the antenna's radiation pattern) and the resulting gain. As a result, the range of antenna design types is extensive, with a very large number of shapes, sizes, requirements, and applications. Designing and optimizing antennas by hand requires significant domain expertise. This process is both time and labor intensive and is unlikely to reveal new and/or improved antenna designs.

It is not uncommon for an experienced engineer to consume several months developing a new antenna design, depending on the level of difficulty as defined by the antenna specifications. The time and effort invested increases significantly when addressing factors such as antenna interaction with the platform/wireless device or co-site interference. Design delays are compounded when program requirements change, such as in early stage development or in the case where antenna integration requires in-situ optimization. The ability to conduct rapid antenna design and re-design is a growing concern as the number of wireless devices proliferate.

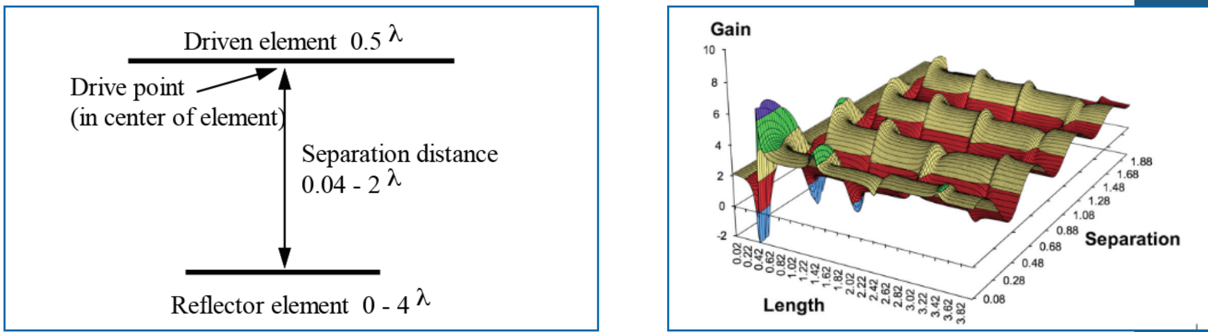


Figure 1. Complexity in antenna design illustrated in wide range of gain resulting from variations in dipole length and reflector separation of a simple antenna.

As an alternative or adjunct to designing by hand, researchers have been investigating methods based on evolutionary antenna design and optimization since the early 1990s. One highly successful technique from NI is based on EA. This technology has been developed into a complete antenna synthesis tool, AntSyn, and has been used successfully by companies and government agencies operating in aerospace, communications, and wireless electronics markets to design antennas operating at frequencies ranging from below high frequency (2 MHz) to above Ka band (40 GHz). In contrast to the man-months of engineering time typically required for a final antenna design, AntSyn can generate a design in hours, finding optimal tradeoffs between criteria and often producing counter-intuitive designs that outperform traditional antennas.

Design by Requirements

AntSyn operates on a "what you want is what you get" principle, where the user inputs the antenna requirements rather than a (parameterized) physical design. Antenna specifications such as frequency band, target impedance match (return loss), gain pattern, and more, are put into the intuitive "spec sheet" user interface, which is automatically organized into a project file, as shown in Figure 2 (left). By running the spec sheet, AntSyn returns one or more optimized antenna designs, the results of which are viewed using a customizable dashboard for rapid evaluation, as shown in Figure 2 (right).

