Vol. 60 • No. 7

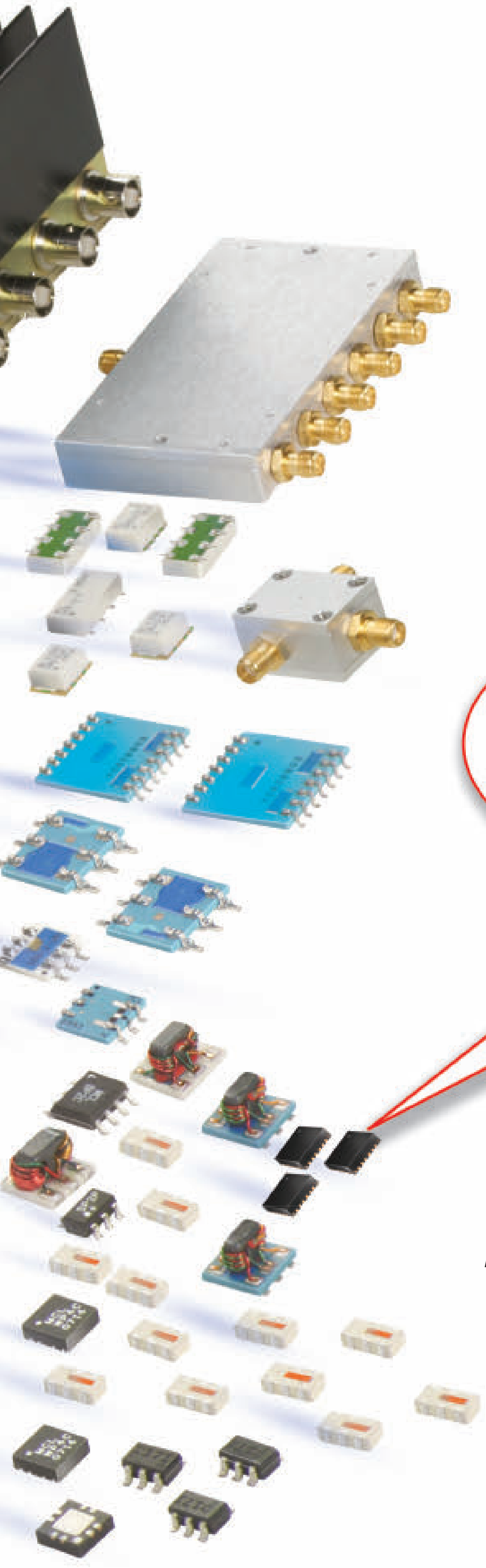
July 2017

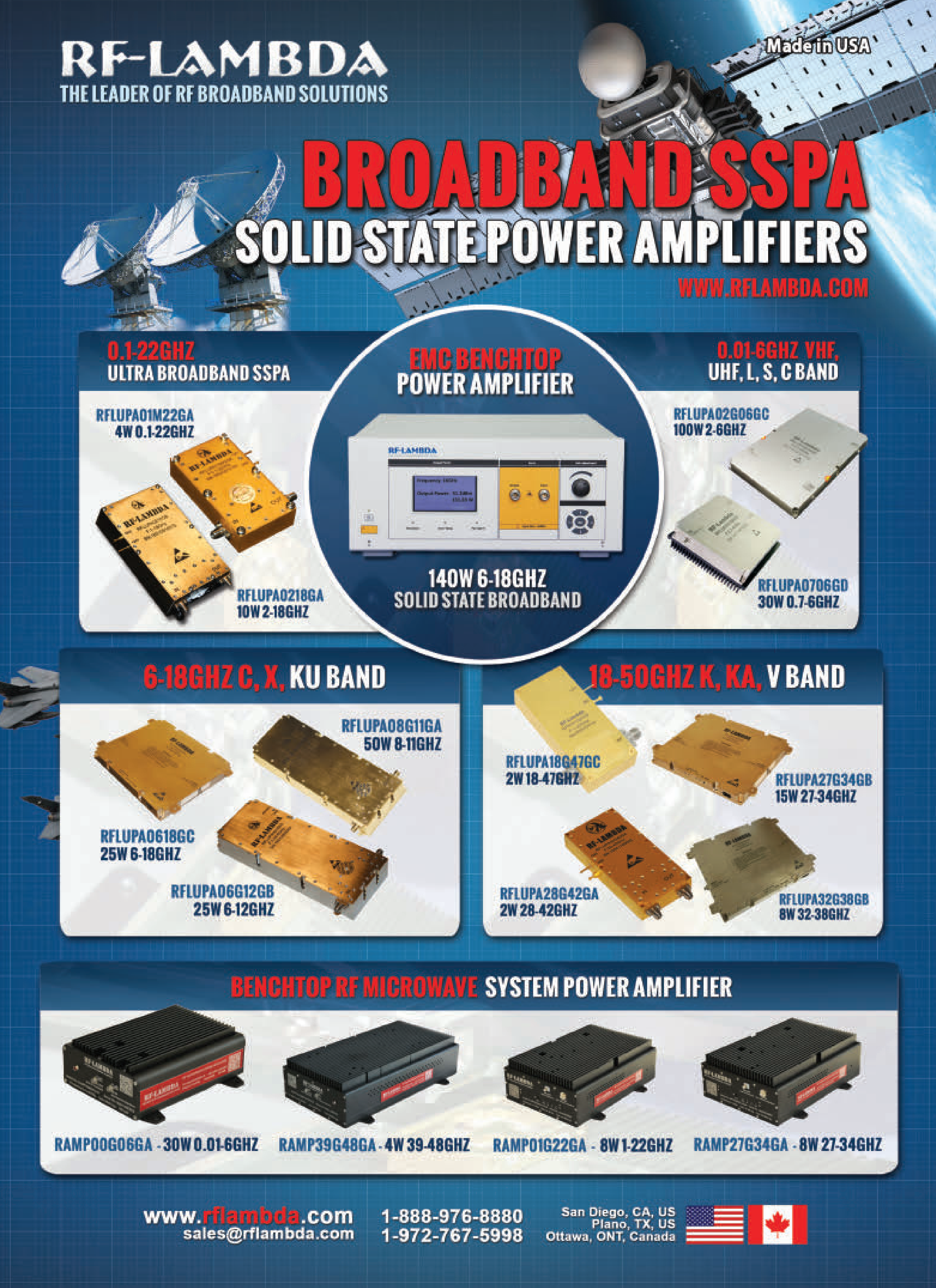
Microwave Journal .com

horizon house®

Founded in 1958


MCL B 744
ADP-2-10




RF-LAMBDA
THE LEADER OF RF BROADBAND SOLUTIONS
Made in USA
BROADBAND SSPA
SOLID STATE POWER AMPLIFIERS
WWW.RFLAMBDA.COM
0.1-22GHZ
ULTRA BROADBAND SSPA
RFLUPA01M22GA
4W 0.1-22GHZ
RFLUPA0218GA
10W 2-18GHZ
EMC BENCHTOP
POWER AMPLIFIER
140W 6-18GHZ
SOLID STATE BROADBAND
0.01-6GHZ VHF,
UHF, L, S, C BAND
RFLUPA02G06GC
100W 2-6GHZ
RFLUPA0706GD
30W 0.7-6GHZ
6-18GHZ C, X, KU BAND
RFLUPA08G11GA
50W 8-11GHZ
RFLUPA0618GC
25W 6-18GHZ
RFLUPA06G12GB
25W 6-12GHZ
18-50GHZ K, KA, V BAND
RFLUPA18G47GC
2W 18-47GHZ
RFLUPA27G34GB
15W 27-34GHZ
RFLUPA28G42GA
2W 28-42GHZ
RFLUPA32G38GB
8W 32-38GHZ
BENCHTOP RF MICROWAVE SYSTEM POWER AMPLIFIER
RAMP00G06GA - 30W 0.01-6GHZ
RAMP39G48GA - 4W 39-48GHZ
RAMP01G22GA - 8W 1-22GHZ
RAMP27G34GA - 8W 27-34GHZ
www.rflambda.com
sales@rflambda.com
1-888-976-8880
1-972-767-5998
San Diego, CA, US
Plano, TX, US
Ottawa, ONT, Canada

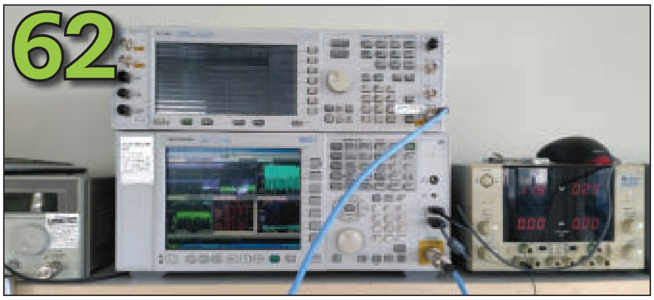

Get Where You're Going with...
K&L MICROWAVE
A DOVER COMPANY
K&L's pre-filtered GPS LNA's
• Covers L1, L2, L5 and combinations
• Gains available 16 to 40 dB
• Low Noise Figure - Typically 1.8 dB or less
• Available with or without internal limiter
• Rugged design for harsh military environments
• Other frequencies available
Microwave Products Group
K&L MICROWAVE
BSC
POLE ZERO.
DowKey Microwave
ENABLING COMMUNICATION AND SIGNAL CONTROL
www.klmicrowave.com • www.klfilterwizard.com • 410-749-2424 • sales@klmicrowave.com •


AMPLICAL
Let Amplical
Jump Those Hurdles for You
with our Complete In-House Design, Manufacturing and Test Capabilities
Customers can depend on us for quick order fulfillment, competitive pricing and dedicated service.
Let us prove our commitment to you today.
High performance standard and custom Control Components and Amplifiers to 40GHz.
• EW Systems
• Communications Systems
• Radar
• Test
• Simulation
Products:
• Switches
• Attenuators
• Phase Shifters
• Limiters
• Switch Matrices
• Broadband Amplifiers
• Low Noise Amplifiers
• High Power Amplifiers
• Custom Components and Sub-assemblies
Phone: 973-386-1119
Fax: 973-386-1131
E-mail: info@amplical.com
web: www.amplical.com

Microwave Journal
July 2017
Vol. 60 • No. 7
Software & Design
mwjournal.com

CONTENTS

Cover image courtesy of CST



Cover Feature

Technical Features

Departments

60 YEARS OF PUBLISHING EXCELLENCE

ONE PLATFORM, ZERO BARRIERS

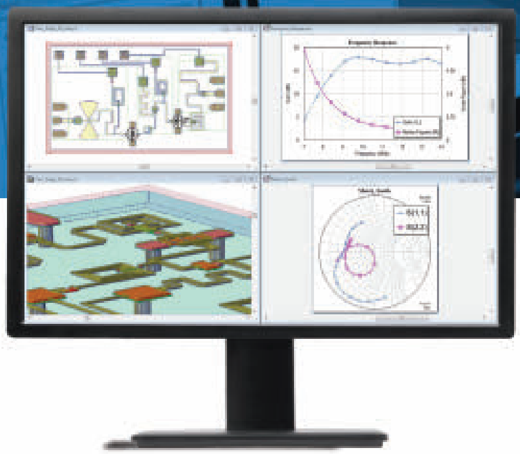
SIMPLY SMARTER

NI AWR DESIGN ENVIRONMENT

NI AWR Design Environment is a single platform that integrates system, circuit, and EM analysis for the design of today's advanced wireless products, from base stations to cellphones to satellite communications. Its intuitive use model, proven simulation technologies, and open architecture supporting third-party solutions translates to zero barriers for your design success.

Simply smarter design.

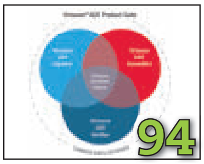
AWR **Learn more at ni.com/awr**



NATIONAL INSTRUMENTS™

Microwave Office | RF and Microwave Circuit Design Software

Microwave Journal
CONTENTS
mwjournal.com



Product Features

Tech Brief

NEXT MONTH

August 2017
High Frequency Components and PCBs+EDI CON USA

- Millimeter Wave Technology Overview and Future Directions
- Microwave Material Measurements Without Cables
- Clocking the RF ADC: Use Phase Noise Instead of Jitter
- Wireless Radio Technology: The Next Frontier

Microwave Journal (USPS 396-250) (ISSN 0192-6225) is published monthly by Horizon House Publications Inc., 685 Canton St., Norwood, MA 02062. Periodicals postage paid at Norwood, MA 02062 and additional mailing offices.

POSTMASTER: Send address corrections to Microwave Journal, PO Box 1143, Skokie, IL 60076 or e-mail mwj@omeda.com. Subscription information: (847) 291-5216. This journal is issued without charge upon written request to qualified persons working in the RF & microwave industry. Other subscriptions are: domestic, $120.00 per year, two-year subscriptions, $185.00; foreign, $200.00 per year, two-year subscriptions, $370.00; back issues (if available) and single copies, $10.00 domestic and $20.00 foreign. Claims for missing issues must be filed within 90 days of date of issue for complimentary replacement.

STAFF

EXECUTIVE EDITORIAL OFFICE
685 Canton Street, Norwood, MA 02062
Tel: (781) 769-9750
FAX: (781) 769-5037
e-mail: mwj@mwjournal.com

EUROPEAN EDITORIAL OFFICE
16 Sussex Street, London SW1V 4RW, England
Tel: Editorial: +44 207 596 8730 Sales: +44 207 596 8740
FAX: +44 207 596 8749

SUBSCRIPTION SERVICES
Send subscription inquiries and address changes to:
Tel: (847) 291-5216
e-mail: mwj@omeda.com

BPA WORLDWIDE

www.mwjournal.com

Printed in the USA

INTRODUCING THE WORLD'S FIRST ULTRAPORTABLE FAMILY OF mmWAVE SPECTRUM ANALYZERS TO 110 GHz.