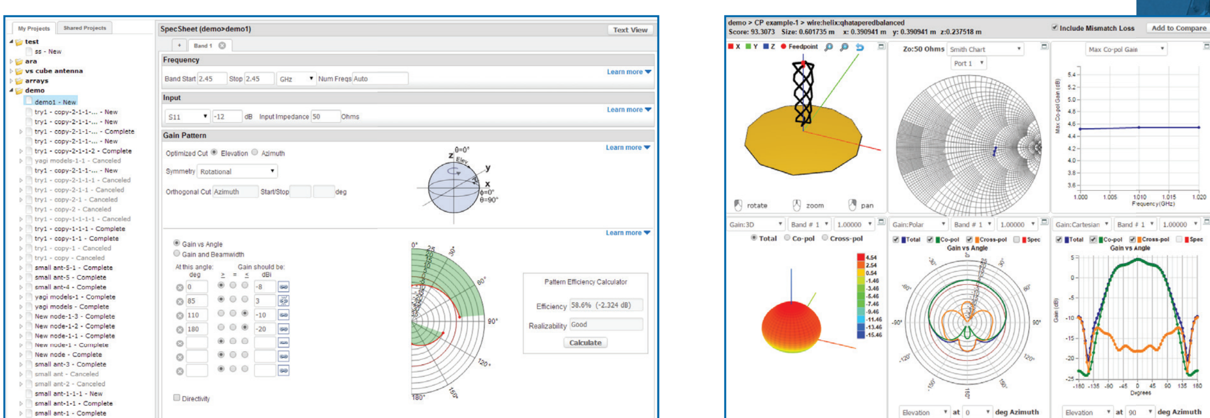
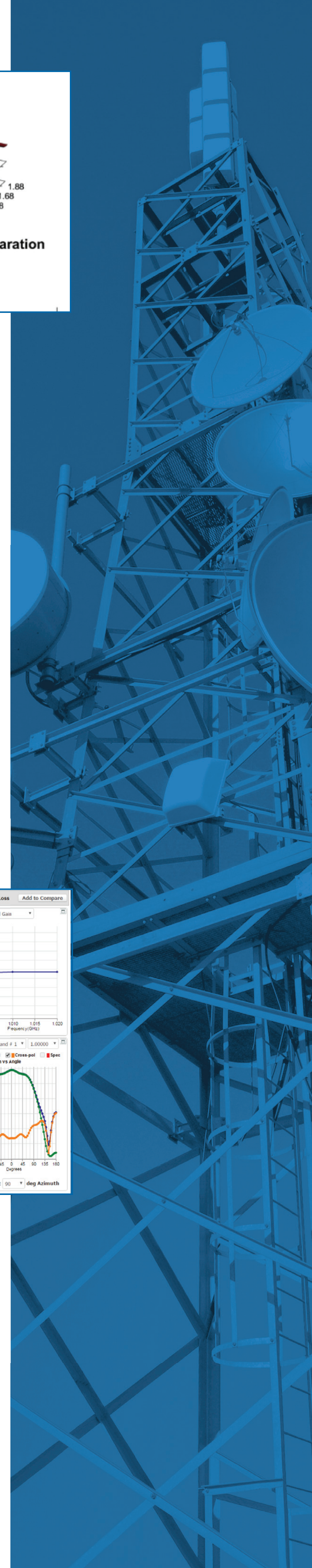


Figure 2. The AntSyn user interface spec sheet (left image) defines antenna requirements and the AntSyn results dashboard (right image).

The user-specified dashboard can be set to view the proposed 3D model, input impedance (match) performance vs. frequency in several formats, max gain vs. frequency, radiation pattern cuts, and qualitative star rating to help identify good performers quickly. AntSyn has been used to develop a wide range of antenna types including single-band, dual-band, multiband, broadband and ultra-wideband (UWB) (>100:1), high efficiency, loaded, electrically small, phased array, wire, patch, conformal, handset, multifunction and multiport, and more.

Learn more at: awrcorp.com/antsyn



Women in Microwaves – Diversity Gone Global

Nearly a year ago now, the WIE (Women in Engineering) Leadership Conference was held in Silicon Valley. I have commented prior about Intel CEO Brian K. Krzanich's keynote and reference to its "Diversity Challenge."

Little does Brian know, but his talk has had far-reaching effects within our own IMS MTT-S WIM organization. It has inspired me to take the essence of this challenge—that diversity brings different viewpoints, skills, and knowledge to the table, improving the workforce and driving better business—and use it to spearhead similar talks.

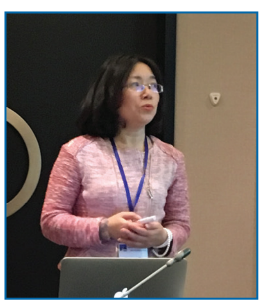
First up was IMS2015 and our WIM-sponsored panel titled, "Diversity in Microwaves: Let's Talk About the Demographics." Moderated by Dr. Kate Remley, National Institute of Standards and Technology (NIST) Metrology for Wireless Systems Project, it included participants representing our global community with the intent to share and discuss issues that women and other minorities face in their career paths around the world. This full afternoon session spotlighted a diverse group of exceptional women and their involvement and contribution to our microwave engineering society.

Next stop on this world tour was COMCAS 2015 in Tel Aviv, Israel. Here I met Professor Orit Hazaan of the Department of Education in Science and Technology at Technion - Israel Institute of Technology. Prof. Hazaan was the featured speaker in our WIM-sponsored session, "Diversity in High-Tech – What's Working and Why?"

In her speech, Prof. Hazaan asserted that it is in the interest of the high-tech world, rather than in the interest of any specific underrepresented group in the community, to enhance diversity in general, and gender diversity in particular. She illustrated how the creation of a culture that enhances diversity benefits the entire STEM community.

The follow-on discussion, which included prominent women from Israel, the U.K., and the U.S., addressed the benefits a diverse organization offers, as well as where we are in achieving a diverse work culture in North America and Europe.

Thereafter was APMC in China in early December, where I met Professor "Cherry" Wenquan Che of the Nanjing University of Science and Technology (NUST), who led a panel discussion, "The Current Status of Women in Microwave Engineering in Universities of China."



Prof. Che NUST

This discussion looked at diversity in engineering throughout the world and especially in China, and focused on diversity in Chinese universities. Online surveys were shared that show the outlook for engineering careers in China is bright. Some key observations were that female professors and students are becoming a more important part of the workforce, males and females have different advantages and teamwork and cooperation are the best way to achieve the highest productivity, and for women who desire to achieve balance between career development and family, more understanding and support are expected from family, colleagues, society, and government policy making.

Now coming full circle, we are back to IMS again. This year the diversity challenge has evolved to take on a new angle, namely, "Leadership: How to Inspire Change." The panel will explore and discuss ideas useful to all technical professionals who are striving to grow their leadership skills. Specific topics explored include:

- How diversity helps us avoid becoming stagnant
- How to overcome career roadblocks
- The role that visibility plays in successful leadership

WIM @ IMS2016

Date: Tue, May 24
Time: 1:30 p.m. - 3:10 p.m.
Location: Moscone Convention Center

Best regards,

Sherry Hess
VP Marketing,
AWR Group, NI

Join me on LinkedIn to share your ideas for WIM: linkedin.com/groups/6955695

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 Layout/Verification
- Cadence
- DWT
- Intercept
- Mentor Graphics
- Zuken

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

Test/Measurement
- Anritsu
- Focus
- Maury Microwave
- National Instruments
- Rohde & Schwarz

Alliance Partners

NI AWR Software Alliance Partners span industry consortiums as well as leading GaAs/GaN and silicon foundries. All of these relationships enable us to deliver a better user experience to you, our customer.