Now taking it to the extreme just got easier. The footprint for up to 110 GHz measurements is now a whole lot smaller, and so is the price tag. Anritsu introduces a new family of 9 kHz to 110 GHz direct-connect solutions which offer superior dynamic range in the mmWave bands and in a form factor that fits in your pocket! Nothing on the market comes close.

ANRITSU MS2760A SPECTRUM MASTER

mmWAVE
Test and measurement for Automotive Radar, Satellite, 5G, WiGig and more

ULTRAPORTABLE
Benchtop power from a smartphone-sized instrument that fits in your pocket

PERFORMANCE
Best-in-class dynamic range, sweep speed, and amplitude accuracy

Anritsu

1-800-ANRITSU
WWW.ANRITSU.COM/TEST-MEASUREMENT

Microwave Journal Online

Visit us @ mwjournal.com

E LEARNING CENTER

Technology and Market Outlook for Next Generation MilSatComs

Sponsored by: Rohde & Schwarz and Wolfspeed 7/25

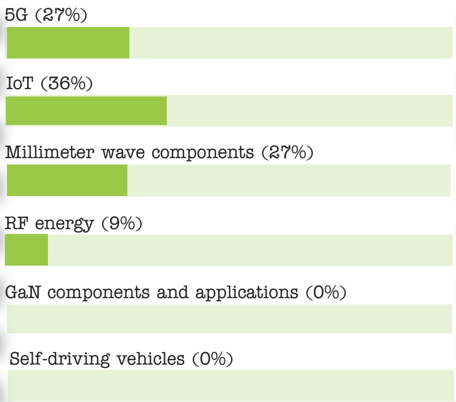
Web Survey

Which EMC/EMI software do you use in your design process?

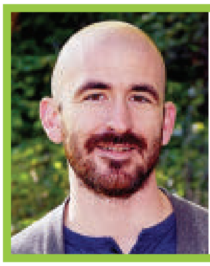
Look for our multiple choice survey online at mwjournal.com

May Survey

What current industry developments most interest you?



Executive Interview



Nathan Kundtz, founder, CEO and president of **Kymeta Corporation**, makes the case for satellites' role in serving the global demand for connectivity and discusses how Kymeta's unique metamaterials beamforming technology enables lightweight, slim and cost-effective antenna systems for satellite terminals.

WHITE PAPERS

KEYSIGHT TECHNOLOGIES — Get More From Your Test Assets

MORION US, 80 YEARS OF STABILITY — New Class of Ultra Precise Quartz Oscillators Combining Lowest Noise and Minimal Allan Deviation

NATIONAL INSTRUMENTS — mmWave: The Battle of the Bands

TotalTemp Technologies, Inc.

Stay Connected

Follow us:@ MWJ editor @MWJpromo

Editors: @Pathindle @MWJGary

Like us at facebook.com/microwavejournal

Follow us @microwavejournal

Catch *Frequency Matters*, the industry update from *Microwave Journal*, www.microwavejournal.com/FrequencyMatters

COM

AUGUST

MARK YOUR CALENDAR

2

Call for Papers Deadline

I E D M 63rd International Electron Devices Meeting

IEDM 2017
San Francisco, Calif.

IEDM encourages submissions in all areas, with special emphasis on:

- Sensors and MEMS devices for biological/medical applications
- Technologies for 5 nm and beyond
- Neuromorphic computing/ machine learning
- Advanced memory technologies
- Steep subthreshold devices
- Spin for memory and logic
- More than Moore device concepts
- Package-device level interactions
- Optoelectronics, photonics, displays and imaging systems

www.ieee-iedm.org

2

WEBiNAR

Microstrip Cross-Coupled Filter Design

Sponsored by:

SONNET® PRECISION ELECTROMAGNETICS

3

WEBiNAR

Sponsored by:

KEYSIGHT TECHNOLOGIES

29

Signal Integrity WEBiNAR

Sponsored by:

ANSYS®

7-11

EMC+SIPI

IEEE EMC+SIPI
National Harbor, Md.

EMC + SIPI 2017 is the leading international event where you can share your insights, exchange ideas, ask questions and learn from other EMC & SIPI experts. Experience five days of technical workshops and tutorials, special sessions, technical papers, panel discussions and 200+ booth Exhibit Hall.

www.emc2017.emcss.org

8/30-9/1

RFIT

RFIT 2017
Seoul, South Korea

RFIT provides a forum for the integrated circuit and RF technology communities to meet and present the latest developments in integrated circuit design, technology and system integration, with emphasis on wireless communication systems and emerging applications.

www.rfit2017.org

8/28-9/2

meta metamorphose METAMATERIALS CONGRESS

Metamaterials 2017
Marseille, France

The Congress will provide a unique topical forum to share the latest results of the metamaterials research in Europe and worldwide, and bring together the engineering, physics, applied mathematics and material science communities working on artificial materials and their applications from microwaves to optical frequencies.

www.congress2017.metamorphose-vi.org

FOR DETAILS, VISIT MWJOURNAL.COM/EVENTS

ComingEvents

CALL FOR PAPERS

IEEE IMaRC
July 16, 2017

IEEE CSICS 2017
July 20, 2017

EMV 2018
July 24, 2017

RWW 2018
July 25, 2017

IEDM 2017
August 2, 2017

90th ARFTG Conference
September 29, 2017

mwjournal.com

AUGUST

IEEE EMC + SIPI
August 7–11, 2017 • National Harbor, Md.
www.emc2017.emcss.org

Metamaterials 2017
August 28–Sept. 2, 2017 • Marseille, France
www.congress2017.metamorphose-vi.org

RFIT 2017
August 30–Sept. 1, 2017 • Seoul, South Korea
www.rfit2017.org

SEPTEMBER

EDI CON USA 2017
September 11–13, 2017 • Boston, Mass.
www.ediconusa.com

IEEE AUTOTESTCON
September 11–14, 2017 • Schaumburg, Ill.
www.autotestcon.com

MWC Americas 2017
September 12–14, 2017 • San Francisco, Calif.
www.mwcamericas.com

OCTOBER

Satellite Innovation Symposium
October 2–3, 2017 • Silicon Valley, Calif.
www.satelliteinnovation.com

EuMW 2017
October 8–13, 2017 • Nuremberg, Germany
www.eumweek.com

AMTA 2017
October 15–20, 2017 • Atlanta, Ga.
www.amta2017.org

IEEE CSICS 2017
October 22–25, 2017 • Miami, Fla.
www.csics.org

MILCOM 2017
October 23–25, 2017 • Baltimore, Md.
www.milcom.org

ITC/USA Conference
October 23–26, 2017 • Las Vegas, Nev.
www.telemetry.org

IME/China 2017
October 25–27, 2017 • Shanghai, China
www.imwexpo.com

Space Tech Expo Europe 2017
October 24–26, 2017 • Bremen, Germany
www.spacetechexpo.eu

NOVEMBER

Global MilSatCom 2017
November 7–9, 2017 • London, U.K.
www.globalmilsatcom.com

IEEE COMCAS 2017
November 13–15, 2017 • Tel Aviv, Israel
www.comcas.org

IEEE APMC 2017
November 13–16, 2017 • Kuala Lumpur, Malaysia
www.apmc2017.org

90th ARFTG Conference
November 28–Dec. 1, 2017 • Boulder, Colo.
www.arftg.org/index.php

DECEMBER

IEDM 2017
December 4–6, 2017 • San Francisco, Calif.
www.ieee-iedm.org

ESC Silicon Valley
December 6–7, 2017 • San Jose, Calif.
www.escsiliconvalley.com/conference

IEEE IMaRC
December 11–13, 2017 • Ahmedabad, India
www.imarc-ieee.org

JANUARY 2018

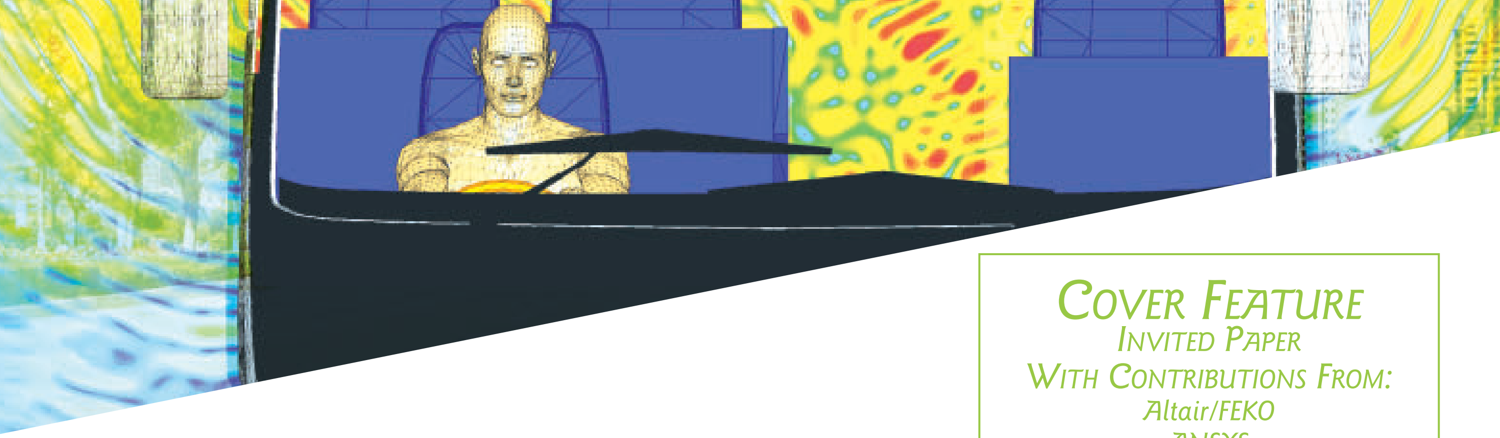
Radio and Wireless Week
January 14–17, 2018 • Anaheim, Calif.
www.radiowirelessweek.org

DesignCon
January 30–Feb.1, 2018 • Santa Clara, Calif.
www.designcon.com

FEBRUARY 2018

EMV 2018
February 20–22, 2018 • Duesseldorf, Germany
www.mesago.de/en/EMV/For_visitors/Welcome/index.htm

Mobile World Congress 2018
February 26–March 1, 2018 • Barcelona, Spain
www.mobileworldcongress.com



COVER FEATURE
INVITED PAPER
WITH CONTRIBUTIONS FROM:
Altair/FEKO
ANSYS
Computer Simulation Technology (CST)
Keysight Technologies
NI AWR

5 Leading EDA Tools for EMC/EMI Design Challenges

Editor's Note: *Microwave Journal* asked some of the leading electromagnetic compatibility (EMC)/electromagnetic interference (EMI) electronic design automation (EDA) software suppliers to provide a description of their features for EMC/EMI applications and unique solving capabilities for these markets.

Altair/FEKO
Stellenbosch, South Africa

FEKO assists original equipment manufacturers (OEM) and their suppliers across many industries to solve EMC problems related to design, analysis and validation. By using software applications such as FEKO, the number of prototypes and tests are reduced, which changes the development process from measurement-driven to simulation-driven. Key applications where FEKO is being used on EMC/EMI include emissions, immunity, lightning effects, high intensity radiated fields (HIRF), electromagnetic pulses (EMP), shielding, radiation hazard and antenna coupling, among others.

EMC SIMULATION

Antenna coupling in platforms is one of the sweet spots of FEKO (see ***Figure 1***). This aircraft geometry is part of the Computational Electromagnetics for EMC (CEMEMC) workshop and corresponds to a morphed version of EV55 (Intellectual Property of EVEKTOR, spol. s r.o. and the HIRF SE Consortium, HIRF-SE FP7 EU project). Depending on the problem and its electrical size and complexity, users just need to select one of the solvers in FEKO. One way to easily calculate antenna coupling in FEKO is through S-parameters, where users can see the effect of changing antenna loads without re-running the solver, easily visualize results for a large number of ports and plot a co-site interference matrix to visually identify and analyze critical couplings. In addition to this, model decomposition in FEKO works with equivalent antenna and EMC sources to reduce computational requirements.

EMI DESIGN CHALLENGES

There are multiple key use cases related to EMI being solved with FEKO. For example, coupling of radiated fields from cable harnesses to windscreen antennas (and to other types of antennas) in a vehicle, also related to CISPR-25 EMC standard (CISPR is the International Special Committee on Radio Interference or Comité International Spécial des Perturbations Radioélectriques) that sets industry test standards. There can be noisy signals propagating through different cables in the car and the radiation from such cables is coupled into different antennas, adding noise, thus reducing the performance of systems like ana-

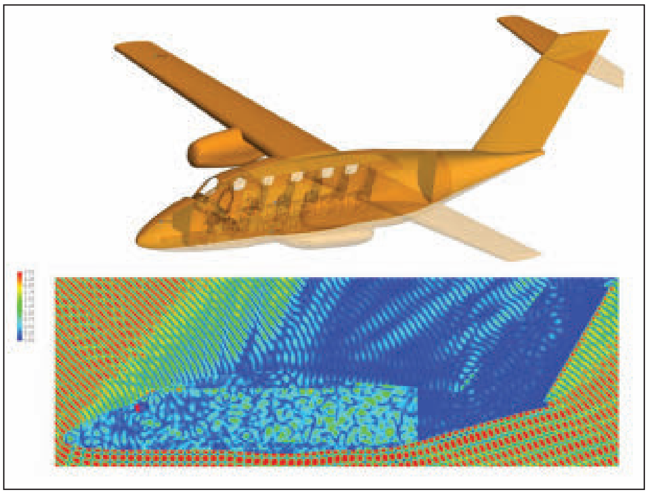


Fig. 1 Aircraft and magnetic field strength at 1 GHz computed by FEKO.