Consortiums
- Accellera
- ESDA (formerly EDAC)
- IPC-2581
- Si2

Foundry Partners
- ams
- Cree Inc.
- Global Communications Semiconductors
- IHP Microelectronics
- LFoundry
- Northrop Grumman Space Technology
- OMMIC
- Qorvo
- Silanna
- TSMC
- TowerJazz
- United Monolithic Semiconductors
- WIN Semiconductors

New Technical Resources

White Papers

- Integrating EM Simulation Technologies Within an RFIC Design Flow
- Design of Class F Power Amplifiers to Optimize Gain, Efficiency, and Stability

Application Notes

- Using AntSyn to Design an Ultra-Wideband Antenna
- Using Enhanced Load-Pull Measurements for the Design of Base Station PAs
- A Simulation-Based Flow for Broadband GaN Power Amplifier Design
- Design of a 10 GHz Low-Noise Amplifier for Amateur Radio Operation
- Load-Pull Analysis Using NI AWR Software
- Design, Optimization and Production of an Ultra-Wideband (UWB) Receiver

Visit awrcorp.com/solutions/technical-papers for the latest white papers, application notes, and web events/archives.

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. Recent additions include:

Analyst 3D FEM EM

- Introduction to Analyst
- 3D Cells
- An Example - Coil
- Setup Through Simulation

To learn more and get started visit: awrcorp.com/e-learning

Academic Programs

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Visit awrcorp.com/graduates to review qualification terms

Design of Base Station Power Amplifiers From Load-Pull Measurements

Overview

Load-pull simulation is a very simple yet powerful concept in which the load or source impedance presented to an active device is swept and its performance is measured. Performance contours are then plotted on a Smith chart, which shows the designer how changing impedances impact the device's performance (Figure 1).

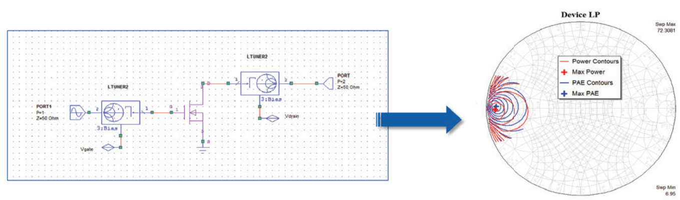

Figure 1: The load-pull methodology in which the load (or source) impedance of a device is swept and measured, then performance contours are plotted on a Smith chart.

Recent advances in data file formats by load-pull measurement system vendors have significantly expanded the usefulness of load-pull characterization. These file formats now support input power, DC bias, temperature, or tone spacing (in the case of two-tone load pull), swept source, and/or load impedances, to name a few. The ability to import and manipulate these load-pull data sets in NI AWR Design Environment greatly simplifies and speeds the design process, giving designers a broader design space to explore.

Traditional Design Flow

The traditional circuit design flow often involves running a load-pull simulation on a nonlinear model of the device in circuit design software, but there are issues. The first is overall accuracy of nonlinear models across all operating conditions such as bias, frequency, and power level. The second is the ready availability of such models. Consequently, PA designers have begun to design their matching networks and associated circuitry directly from measured load-pull data.

The challenge for EDA companies, however, is to provide intuitive methods for dealing with these new and expanded complex swept load-pull data sets, which can include nested harmonic load pull, nested load and source pull, and two-tone excitation, in which intermodulation distortion levels can be analyzed as a function of load impedance. The data can also include multiple fundamental frequencies. As such, an entire array of possibilities exists for manipulating the data, including plotting as a function of frequency, power, bias, load, or source impedance at the fundamental frequency, and load or source impedance at harmonic frequencies.

Above and beyond viewing and plotting swept load-pull data, the ability to directly optimize matching networks is of paramount importance. Matching networks that are designed from measured load-pull data enable fast and accurate prototype builds, as the uncertainty of a nonlinear model is removed and replaced with empirical, verifiable data. In this case, the EDA software must establish a means of interpolating device performance from load-pull data using the impedances computed from an output matching network. In this way, after the load-pull data has been imported into the circuit design tool, the matching networks can be designed directly.

A final consideration is the ability to produce equivalent data sets from nonlinear models. That is, the circuit tool must be capable of producing data that can be fit to empirical data, in order to enable modeling groups to produce accurate device models. In this way, the circuit simulator can be used not only for data manipulation and circuit design, but also for improving the accuracy of nonlinear device models.