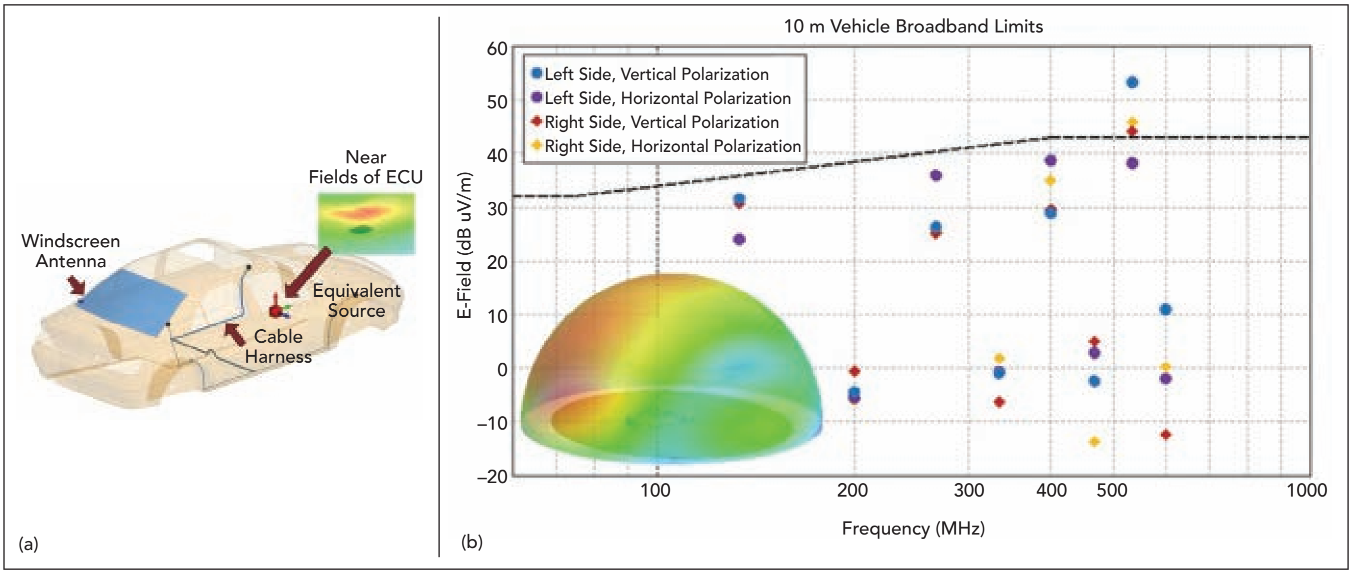


Fig. 2 Car model with windscreen antenna, cable harness and equivalent source for the engine control unit (ECU) (a) and simulated electric near fields including measurement setup (b).

log or digital radio. To address this, FEKO includes a complete integrated cable modeling tool that permits the analysis of the radiation (and irradiation) of cables. This tool, together with a windscreen antenna method specifically designed to model real windscreen antennas, permits one to analyze and find solutions related to these cases (see ***Figure 2***). In Figure 2b, fields at two points are simulated at 10 m, and for each point the vertical and horizontal polarizations are calculated.

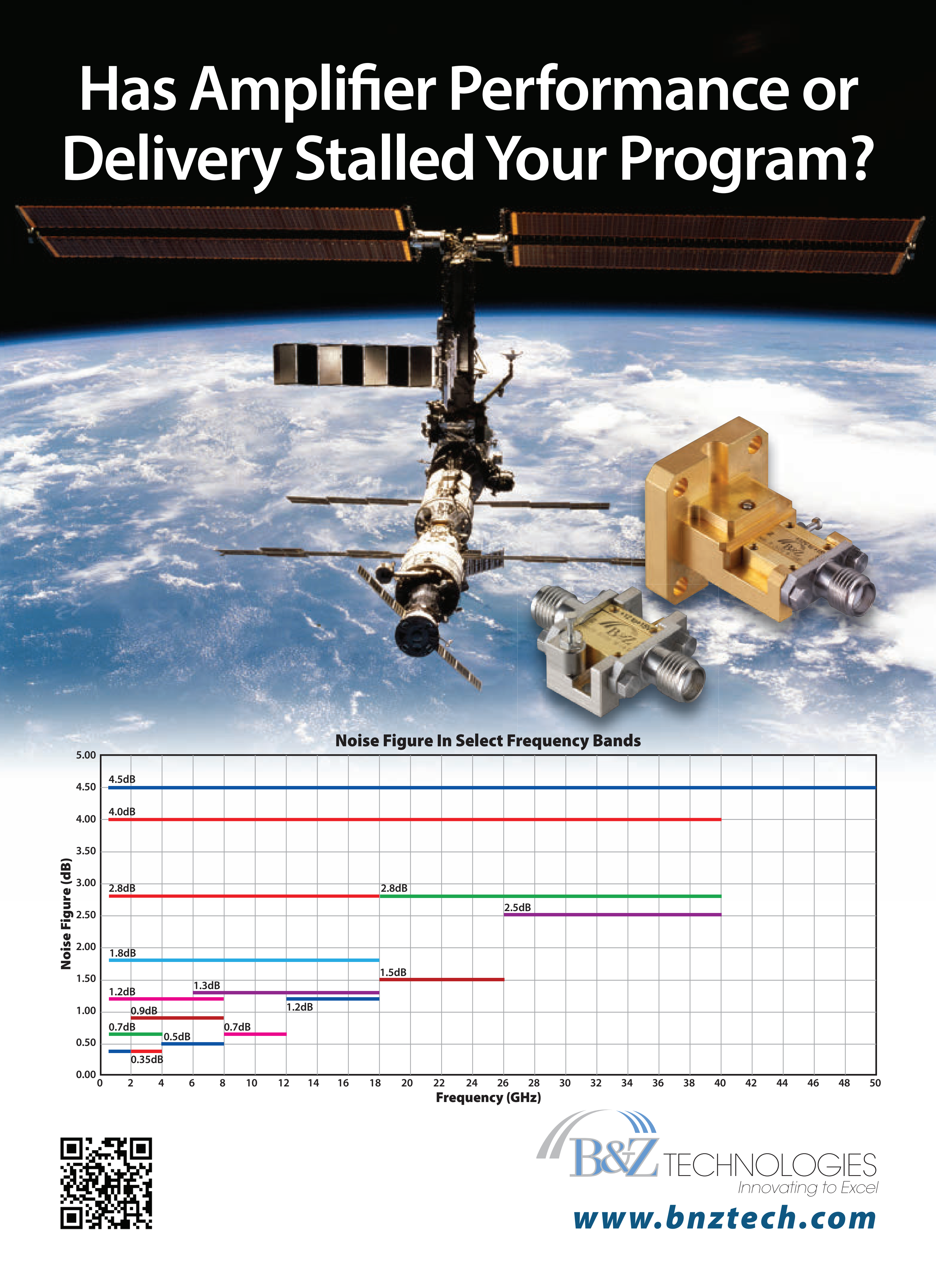
UNIQUE FEATURES

FEKO is easy to use and has a comprehensive, accurate, reliable and fully parallelized set of solvers with true hybridization, including Method of Moments (MoM),

Multilevel Fast Multipole Method (MLFMM), Finite Element Method (FEM), Finite Difference Time Domain (FDTD), Physical Optics/Large Element-Physical Optics (PO/LE-PO), Ray-Launching Geometrical Optics (RL-GO) and Uniform Theory of Diffraction (UTD). These solvers are widely used to solve antenna design and placement, EMC, radar cross-section (RCS), bio-electromagnetics, radomes and RF devices problems, among others. Depending on the electrical size and complexity of the problem, one solver or another just needs to be used. FEKO's integrated cable modelling tool addresses EMC problems involving complex cables. Two special methods in FEKO for cables are Multi-Conductor Transmission Line (MTL) and the combined MoM/MTL, which is used for real problems where ground planes below the cables are not continuous. FEKO, as part of Altair HyperWorks Computer Aided Engineering (CAE) platform, brings a set of additional and differential capabilities that can be leveraged at no extra cost due to Altair's unique licensing system. Very complex Computer Aided Design (CAD) models can be cleaned-up and meshed in less time (including automation) thanks to HyperMesh, a leading finite element analysis preprocessor. With HyperStudy, FEKO users can perform design of experiments to further optimize designs, including other physics analysis, and with activate electrical circuits, like DC/DC converters, can be analyzed and designed.

ANSYS
Canonsburg, Pa.

The problem of RF interference between co-located platform integrated radios can be difficult to manage. With continued integration into the IoT infrastructure, modern commercial electronic devices are becoming ever more complex and feature rich with increasing wireless capability. This dense wireless capability has resulted in an exponential growth of the radio frequency interference (RFI) problem throughout the electronics industry. Examples of radio environments are a single structure such as an airplane, satellite, wireless electronic device or multiple radios in a more dispersed environment, such as many wireless devices within an office setting or at outdoor cell communications sites. These multiple, multi-band RF systems need to coexist peacefully and "play well" together and not degrade the performance of the other systems in the environment. And the problem of interference is not limited to explicit radio channels. Electronic devices are composed of both RF and digital signals and components which can share a common ground plane or reference. The digital signals alone, although typically operating at clock frequencies be-


Has Amplifier Performance or
Delivery Stalled Your Program?
Noise Figure In Select Frequency Bands
Noise Figure (dB)
Frequency (GHz)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
4.5dB
4.0dB
2.8dB
2.8dB
2.5dB
1.8dB
1.5dB
1.3dB
1.2dB
1.2dB
0.9dB
0.7dB
0.7dB
0.5dB
0.35dB
B&Z TECHNOLOGIES
Innovating to Excel
www.bnztech.com

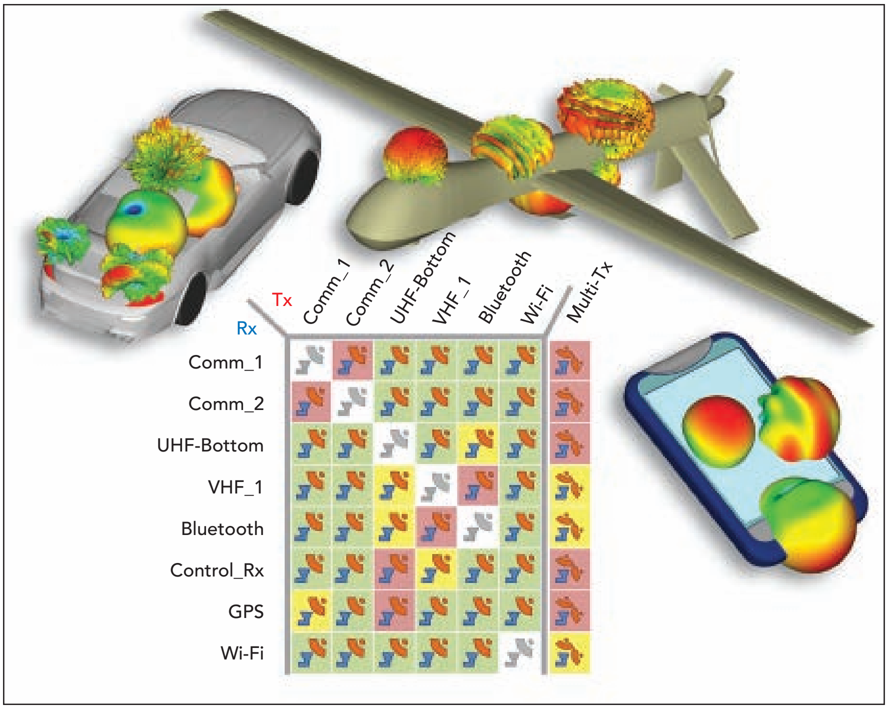


Fig. 3 Examples of multi-radio and radio-digital systems that can be analyzed with ANSYS EMIT.

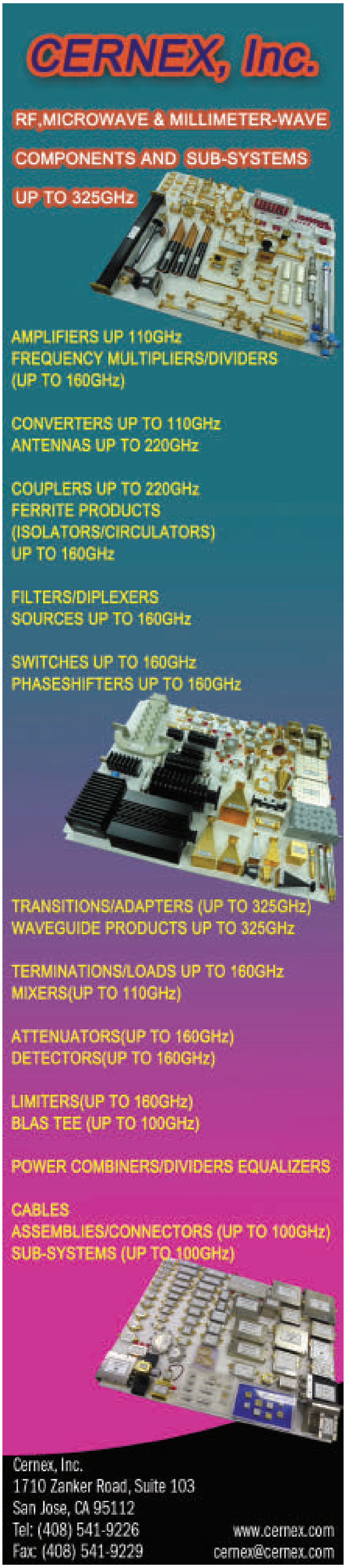
low the radio frequencies, can contain harmonics that interfere with the radio channels through their common reference geometry. This latter, RF-digital interference is commonly referred to as de-sense, and is one of the more difficult design challenges in wireless electronic devices since it requires a complete system understanding to predict and/or detect (see ***Figure 3***).

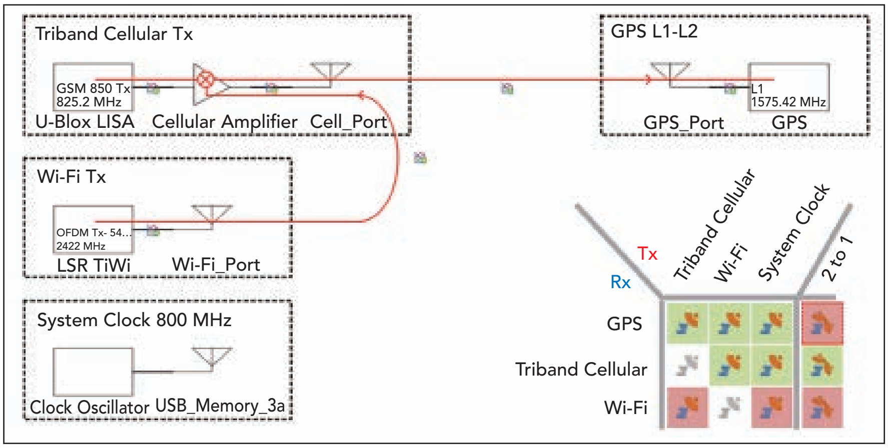
ANSYS EMIT FOR EMI ANALYSIS

ANSYS EMIT is an industry leading software for the simulation of RFI in complex environments. EMIT works together with ANSYS HFSS and HFSS SBR+, formerly Delcross Savant, to combine RF system interference analysis with best-in-class electromagnetic simulation for modeling installed antenna-to-antenna and radio-to-radio coupling. This solution reliably predicts the effects of RFI in multi-antenna environments with multiple transmitters and receivers. EMIT's analysis engine computes important RF interactions, including nonlinear system component effects. Diagnosing RFI in complex environments is notoriously difficult and expensive to perform in a testing environment. To address this challenge, EMIT provides a dynamically linked result view to aid in the identification of the root-cause of interference via graphical signal trace-back and diagnostic summaries. These summaries show the origin and paths of transmit-to-receiver interfering signals (see ***Figure 4***).

With the cause of interference uncovered, EMIT enables rapid evaluation of various RFI mitigation measures to arrive at an optimum solution. Including accurate physical effects associated with electromagnetic coupling will improve the fidelity and reliability of the RF system simulation. An HFSS/EMIT datalink allows the model for RFI analysis to be created in EMIT directly from the physical 3D model of the installed antennas in HFSS, providing a seamless end-to-end workflow for a complete RFI solution of systems and environments ranging from large platform co-site interference to receiver de-sense in compact electronic devices.

ANSYS EMIT in the ANSYS RF Option provides a software framework for managing system performance data including a library of RF systems, a computational engine for simulating RFI effects in complex multi-system environments, a dynamic analysis tool for





▲ **Fig. 4** Interaction diagram and scenario matrix from EMIT, used to reconstruct interference paths and identify root causes for EMI.

rapid automatic identification of the root-cause of RFI problems and allows engineers to quickly evaluate different "what-if" analyses to resolve EMI issues.

Computer Simulation Technology (CST)
Darmstadt, Germany

EMC CHALLENGES

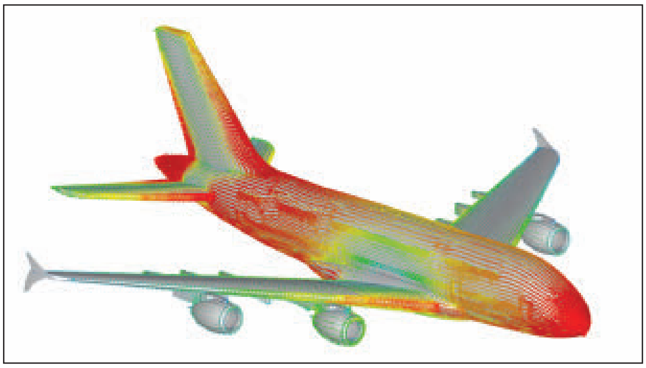
CST EMC STUDIO is an EM simulation tool used by industry leaders to analyze and optimize products for performance and compliance with EMC norms. The CST "Complete Technology" approach means that CST EMC STUDIO includes a range of solvers for many different scenarios, from general purpose time and frequency domain solvers to specialized solvers for cables and printed electronics. These solvers are all included in one interface, allowing for a uniquely integrated workflow.

Both CAD data and printed circuit board (PCB) layouts from EDA tools can be imported into CST EMC STUDIO. Specialized PCB simulation tools can quickly calculate signal integrity and power integrity (SI/PI) and identify violations of EMC design rules, while the general purpose 3D solvers can simulate radiated and conducted emissions/susceptibility in detail. Fields and currents on the 3D structure, including the attached circuits, can be visualized to help engineers identify coupling paths.

EMI CHALLENGES

Immunity to emissions and environmental electromagnetic effects (E3) such as lightning is an important application (see ***Figure 5***). The Transmission Line Matrix (TLM) Solver is especially well suited to these applications, and can simulate very large structures effectively. It supports octree meshing and compact models of seams, vents, composite materials and other relevant features, which can further accelerate simulations while maintaining accuracy, and also offers bi-directional coupling to CST CABLE STUDIO for simulating how fields couple into and propagate through cables and cable harnesses.

Another major application of CST EMC STUDIO is antenna coupling.

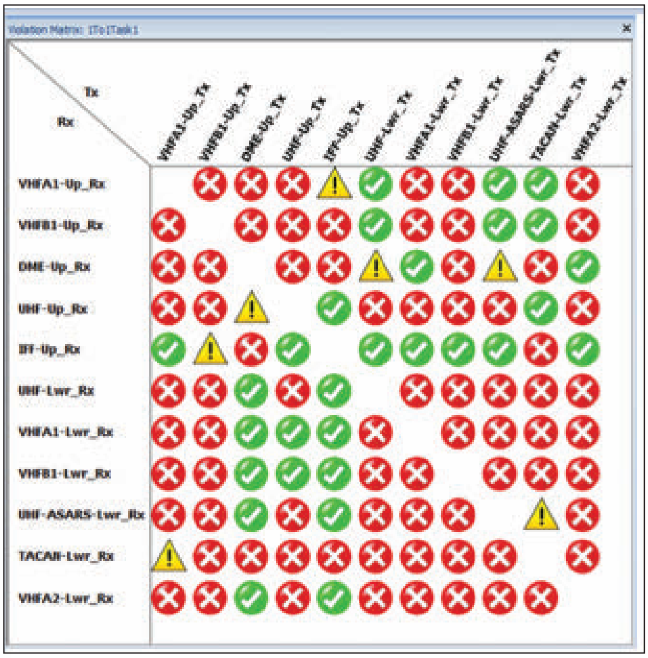


▲ **Fig. 5** Surface currents on an aircraft during a lightning strike.


NATIONAL INSTRUMENTS
SMART DEVICES REQUIRE
SMARTER
AUTOMATED TEST SYSTEMS
The old approach to automated test isn't scaling, but you already knew that. Look at your balance sheet. To test smart devices, you need a smarter test system built on a platform of NI PXI, LabVIEW, and TestStand. More than 35,000 companies deploy NI technology to lower their cost of test. What are you waiting for?
Prepare for the future at ni.com/smarter-test.
©2017 National Instruments. All rights reserved. LabVIEW, National Instruments, NI, ni.com, and NI TestStand are trademarks of National Instruments. Other product and company names listed are trademarks or trade names of their respective companies. 29911

In a typical antenna-to-antenna scenario, the antennas may be installed on extremely large platforms such as aircraft, ships or buildings, but the coupling itself can depend on fine details such as the exact design of the antenna or the seams, vents and cables in the platform. CST EMC STUDIO supports a hybrid approach where the antennas can be simulated in detail with a suitable solver such as the Time Domain Solver, and then used as field source for a coupling simulation with a different solver such as the Integral Equation Solver, TLM Solver or Asymptotic Solver. Combining solvers in this way gives engineers the best of both and can significantly speed up simulation times.

As well as calculating the coupling between subsystems, such as antennas on a platform or channels on a PCB, a co-site interference analysis also involves taking into account the frequency spectra of each subsystem. The Interference Task, new in CST EMC STUDIO 2017, offers a straightforward approach for investigating potential EMI issues using coupling data from simulations combined with information about each Rx/Tx system (see ***Figure 6***). Using this, the Interference Task produces a violation matrix highlighting combinations that could potentially lead to EMI issues.



▲ **Fig. 6** The Interference Task shows which combinations of RF systems can lead to co-site interference.

This is a very effective way to identify EMI problems and test mitigation approaches on a virtual prototype.

Keysight Technologies
Santa Rosa, Calif.

EMI and EMC are not new issues for system engineers. However, with increasing data rates in computers, networks, storage and mobile devices, design engineers are more challenged to deal with not only the traditional emission issues, but also coupling issues with nearby circuit and system components. Overcoming these challenges using appropriate design tools is essential to successful system design.

RF DE-SENSE OR RFI ISSUES

One of the issues designers face when it comes to EMC and EMI is interference between subsystems and antennas. It is an especially severe problem in mobile devices, where designs are squeezed into very small areas. The interference can cause degradation in receiver sensitivity, also known as "RF de-sense" or "RFI" issues. For example, high-speed application processors, memories, camera modules, DC-DC power converters and high-speed interconnects, like USB 3.1 Type C, may cause "self-jamming" issues with RF circuits that include multi-band antennas (see ***Figure 7***).

INTEGRATED CIRCUIT AND EM SIMULATION IS NECESSARY

Diagnosing RF de-sense and self-jamming issues presents a real challenge for today's designers. They

Rackmount

Bench-Top

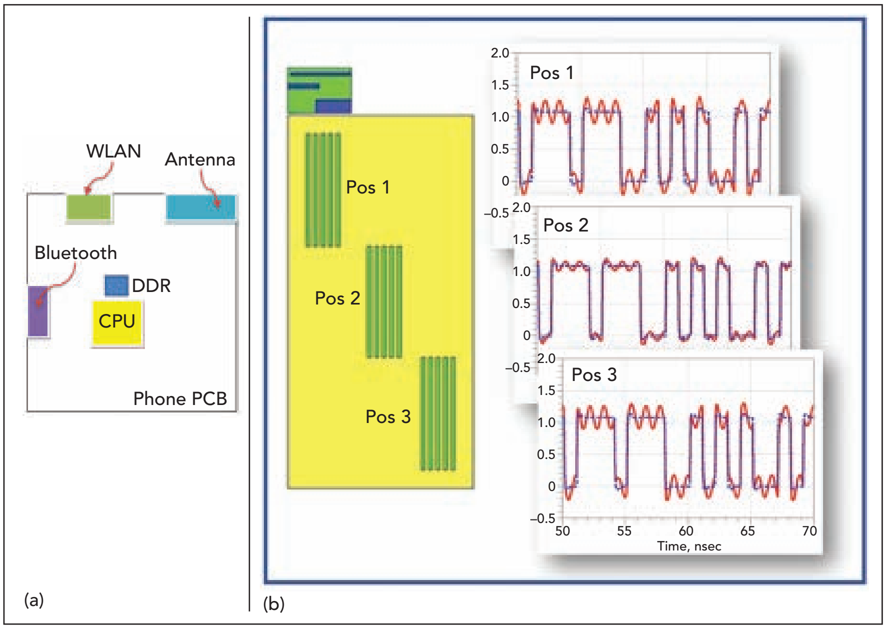
OEM

Multi Channel Phase Coherent RF/Microwave Signal Generators and Synthesizers. Best in class performance, size, cost, and reliability

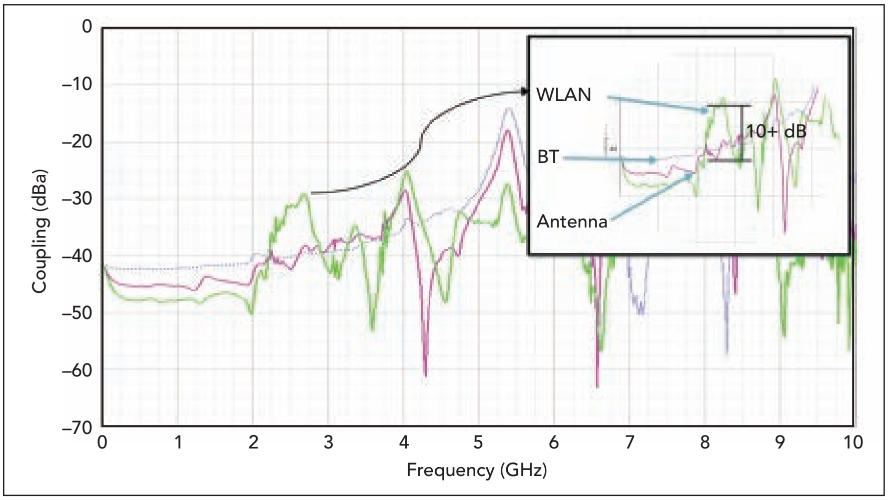
- •Extremely low phase noise performance
- •Frequency range from 10Mhz to 20GHz
- •Very fast switching speed to 10us
- •Multi-Channel phase coherent system from 2 to 8 Independent outputs
- •Very small form factor at 1U 19" rackmount
- •Rich library of API's
- •OEM options for direct integration

BNC

Berkeley Nucleonics Corp., 2955 Kerner Blvd. San Rafael CA 94901
Email RFsales@berkeleynucleonics.com, Call 800-234-7858 or LIVE-Chat @ www.berkeleynucleonics.com



▲ Fig. 7 Example of a mobile device layout (a) and self-jamming vs. locations of the digital interface on the PCB (b).