Load-Pull Capabilities in NI AWR Software

The new load-pull formats in NI AWR Design Environment, specifically Microwave Office software, give designers access to an extensive array of data manipulation possibilities. Figure 2 shows a rectangular graph (left) of the input power versus the index. There is a marker

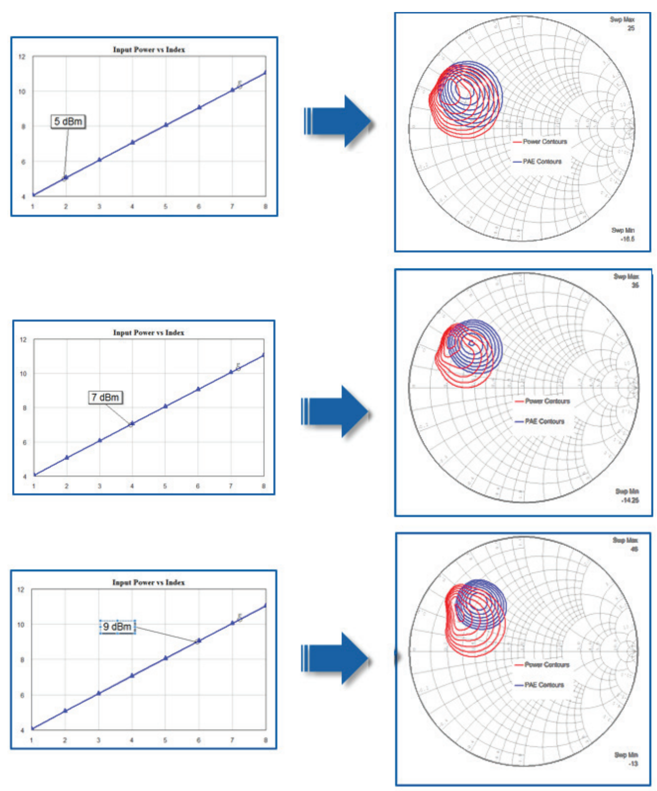

Figure 2: The rectangular graph on the left shows the input power vs. index. A marker points to a specific input power and plots the contours in the Smith chart. When the marker is moved, a new set of contours is plotted.

that points to a specific input power and the contours for that power level are being plotted (right). If the marker is moved, another set of contours is obtained corresponding to that power level. If the marker is moved again, a third set of contours is obtained.

Instead of choosing an input power level and plotting contours, users can choose a gamma point or impedance and plot swept data. Figure 3 shows how the user chooses a gamma point from the impedances that are in the data file and plots gain compression curves. The grayed out curves are the gain compression curves for all the gamma points in the file and the dark blue trace corresponds to the gamma point that has been selected with the marker. Similarly, if the marker is moved to another gamma point, the gain compression curve changes to reflect the performance at the new impedance (Figure 4).

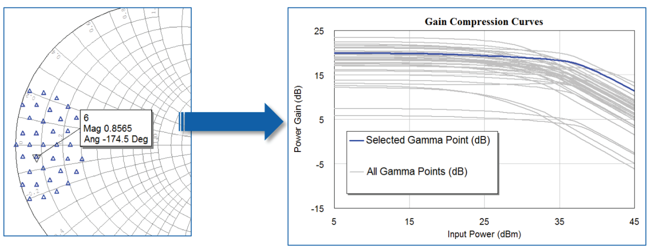

Figure 3: The user chooses a gamma point (left) from the impedances in the local file and plots gain compression curves (right). The grayed out curves are gain compression curves for all gamma points and the dark blue trace corresponds to the gamma point that has been swept with the marker.