▲ Fig. 8 Cellular, WLAN and Bluetooth antenna coupling in a mobile phone.

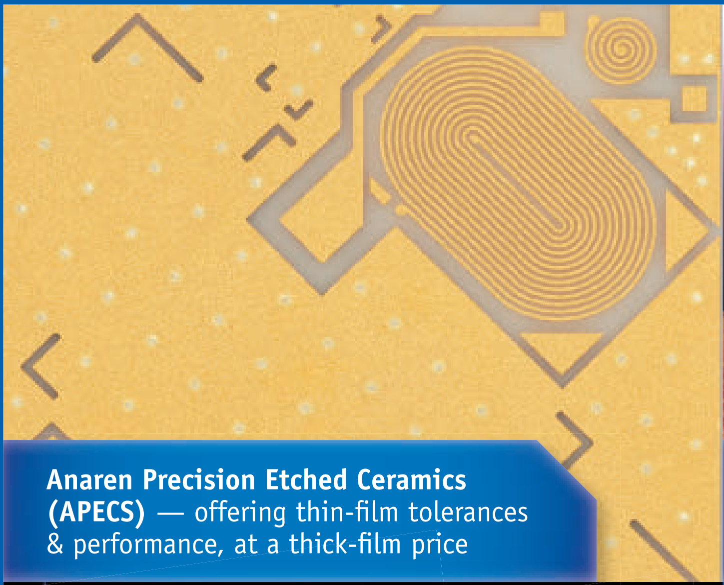
must model EM field interactions within devices using EM solvers and be able to handle digital waveforms from circuit- and system-level design tools. For these tasks, a design environment that integrates both circuits and EM is a must. Keysight's Advanced Design System (ADS) and EMPro provide a uniquely integrated software design platform that offers a solution.

ANTENNA-TO-ANTENNA COUPLING ISSUES

With many antennas crammed into a very small piece of real estate, the coupling between antennas can become quite problematic (see ***Figure 8***). This type of coupling may or may not be as significant if designers use different frequency bands. Designers can also employ the use of bandpass or band-rejection filters, which may reduce unwanted energy coupling. Careful design of the whole device is required, including co-design of the on-board antennas with the ground plane.

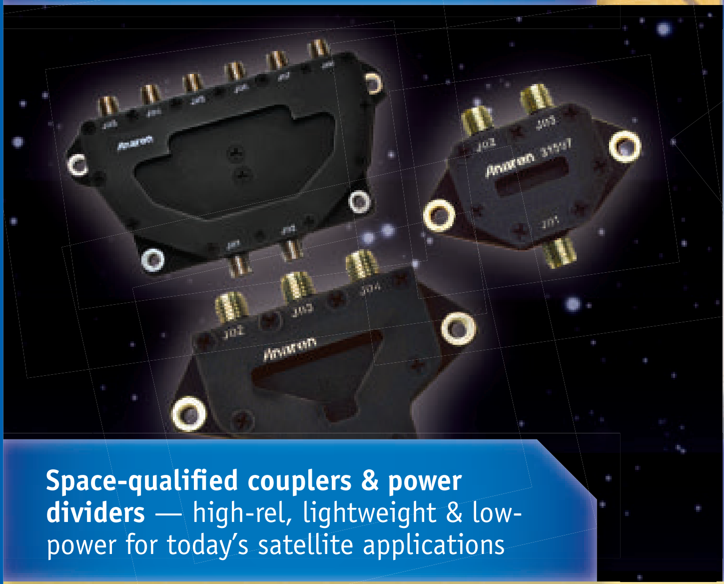
Since antenna-to-antenna coupling is mostly a near field problem, it can be accurately handled with traditional EM simulation technologies such FEM, MoM or FDTD engines. The coupling problem may be mitigated by adjusting the position of the antennas and/or tweaking the antenna performance, such as gain versus frequency or radiation patterns.

With Keysight design tools, designers can simulate the radiated



Anaren Precision Etched Ceramics (APECS) — offering thin-film tolerances & performance, at a thick-film price

Space/Mil-grade Xinger® couplers — proven in Mars missions & ready for tough terrestrial settings, too



Space-qualified couplers & power dividers — high-rel, lightweight & low-power for today's satellite applications

RF solutions for next-gen AESAs — including manifolds, T/R modules & beam-formers for air, sea, and land platforms emissions of electronic circuits and components, determine whether these emissions are within levels specified by common standards, such as FCC Part 15, CISPR 22 and MIL-STD-461F, and whether they are compliant—all before hardware has been developed.

In addition to verifying EMI compliances, it is critical to have the correct noise waveform injected for an accurate calculation of emission level. Keysight tools offer designers access to many different waveforms, whether standard waveforms, user-defined or measured waveforms.

INTEGRATION IS KEY

As data rates continue to increase, system designers will likely face even greater EMI and EMC design challenges. Using the right design tools that offer integrated circuit and EM simulation are essential. Keysight's design tools not only offer that level of integration, but are designed to handle a range of design issues, making them ideal for helping system engineers overcome the EMC and EMI design challenges they face today and in the future.

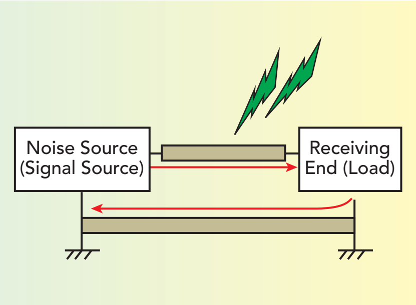
NI AWR
El Segundo, Calif.

Addressing EMC/EMI performance is an integral part of product development, especially when electronics are densely packed, causing high-frequency signals and fast transients to give rise to either radiated or conducted (transmission) emissions with the potential to adversely affect each other. NI AWR Design Environment, an open design platform for high-frequency circuit and system product development, addresses these concerns with integrated design tools that incorporate planar and arbitrary 3D EM analysis directly within circuit- and system-level design and simulation. The analysis capabilities offered through integrated circuit, system and EM co-simulation are illustrated with the following two examples in which the capabilities in NI AWR software were leveraged to overcome several EMC/EMI design challenges.

MITSUBISHI EXAMPLE

Designers at the Mitsubishi Electric Corporation used NI AWR Design Environment to tackle their EMC/EMI design challenges and improve the sound quality of the company's DIATONE car audio system. The design team used Microwave Office circuit design software and AXIEM planar EM analysis software to perform a rigorous EMC noise analysis of the navigation system's circuit board design, including identification of the noise source through analysis of the transmission path and the radiation noise.

The designers considered the overall system, which included an emission source (emitter) and susceptible receptors within a given environment. EMI comes from EM waves that are generated by the in-



▲ Fig. 9 EMC radiation noise analysis model.

tegrated circuit. Modeling the high-frequency noise comprised three basic components: noise source, transmission path and radiation end, as shown in ***Figure 9***.

In this model, the audio board was designed using a two-board configuration of a power supply board and a main board containing a microcontroller, digital signal processor and digital-to-analog converter. The designers developed an accurate model of the noise source as verified through measurements in a test system. This model was then used in conjunction with EM simulations of possible board geometries to investigate how to mitigate EM problems (see ***Figure 10***). The improvement in anti-noise measures combined with a significant reduction in the number of trials resulted in a dramatic reduction in overall trial cost while still maintaining sound quality.

The tight coupling of Microwave Office and AXIEM accelerated the design process tremendously. EMC noise analysis of the transmission noise components revealed a return path that resulted in a degradation of the audio system sound quality. Hot spots were quickly identified with AXIEM's current view; changes to components could then be quickly implemented in Microwave Office, which in turn coupled back into AXIEM results, as shown in ***Figure 11***. Through EMC noise analysis, the trial cost was reduced by at least 60 percent, the parts cost was reduced by at least 30 percent, the labor cost was reduced by at least 60 percent and the utility cost was reduced by at least 50 percent.

RF MICROTECH EXAMPLE

Another EMI/EMC design challenge was successfully addressed by RF Microtech using NI AWR Design Environment in the design of a very large and complex ultra-wideband (UWB) filter for use in preventing mobile service bands from interfering with a critical security control base station at Expo Milano 2015. This type of problem differs from the first example, in that the designers were asked to develop a high-performance filter from interfering signals with known characteristics. The challenge was to develop this filter in less than a month.

RF Microtech was challenged to provide a validated full-wave EM simulation of a two-port UWB filter that could reject all five mobile service bands with greater than 35 dB. The validated EM simulation had to be delivered within two weeks and the complete deployable device by the time the expo opened. The design team used Microwave Office to develop a circuit model of five inde-

pendent notched-band filters (NBF) cascaded along a transmission line (see ***Figure 12***).

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.

These two use cases have illustrated how EMC/EMI performance issues were overcome with the use of NI AWR Design Environment integrated circuit and EM design tools that enabled both design teams to dramatically cut design cycles and costs and deliver high quality solutions on time.■

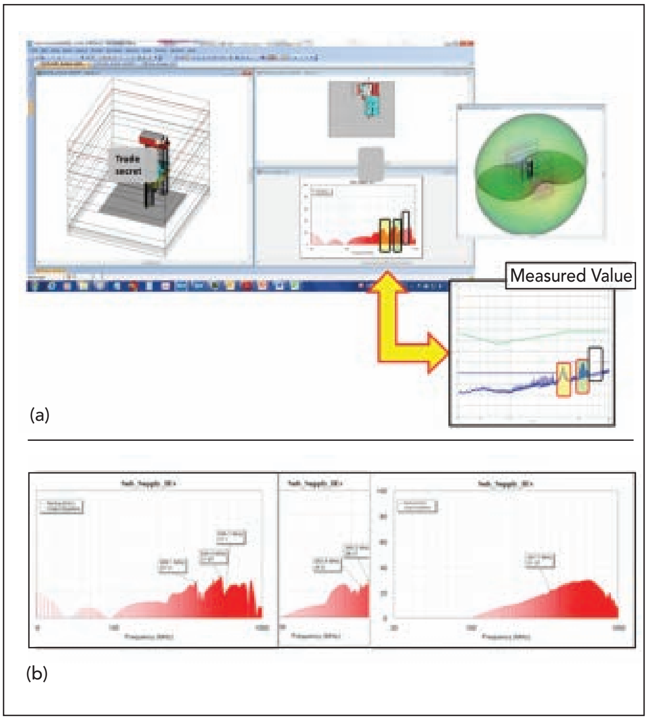


Fig. 10 EMC radiation noise analysis model (a) and elimination of resonances after anti-noise measures were implemented in the design (b).

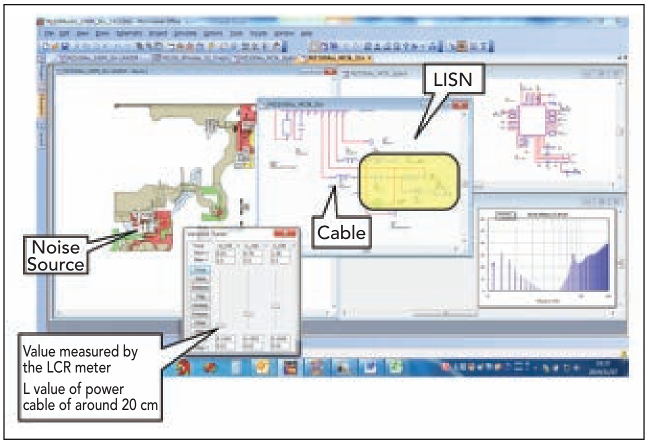


Fig. 11 Integration of circuit analysis with EM modeling speeds problem identification and resolution.

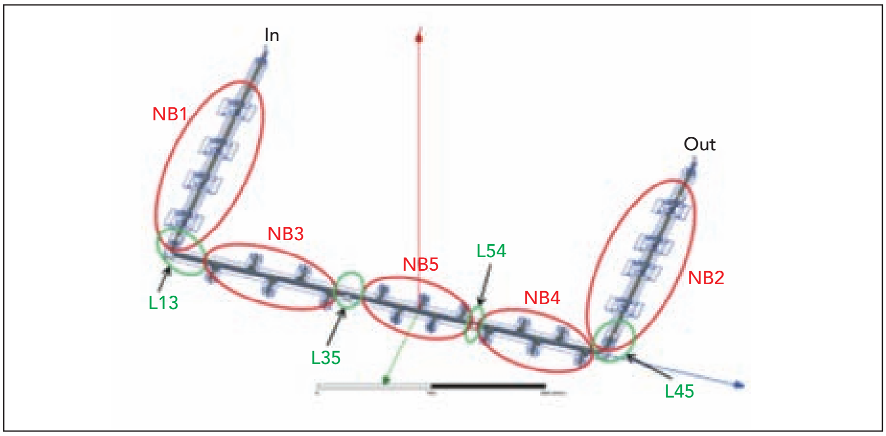


Fig. 12 Circuit model of notched-band filter.

Missile Defense Agency: BMD System "Ready to Defend the Homeland Today"

The recent successful test of part of the nation's ballistic missile defense (BMD) system shows that the U.S. can defend itself against the threat of ballistic missile launches from North Korea or Iran, according to the director of the Missile Defense Agency (MDA). Navy Vice Adm. James D. Syring, speaking to members of the press from Schriever Air Force Base, Colo., said the test replicated an operational scenario that concerns the military and represents a critical program milestone. "I was confident before the test that we had the capability to defeat any threat that [North Korea or Iran] would throw at us," Syring told reporters, "and I'm even more confident, after seeing the intercept test, that we continue to be on that course."

Ground-Based Midcourse Defense

The BMD System can target an incoming ballistic missile at three points in its trajectory. These are the boost phase, from launch through ascent, one to five minutes; the midcourse phase, when the missile booster burns out and the missile coasts in space toward its target, up to 20 minutes; and the terminal phase, a brief period when the missile reenters the atmosphere, according to the MDA website. This most recent test involved the midcourse phase and was the system's first live-fire event, matching a ground-based interceptor carrying an exo-atmospheric kill vehicle (EKV) against an intercontinental ballistic missile (ICBM)-class threat designed to replicate something from North Korea or Iran, Syring said.

Intercerpter Launch (DoD photo by Senior Airman Robert J. Volio)

During the test, the target ICBM launched from the Reagan Test Site on Kwajalein Atoll in the Marshall Islands. Sensors fed target acquisition and tracking data to the command, control, battle management and communication system. The Sea-Based X-Band radar positioned in the Pacific Ocean also acquired and tracked the target.

The ground-based missile defense (GMD) system received the target tracking data and developed a fire-control solution to intercept the target. Then a ground-based interceptor—a multistage solid-fuel booster—launched from Vandenberg Air Force Base in Calif., carried the EKV toward the target ICBM's location in space. The interceptor released the kill vehicle, which used guidance data transmitted from ground and onboard sensors to collide with and destroy the target warhead. The interceptor tested is the same configuration that will complete the fielding of 44 total interceptors by the end of 2017, the admiral said.

Challenging Mission

Syring said that though this was a developmental test, the scenario is the same as one they would expect to occur during an actual operational engagement. BMD is an incredible challenge, the admiral explained. The defending missile must intercept a missile that can travel thousands of miles per hour, in this case, outside the Earth's atmosphere. "Yesterday's test did demonstrate that the system continues to improve and mature, and it is ready to defend the homeland today."

The next test, to take place in the fall or later in the 2018 calendar year, will involve one target and two interceptors/kill vehicles, the next step in ever-increasing operational realism. The program plan for testing adversary ICBM salvos is scheduled for the 2023 time frame.

DARPA Technology to Improve UAS Adaptability and Mission Efficiency

Today, unmanned aerial systems (UAS) typically require multiple payloads with dedicated components, including antennas, RF circuitry and processors, to conduct communications, radar and electronic warfare (EW) missions. These single-function payloads cannot be installed on a compact UAS at the same time because of the size, weight and power (SWaP) constraints of these platforms, limiting what they can do without swapping payloads on the ground—a process that seriously hinders mission efficiency.

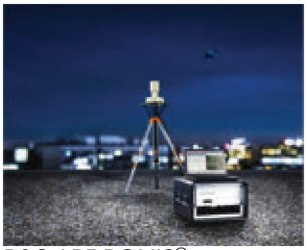
Under two recently awarded contracts from DARPA worth a combined $5.4 million, BAE Systems is developing technology that will enable compact UAS to conduct multiple mission tasks with single, multifunction payloads that can adapt to changing battlefield situations and mission needs in real-time.

DARPA's program, called CONverged Collaborative Elements for RF Task Operations or CONCERTO, focuses on supporting communications, radar and EW systems with a flexible RF architecture that uses shared common hardware, enabling multifunction systems that meet the low-SWaP requirements of compact UAS. The converged systems will be able to efficiently switch between intelligence, surveillance and reconnaissance; command and control; networking and combat operations support missions without physical payload changes.

Protection Against Drones

Drones pose a serious security risk at major public events and also to high-risk infrastructures and facilities such as airports, industrial

For More Information Visit mwjournal.com for more defense news.



R&S ARDRONIS© Rohde & Schwarz

test sites, large plants, military sites and correctional facilities, especially in light of the fact that sales are booming and anyone can use them.

With this in mind, ESG Elektroniksystem und Logistik-GmbH, Diehl Defence and Rohde & Schwarz signed a cooperative agreement in the area of drone defense. Building on experience gained through their successful cooperation during both the 2015 G7 Summit in Elmau and the U.S. presidential trip to Hanover in 2016, the companies seek to coordinate their efforts even more closely and provide fully customized, bundled solutions based on their proven expertise in the fields of radar, radiomonitoring, electromagnetic countermeasures, command and control information systems and position mapping.

The GUARDION drone defense system combines the scalable solutions customized to very specific customer requirements to reliably detect and defend against threats posed by the unauthorized use of drones. GUARDION focuses on integrating electronic detection, verification and countermeasures and connecting them to a position mapping and command and control tool. The HPEMcounterUAS effectors from Diehl Defence, R&S ARDRONIS from Rohde & Schwarz and the TARANIS command and control and position mapping system developed by ESG have proven their capabilities in operational use.

"Such deployment scenarios as well as experience gained elsewhere have confirmed our opinion that multiple intermeshed measures must be employed to ensure reliable protection against drones," stated Christoph Weber, head of Defence & Public Security at ESG, on behalf of the cooperation partners.

Dietmar Vahldiek, executive vice president Monitoring and Network Testing at Rohde & Schwarz, adds: "For many customers, it is important to receive early warning of potential threats. Detecting radio signals from remote control units therefore plays a key role. Security forces can respond even before the drone is in the air."

The trend toward increasingly intelligent drones also requires an effector that civil forces can use against autonomously flown systems, i.e. systems that are not dependent on radio signals or GPS for navigation. A significant countermeasure component in GUARDION is therefore the HPEMcounterUAS from Diehl. "Today, reliable protection against small airborne vehicles must function against both radio-controlled and autonomously flown objects," added Helmut Rauch, managing director at Diehl Defence.

The 2017 Defence, Security and Space Forum

At European Microwave Week

EuMA | Microwave Journal

Wednesday, 11 October – Nürnberg Convention Center – Room St. Petersburg

A focused Forum addressing the application of RF and microwave technology to The Internet of Space.

Vast areas of the globe are without sufficient Internet connectivity. Commercial and societal progress as well as safety and security are linked to access to the information superhighway, while military missions require reliable and secure data communication pathways. This one-day Forum highlights **The Internet of Space – Technologies and Applications**, a new class of satellite communication services being developed to address these needs.

Programme:

08:30 – 10:10 EuRAD Opening Session

10:50 – 12:30 The Internet of Space – Technologies and Applications

Two keynote speakers from the industry will present their view on key applications and the related technologies needed for the realisation of the **Internet of Space**. The presentations will cover commercial as well as military applications.

- The World's Largest Satellite Constellation 'OneWeb' – Redefining Satellite Communications
  Wolfgang Duerr, Airbus DS Inc.
- The Connections are Key: The Implications of the Internet of Things on Military Technology – *Joe Mariani, Deloitte*

12:40 - 13:40 Strategy Analytics Lunch & Learn Session

This session adds a further dimension to the topics by offering a market analytics perspective, illustrating the status, development and potential of the market for the **Internet of Space**.

14:20 – 16:00 *Microwave Journal* Industry Panel Session

This session offers an industrial perspective on the key issues to be addressed in the defence, security and space sector. In accordance with this year's Defence, Security and Space theme the panel will investigate the opportunities for applications of the **Internet of Space** as well as address the technological challenges. The presentations are:

- *The Internet of Space – Technologies and Applications – Mark Lombardi, Keysight Technologies*
- *Internet of Space, Past, Present, & Future – Timothy Boles, MACOM*
- *Leveraging Technology to Develop Solutions for IoT to the IoS – Roger Hall, Qorvo*
- *New Approaches in End-To-End Payload Testing – Yassen Mikhailov, Rohde & Schwarz*

16:10 - 17:50 Defence, Security & Space Executive Forum

High level speakers from leading Defence and Space companies present their views and experiences on the upcoming technologies and applications in the civil and military domains. They will be complemented by speakers from a government agency, consulting company and a start-up, who will offer their views on research needs, trends and New Space opportunities and challenges. Speakers at the Forum will include:

- *Erich Auer, TeSat SpaceCom*
- *Wolfgang Duerr, Airbus DS Inc.*
- *Matthias Spott, eightyLEO*
- *Joe Mariani, Deloitte*
- *Siegfried Voigt, DLR*

Register online at www.eumweek.com

A PRIME YEAR FOR A PRIME EVENT

17:50 - 18:30 Cocktail Reception

The opportunity to network and discuss the issues raised throughout the Forum in an informal setting.

Registration and Programme Updates

Registration fees are €20 for those who registered for a conference and €60 for those not registered for a conference

As information is formalized, the Conference Special Events section of the EuMW website will be updated on a regular basis.

Sponsors:

KEYSIGHT TECHNOLOGIES | MACOM Partners from RF to Light | qorvo all around you | ROHDE&SCHWARZ

Infineon Launches Productive4.0 Research Project

Productive4.0, the largest European research initiative to date in the field of Industry 4.0, has been launched by Infineon Technologies. Working with more than 100 partners from 19 European countries, Infineon Technologies will coordinate work on digitizing and networking industry.

"Real-time connected value chains will dramatically increase agility in development and production. They will thus help shorten time to market," said Dr. Reinhard Ploss, CEO of Infineon Technologies. "Microelectronics is a key enabler for further digitization of the manufacturing industry and for an optimized and integrated supply chain management. With its high level of automation, our industry can serve as a blueprint showing how to secure important parts of the value chain and qualified jobs in Europe. We now want to share our know-how with other industrial sectors."

> "...our industry can serve as a blueprint..."

Europe and, in particular, Germany have special strengths in the field of microelectronics in automotive, energy, safety and industrial electronics. *Productive4.0* is part of the Electronic Components and Systems for European Leadership (ECSEL), the European funding program for microelectronics. Its aim is to strengthen expertise in microelectronics with a view to broad digitization. Thirty partners from Germany and a further 79 participants will work together for three years on the €106 million project. The EU and the participating Member States are funding the project as part of ECSEL with around €51 million. The Free State of Saxony and the German Federal Ministry of Education and Research (BMBF) will jointly contribute €9.6 million to the project.

The aim is to create a user platform across value chains and industries that especially promotes the digital networking of manufacturing companies, production machines and products. The participating partners will examine methods, concepts and technologies for service-oriented architecture as well as for components and infrastructure in the Internet of Things. The *Productive4.0* project will run until 30 April 2020.

Dr. Max Lemke, representing the European Commission, summed up the project from a European viewpoint: "*Productive4.0* is one of the first Lighthouse projects funded under the ECSEL Joint Undertaking. The platform approach and the collaboration across value chains and sectors, which is strongly promoted in the Digitising European Industry strategy of the European Commission, promises sustainable impact on the collaboration between and across companies in production and beyond."

u-blox, Commsignia and NXP Collaborate to Drive V2X

U-blox, Commsignia Inc. and NXP Semiconductors are collaborating to address the rapidly growing demand for reliable Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) technology.

The adoption of V2X technology in North America and European markets equips new vehicles with the ability to securely and anonymously share information with other similarly equipped vehicles, infrastructure and even pedestrians within a radius of up to 1 km. V2X information will augment the awareness of drivers to improve safety, reduce congestion and emissions, thereby delivering real savings and benefits to all road users today and in the future for self-driving autonomous vehicles.

This collaboration builds on the strengths of all three companies to deliver substantial time-to-market advantages and benefits to automotive customers, with future-proof solutions that optimise investments and mitigate risks. Automotive manufacturers are looking for ways to bring V2X to market now, ramping up to 100 percent implementation in new cars within the next five years. This collaboration between three of the market leaders will accelerate the adoption of V2X technology thanks to the availability of fully integrated hardware and software solutions in a fully-fledged and secure (US DOT SCMS compliant) V2X system.

V2X is the only ADAS technology that operates in real-time, lowest latency and sees around corners, facilitating self-driving autonomous vehicles. V2X, IEEE 802.11p based, is complementary to 5G versions of V2X and both technologies are expected to co-exist for the foreseeable future.

ITU Council Assesses Results and Shapes Future Course

The International Telecommunication Union's (ITU) governing Council met in Geneva in May 2017 to review progress and to chart future developments. Chaired by Eva Spina, director general for Planning and Management of Spectrum, at Italy's Ministry of Economic Development, the Council was attended by over 380 delegates, representing a total of 84 Member States (48 Member States of Council and 36 Observer Member States), including several ministers, vice-ministers and ambassadors.

In his State of the Union Address, ITU Secretary-General Houlin Zhao noted the advances that have been made over the past year, saying, "We've seen tremendous progress in the area of information and communication technologies in recent years. More

For More Information Visit mwjournal.com for more international news.

> "…an important moment of transition…"

people are connected. Technologies such as broadband and 4G services have been deployed. E-commerce, e-health, e-money and many more electronic services have reached more and more people around the world. I am pleased to see that the role of ICTs in helping to achieve the Sustainable Development Goals is gaining wide recognition."

In her opening remarks, Spina commented, "We are on the eve of the 2018 Plenipotentiary Conference, in an important moment of transition, in which to make an assessment on the results achieved and to shape activities for the coming years. The great spirit of collaboration among ITU members is the tool that will allow us to meet all of our goals."

Council members engaged in rich debates throughout the meeting and came together to agree on several important decisions that serve to strengthen the ITU. These include the approval of the draft ITU budget for 2018-2019, approval of the four-year rolling operational plans for its Radiocommunication, Standardization and Development sectors, as well as that of the General Secretariat for 2018-2021. A Council working group on the elaboration of the ITU's strategic and financial plans for 2020-2023 was also established.