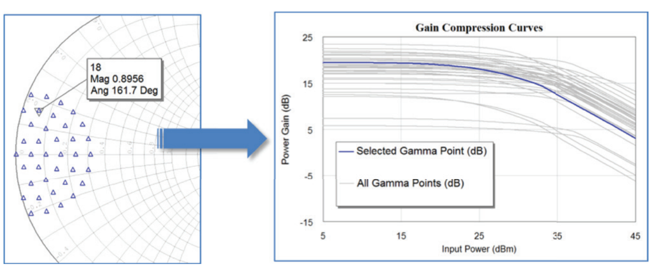

Figure 4: If the marker (left) is moved to another gamma point, the gain compression curve (right) changes to update that impedance.

Another capability in NI AWR software enables something called an "overlap contour." Figure 5 shows general contours for output power and power-added efficiency (PAE), along with the overlap contour for specific output power and PAE levels. 50 dBm power capability and 70 percent PAE have been chosen, and the overlap contour shows the tiny locus of impedances where both of these design criteria are being met.

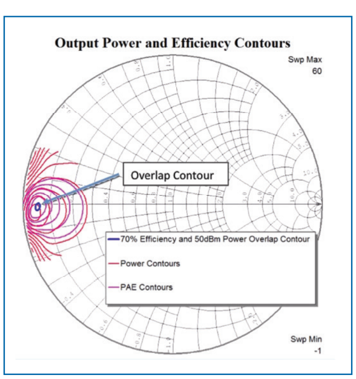

Figure 5: Overlap contour for design criteria of 50 dBm power and 70 percent PAE.

For base station designers, you are never designing for just one target. When there are multiple performance criteria that must be met simultaneously, this measurement helps to quickly convey where both design criteria are achieved. It's also important to note that just because users are sweeping input power doesn't mean they are constrained to making all their measurements based on input power. Designers who are interested in plotting contours or designing in terms of output power or gain compression level, can use the capability in NI AWR Design Environment to easily plot output power-based or gain compression-based contours.

Additionally, matching networks can also be optimized directly from load-pull data. In Figure 6, output power capability, gain, and PAE have been plotted, this time as a function of frequency. The matching networks can now be tuned or optimized based directly on these performance criteria. The bars in the figure are the goals for the optimizer. Once goals have been set, the optimization runs on the matching network to meet the desired performance and the physical parameters for the matching network are updated. Figure 7 shows the result of the optimization and the updated matching network.

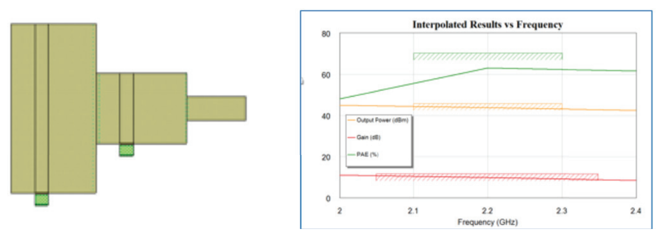

Figure 6: Several performance criteria have been plotted and matching networks can now be optimized based directly on those performance criteria.

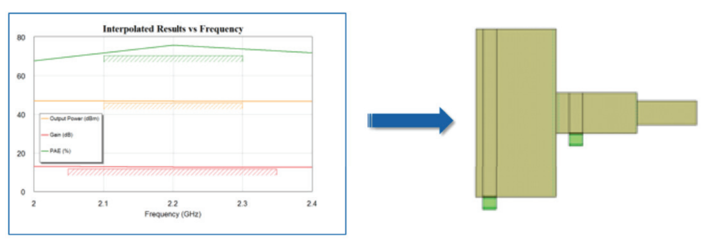

Figure 7: Performing the optimization based on empirical load-pull data updates the matching network's physical parameters.

Conclusion

Load pull will continue to be an integral part of the design flow for microwave and RF power devices for the foreseeable future. The new swept format files combined with updated EDA vendor capabilities has served to encourage the use of load pull. The collection of a rich load-pull data set can shorten design cycles and NI AWR Design Environment provides enough flexibility in interacting with load-pull data that users have the ability to choose whatever is best for each design project at hand.