Scientific Cooperation Between Europe and Japan

The Joint Research Centre (JRC), the European Commission's science and knowledge service and the Japanese National Institute of Advanced Industrial Science and Technology (AIST) signed a Research Framework Agreement (RFA) to boost cooperation and scientific excellence. The agreement opens new avenues for scientific exchange and synergies in the fields of nanotechnology and chemicals, metrology and measurement and energy, among others.

> "…boost cooperation and scientific excellence."

The Japanese partner AIST is one of the largest public research organisations in Japan. It focuses on the creation and application of technologies for industry and society, and intends to bridge the gap between technological seeds and commercialisation.

The agreement will formalise the cooperation between DG JRC and AIST, which has been in place for several years, concerning mainly the inter-laboratory testing of nanomaterials by in vitro tests, the harmonisation and standardisation of measurements and the development of new measurement standards.

Cellular, LPWAN Challenge Short-Range Wireless Solutions in IoT Markets

Short-range wireless technologies, like Bluetooth, Wi-Fi and 802.15.4, increasingly target nascent IoT markets beyond the consumer space. These technologies will face a greater competitive risk from emerging M2M cellular and LPWAN technologies, particularly in specific IoT market segments. The new competition will target transportation and logistics, utilities and energy management, smart cities and smart buildings, industrial automation and smart agriculture markets, among others.

"LPWAN technologies including RPMA, SIGFOX, LoRa, LTE Cat-M1, NB-IoT and EC-GSM-IoT comprise a very competitive and rapidly evolving IoT connectivity landscape," says Andrew Zignani, senior analyst at ABI Research. "These technologies are specifically designed for IoT and are arguably much better matches for outdoor, larger-scale IoT applications due to their abilities to target greater coverage areas, their ease of deployment and their greater scalability. In contrast, short-range wireless connectivity solutions, such as Bluetooth, Wi-Fi and ZigBee, are created for computing and consumer applications but are increasingly extended to address IoT verticals, as well."

> "IoT markets are diverse, and there is no one size fits all technology solution..."

IoT is forecast to represent 15 percent of Wi-Fi, 27 percent of Bluetooth and over 60 percent of 802.15.4 device shipments by 2022, as these technologies continue to evolve and target emerging opportunities. LPWAN and legacy M2M cellular technologies are set to ship nearly 575 million chipsets by 2022, growing faster than any short-range connectivity solution across IoT verticals.

Cellular and LPWAN technologies, often perceived as more reliable than short-range connectivity solutions, require less intermediary gateways, can support greater distances between end nodes and scale from the very smallest to the largest number of end devices, while providing a battery life that exceeds 10 years. Therefore, to maintain their status in the competitive market, short-range wireless chipset suppliers will need to take advantage of mesh networking functionality, lower chipset costs, wider availability, greater brand awareness, established and proven technologies, security features, IPv6 support, no service costs and other unique advantages that include higher data rates and strong presence in human-machine interface devices like smartphones.

"IoT markets are diverse, and there is no one size fits all technology solution," concludes Zignani. "Implementers and product designers must make numerous decisions on the required bandwidth, coverage area, capacity, reliability, battery life, cost, security features, topology and frequency of messages, scalability, among other criteria. Only then will many of these technologies be able to carve out success stories despite the strong competitive landscape."

Tech Vendor Marketing of Blockchain, 5G, Indoor Location and Autonomous Vehicle Solutions Not Resonating with US Enterprises

Despite a huge push by technology vendors in 2016 and early 2017, several technological solutions that have been positioned as fundamental to the evolution of the enterprise landscape are not being widely noticed by the business community—most notably, blockchain, 5G, indoor location and autonomous vehicles. In its Q1 2017 survey of 455 U.S.-based companies in nine vertical markets (retail, healthcare, transportation, logistics, automotive, manufacturing, utilities, consumer packaged goods and government), ABI Research found that:

- 93 percent of organizations had no awareness of blockchain.
- 62 percent of companies had no familiarity with 5G, and only 37 percent were just beginning to embark on early investigation processes.
- Only 7 percent of companies were planning or had autonomous vehicle solutions in play.
- Despite indoor location being a key component of many IoT solutions in vertical markets, such as retail, only 22 percent of organizations surveyed were assessing or planning indoor location solutions.

"The survey clearly shows that we are currently in the phase of adding connectivity to physical first products," says Stuart Carlaw, chief research officer at ABI Research. "The top three most significant technology segments identified by respondents all centered on connecting physical first products to digital domains. These were wired (Ethernet, PoE), short-range wireless (Bluetooth, Wi-Fi) and cellular technologies (4G/4.5G, LTE-M, NB-IoT, LPWA)."

> Technology-based solutions fundamental to the evolution of the enterprise landscape are not widely noticed by the business community.

Carlaw goes on to state that the "air gap" between technological evangelism and end user focus is something that the tech vendor community will need to address

For More Information Visit mwjournal.com for more commercial market news.

through significant education and awareness activities. "All initiatives must factor in company size and vertical market as key demographic indicators," concludes Carlaw.

Gigabit LTE Expected to Grow to 30 Percent of LTE Subscriptions by 2026

LTE is forecast to grow from approximately 30 percent of global mobile subscriptions in 2017 to 50 percent in 2024. The most advanced LTE service, Gigabit LTE, is expected to near two million subscriptions globally in 2017, which is less than 5 percent of LTE Advanced Pro subscriptions in 2017. Gigabit LTE devices, launched in 2017, will far exceed the subscription numbers, as few cell sites are expected to reach Gigabit LTE speeds in 2017. Gigabit LTE is a pivotal piece of an advanced 4G mobile network that can support an operator's mobile service goals over the next six to eight years and beyond.

"Gigabit LTE is a specific configuration of the LTE Advanced Pro standard and is expected to account for 70 percent of LTE Advanced Pro subscriptions by 2026," says Prayerna Raina, senior analyst at ABI Research. "It is a critical network milestone for operators in an increasingly competitive environment in the evolution to 5G. It is essential for operators to support the ever-rising bandwidth needs of consumers, while also upgrading the network to support 5G in the future."

As Gigabit LTE offers higher bandwidth to consumers and very efficient use of spectrum for operators, ABI Research expects more operators to launch Gigabit LTE globally over the next year and a half. Sprint launched the first Gigabit LTE service for mobile devices in New Orleans in March 2017. Telstra launched a Gigabit LTE mobile hotspot service in Sydney, Australia in February 2017 and is expected to support Gigabit LTE mobile devices as they become available. Monaco Telecom launched a mobile Gigabit LTE service in April 2017. Additional launches are expected to take place this year from all key operators in the U.S., as well as by some operators in Asia, Europe and Canada.

"Today, operators globally are in various stages of upgrading their LTE networks," concludes Raina. "Over the next four to six years, we expect mobile networks to evolve considerably with the proliferation of LTE Advanced, LTE Advanced Pro and Gigabit LTE on one hand and the launch of 5G on the other. The vendor ecosystem is essential to this network evolution with device availability being critical for the service launch. It is, therefore, imperative for vendors to align their competitive strategies with operators' network transition timelines as well as alliances in the ecosystem."

Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

RFMW Ltd., a specialized distributor providing customers and suppliers with focused distribution of RF and microwave products as well as component-engineering support, announced the acquisition of **Microwave Marketing Ltd.** (MML). MML is also a specialized RF and microwave product supplier with operations based in Lincoln, U. K., an area central to RF and microwave design activity. The agreement increases RFMW's global footprint and enhances their corporate standing as an RF focused, technically proficient distribution organization.

L3 Technologies announced that it has acquired **Open Water Power Inc.** The acquisition was completed on May 19, 2017, and the terms were not disclosed. The business will be renamed L3 Open Water Power and will be integrated into L3's Sensor Systems business segment. Based in Somerville, Mass., Open Water Power is developing safe and high-energy-density undersea power generation technologies for use by unmanned underwater vehicles (UUV) and other maritime platforms. Its breakthrough technology enables safe power generation solutions for UUVs and results in significant safety and endurance improvements over current technologies. Additionally, the company's capabilities complement and are applicable to L3's existing portfolio of maritime platform, sensor and payload offerings.

Nokia and **China Huaxin Post & Telecommunication Economy Development Center** signed definitive agreements for the proposed integration of **Alcatel-Lucent Shanghai Bell Co. Ltd.** and **Nokia's China business**. The new joint venture, which will be branded as Nokia Shanghai Bell (NSB), reflects Nokia's acquisition of Alcatel-Lucent in November 2016. Nokia will own 50 percent plus one share of NSB, with China Huaxin owning the remainder. The new JV will have one board of directors and one management team. The closing of the JV is targeted for July 2017, following various customary administrative, legal, regulatory and other conditions.

OSI Systems Inc. announced that it has signed a definitive agreement to acquire the global explosive trace detection (ETD) business from **Smiths Group plc** for $75.5 million in cash, subject to certain adjustments as of the closing date. The ETD business, headquartered in Andover, Mass., is a leader in trace detection with a current worldwide installed base of approximately 11,000 units. This business was acquired by Smiths in April 2017 as part of its acquisition of Morpho Detection. The closing of the transaction is subject to antitrust approval and other customary closing conditions.

COLLABORATIONS

Remcom announces a partnership with **P3 group** to provide a fully comprehensive solution for test and measurement combined with EM modeling and simulation. The partnership further extends the successful collaboration in air cabin communications modeling that commenced between Remcom and P3 aero systems in late 2016. The partnership gives P3's customers access to Remcom's electromagnetic simulation and propagation prediction software to augment test and measurement efforts. In addition, Remcom will now offer its customers consulting services that leverage P3's management and engineering expertise. These complementary offerings provide a convenient option for design projects that require test and measurement validation and communication channel predictions.

u-blox, **Commsignia** and **NXP Semiconductors** have announced a strategic collaboration, in order to address the rapidly growing demand for reliable vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technology. The adoption of V2X technology in North American and European markets equips new vehicles with the ability to securely and anonymously share information with other similarly equipped vehicles, infrastructure and even pedestrians within a radius of up to 1 km. IEEE 802.11p V2X technology is the only proven and production-ready technology that can reliably see around corners. V2X information will augment the awareness of drivers to improve safety, reduce congestion and emissions, thereby delivering real savings and benefits to all road users today and in the future for self-driving autonomous vehicles.

BAE Systems has signed a teaming agreement with **QinetiQ** to incorporate the latest technology for electric drive mobility systems on combat vehicles. This agreement combines BAE Systems' capabilities as a vehicle designer, developer, manufacturer and systems integrator with the electric drive expertise offered by QinetiQ, a leading U.K. science and engineering company operating primarily in the defense, security and aerospace markets. The technology offers improved fuel efficiency, reliability and mobility performance, as well as reduced life-cycle costs and unmatched electrical power available to the platform. This combination allows for advanced weaponry, communications, radar and field power generation on vehicles.

ACHIEVEMENTS

Anritsu Co. announces that its LTE-Advanced RF Conformance Test System ME7873LA has earned the first GCF certification for the LTE Category M1 (Cat M1) RF Conformance Test, as part of IoT communications technology. With the GCF certification achievement at the recent CAG#50 meeting in London, the ME7873LA has approval for more than 70 test cases across seven bands, including frequency bands in Japan, North America and Europe. Anritsu has the highest number

For More Information For up-to-date news briefs, visit mwjournal.com

of validated tests, as well as the largest number of band combinations supported for Cat M1, positioning Anritsu as the world leader in GCF-validated test cases.

Custom MMIC announced their recognition by **Raytheon Co.** with an award received in May during the Raytheon Integrated Defense Systems 2017 Supplier Excellence Conference. Raytheon IDS business instituted the Supplier Excellence Award to recognize suppliers who have provided outstanding service and partnership in exceeding customer requirements. Award candidates are judged on certain criteria, including overall quality and on-time delivery. Custom MMIC was one of 84 companies recognized by Raytheon's Integrated Defense Systems business for 4-Star Honors.

Kyocera International Inc. announced that it has received Class Y certification for its semiconductor assembly operations in San Diego. Class Y certifies ceramic non-hermetic semiconductor packages for use in space applications. The certification reinforces Kyocera's position as the premier, one-stop supplier of high performance ceramic packaging products and full turnkey, flip-chip assembly services for wide-ranging semiconductor device applications in commercial space satellites, space vehicles and orbiting systems.

CONTRACTS

Orbital ATK, a global leader in aerospace and defense technologies, announced that it has received orders totaling $76 million for .50 caliber ammunition from the **U.S. Army**. The orders were placed under Orbital ATK's supply contract to produce small-caliber ammunition for the U.S. government at the Lake City Army Ammunition Plant in Independence, Mo. Orbital ATK is the largest manufacturer of small-caliber ammunition for the U.S. Department of Defense. Since 2000, Orbital ATK has produced more than 17 billion rounds of small-caliber ammunition at Lake City to support U.S. and allied warfighters around the globe.

The **U.S. Navy** has awarded **Booz Allen Hamilton** a five-year single award, $72 million contract to assist the Program Executive Office Command, Control, Communications, Computer and Intelligence (PEO C4I) in its mission to provide naval warfighters with access to the latest information technology. Specifically, Booz Allen will continue to provide the Navy Command and Control Program Office Systems (PMW 150) with a broad range of acquisition expertise, as well as, program management providing support to all four three of PMW 150's Command and Control (C2) divisions.

The **U.S. Navy** has selected **Raytheon Co.** to provide the new Variable Depth Sonar (VDS) for the Littoral Combat Ship (LSC) class. The $27.9 million contract followed a study and product assessment phase during which Raytheon proved the solution's features and capabilities met all of the Navy's design and performance requirements. A mission-critical anti-submarine warfare


SKYWORKS®
Aerospace and Defense Solutions
High-reliability RF/Analog Semiconductors and Optocouplers
Optocouplers
Diodes
(Limiter and PIN)
Amplifiers
Circulators and Isolators
Hermetic Switches
Skyworks Solutions, through its wholly-owned subsidiaries Trans-Tech and Isolink, offers a complete portfolio of high reliability, hermetic ceramic RFIC and optocoupler products.
For more information about our hermetic ceramic RFIC and optocoupler solutions, please contact us at hirel.sales@skyworksinc.com.
For more information about our advanced material and technical ceramic solutions, please contact us at RFceramics@skyworksinc.com.
www.skyworksinc.com/optocouplers
www.skyworksinc.com/technicalceramics
sales@skyworksinc.com | USA: 781-376-3000 | Asia: 886-2-2735 0399 | Europe: 33 (0)1 43548540 | NASDAQ: SWKS |

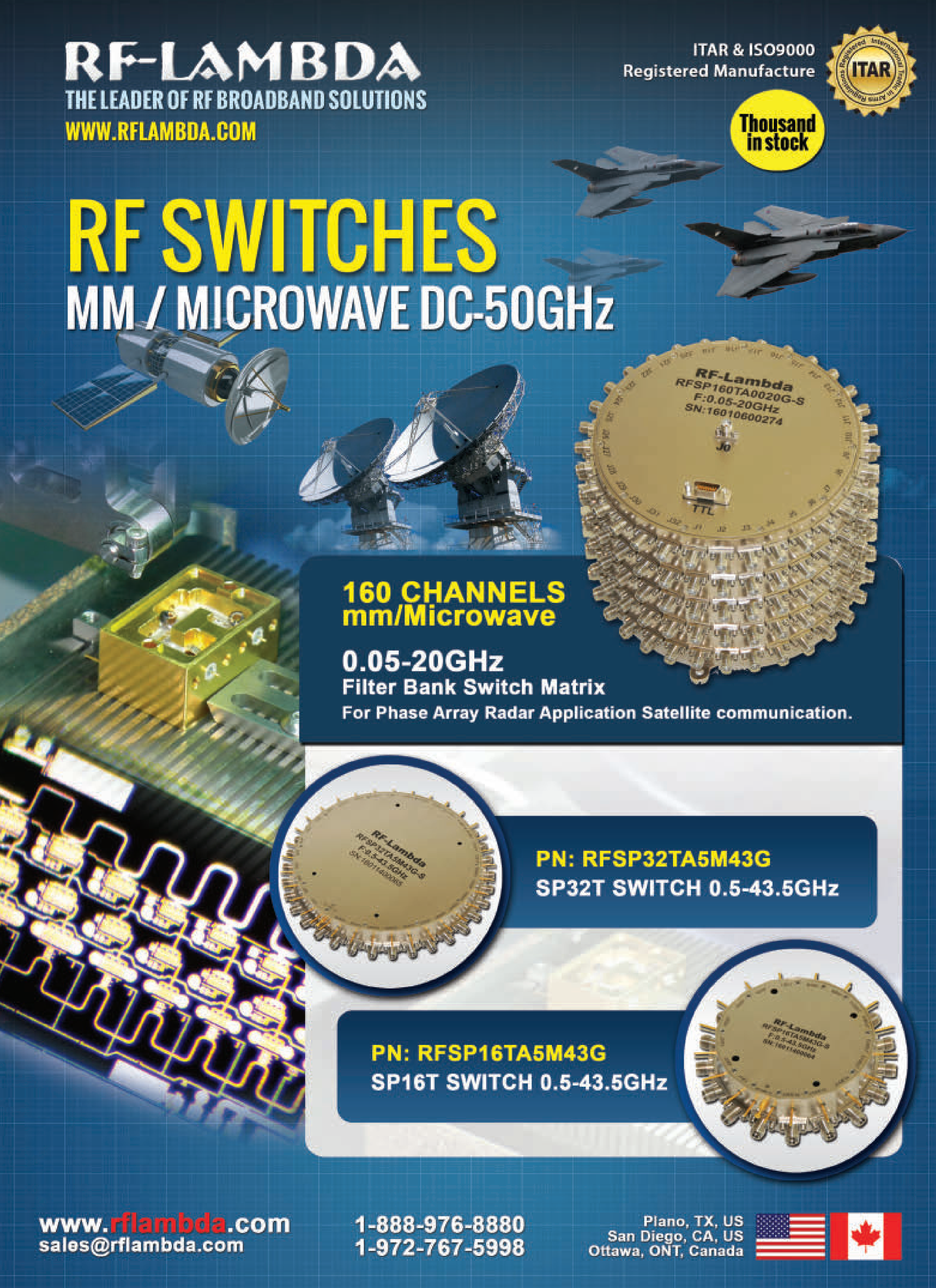
asset, the VDS will be deployed from LCS to locate and track enemy submarines. This ship-deployed sonar system design, identical for both LCS variants, features reduced weight to minimize ship impact, increased maneuverability and it provides the opportunity for increased warfighting payloads.

Anti-submarine warfare experts at **Lockheed Martin Corp.** will provide system upgrades to the **U.S. Navy's** AN/SQQ-89A(V)15 shipboard undersea warfare systems for surface warships under terms of a $33.7 million contract modification announced. Officials of the Naval Sea Systems Command in Washington D.C. are asking the Lockheed Martin Rotary and Mission Systems segment in Manassas, Va. to develop, integrate and produce future advanced capability build and technical insertion baselines of the AN/SQQ-89A(V)15 undersea warfare combat systems. The AN/SQQ-89A(V)15 is designed to search for, detect, classify, localize and track underwater contacts, and to attack or avoid enemy submarines, floating, tethered or bottom-attacked mines, and torpedoes.

Comtech Telecommunications Corp. announced that its Maryland-based subsidiary, **TeleCommunication Systems Inc.**, through its Command & Control Technologies group, which is part of Comtech's Government Solutions segment, has been named as an awardee under the General Service Administration (GSA) Complex Commercial SATCOM Solutions (CS3) IDIQ Contract. This is a 10-year contract which enables U.S. federal agencies to purchase end-to-end, turnkey solutions which incorporate commercial satellite communication services through the GSA. The multiple-awardee, Indefinite Delivery-Indefinite Quantity (IDIQ) contract has an estimated value of $2.5 billion over its 10-year term.

Roberts Communications Network LLC, a Las Vegas-based provider of satellite and terrestrial communications services to numerous industries, has selected the **ASC Signal Division of Communications & Power Industries LL** to provide seven satellite antenna systems for its new teleport in Las Vegas. Roberts has provided communications services to the pari-mutuel industry for more than 30 years, pioneering the creation of simulcasting for the horse racing industry and helping fuel its subsequent rapid growth. Roberts has been diversifying into other industries that rely on satellite and terrestrial communications, and the new teleport will support the company's continued growth.

Elbit Systems has received contract to provide the **Israeli Ministry of Defense** (IMOD) with dozens of satcom-on-the-move (SOTM) systems. Elbit Systems will provided these systems to IMOD over a two-year period. SOTM systems are simply a system of satellite antennas established over vehicles to enable communication with a satellite and maintain that communication while the vehicle is moving. Modern military operations often employ commercial satellites to fulfill theater


RF-LAMBDA
THE LEADER OF RF BROADBAND SOLUTIONS
WWW.RFLAMBDA.COM
ITAR & ISO9000
Registered Manufacture
ITAR
Thousand in stock
RF SWITCHES
MM / MICROWAVE DC-50GHz
RF-Lambda
RFSP160TA0020G-S
F:0.05-20GHz
SN:16010600274
J0
TTL
160 CHANNELS
mm/Microwave
0.05-20GHz
Filter Bank Switch Matrix
For Phase Array Radar Application Satellite communication.
RF-Lambda
PN: RFSP32TA5M43G
SP32T SWITCH 0.5-43.5GHz
RF-Lambda
PN: RFSP16TA5M43G
SP16T SWITCH 0.5-43.5GHz
www.rflambda.com
sales@rflambda.com
1-888-976-8880
1-972-767-5998
Plano, TX, US
San Diego, CA, US
Ottawa, ONT, Canada

capacity requirements. However, as modern warfare is highly asymmetric and mobile, military units desire a SOTM system. Elbit will be providing IMOD with its popular SOTM family of ELSAT 2100.

Harris Corp. has been awarded contracts to provide **Boeing** with sonobuoy launching technology for the U.S. Navy's P-8A anti-submarine aircraft. The contracts were awarded during the third quarter of Harris' fiscal 2017. Harris will provide single-shot and rotary launchers capable of rapidly deploying up to 10 sonobuoys. The lightweight, pneumatic launchers will enable 49 P-8As for U.S., Australian and U.K. aircraft to safely and effectively deploy sonobuoys, which are essential to conducting underwater acoustic surveillance.

PEOPLE

▲ *Andrew Kay*

Mobile filter start-up **Resonant Inc.** has recruited **Andrew Kay** to fill the new position of vice president of engineering operations. Kay has more than 15 years management experience in RF filter engineering and packaging. He joins Resonant from Skyworks Solutions, where he worked in various engineering roles since 2002. Most recently, he was the director of component engineering. Prior to Skyworks, he was a senior engineer at Conexant Systems and Intel. Kay holds a bachelor's in electrical engineering from Brigham Young University.

▲ *John Dunstan*

Atlantic Microwave Ltd. has appointed **John Dunstan** as its new U.K. sales manager. His focus is to sell RF and microwave components, interconnects and equipment to a wide range of industries including satellite, aerospace, telecommunications, defence and scientific research. As Atlantic Microwave brings new and innovative products to market and develops its satcom RF test equipment business, the company needs a U.K. sales team focused on building strong customer relationships and delivering the very highest levels of customer service. Dunstan has held a range of sales and account management roles at leading U.K. companies and brings 40 years of industry experience.

REP APPOINTMENTS

RFMW Ltd. and **APA Wireless Technologies** of Oakland Park, Fla., have announced a distribution agreement effective May 15, 2017. APA Wireless Technologies is a custom designer and manufacturer of high performance voltage controlled oscillators, coaxial resonator oscillators, PLL synthesizers and YIG replacement oscillators for commercial and military communication systems. RFMW is a specialized distributor providing customers and suppliers with focused distribution of RF and

microwave components, as well as specialized component-engineering support. Under the agreement, RFMW is franchised worldwide for the complete product offering of APA Wireless Technologies.

Mouser Electronics has signed a global agreement with **Samsung** to distribute the SAMSUNG ARTIK family of modules, development kits and accessories. The SAMSUNG ARTIK Smart IoT platform is designed to help developers capitalize on easy-to-use, open and enterprise-grade APIs, software development kits (SDK) and tools to quickly bring wearable, smart and IoT solutions to market. The platform enables easy development and deployment of secure, interoperable IoT products and services. The tiny, low-power, lightweight ARTIK 0 family is optimized for single-function IoT devices, such as door locks, lights and sensors.

PLACES

IQMS, a manufacturing ERP software and manufacturing execution system authority, held a ribbon-cutting ceremony to mark the opening of the company's new IoT and automation product development office in Pleasanton, Calif. The 30-person facility provides an agile environment for developing smart manufacturing systems that apply IoT and other enabling technologies to lean and Industry 4.0 manufacturing principles. The move comes as IQMS continues to expand the scope of its enterprise resource planning (ERP) system in providing manufacturers with the technology to establish world-class operations that optimize automation, quality assurance and supply chain excellence.

EDI CON USA 2017 ANNOUNCES EUROPEAN RADAR SUMMIT

Leading RADAR speakers bring expertise to event that covers RF/microwave and high-speed digital topics.

The Electronic Design Innovation Conference and Exhibition (EDI CON) USA, the first industry event to bring together RF/microwave and high-speed digital design engineers and system integrators, announced the addition of the European Radar Summit to its conference program at the Hynes Convention Center, September 11-13 in Boston.

EDI CON USA 2017 is building on its inaugural 2016 conference with multiple parallel tracks covering RF/microwave, high-speed digital and EMC/EMI topics. The conference features extended tutorials and short courses on Monday, September 11 followed by technical sessions, invited talks, workshops, panels and exhibition on Tuesday and Wednesday. Technical sessions focus on actionable, educational information for working engineers, rather than product pitches and commercial presentations.

INVITED PAPER

Predicting EVM in the RFIC Design Flow

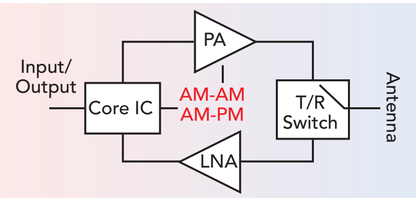
Haim Spiegel
Keysight Technologies, Santa Rosa, Calif.

Solon J. Spiegel
RIO SYSTEMS, Giv'at Shmuel, Israel

High data rate wireless communication systems require high spectral efficiency, power efficiency and low levels of signal distortion. At issue is that low levels of signal distortion are obtained with substantial signal back-off from the saturation region. As the amount of signal back-off increases, the nonlinear distortion decreases at the expense of power efficiency. Error vector magnitude (EVM) is a common figure of merit used to evaluate the quality of a transmitted signal as it relates to the overall signal-to-noise plus interference ratio (SNIR).[1] Quantifying EVM during the RFIC design flow is becoming increasingly important, particularly in high-order modulation transmission systems.[2] That is because integration of EVM analysis during the RFIC design and optimization phases is essential to producing a system with optimum EVM performance over a wide range of output power.

PROBLEM PREDICTING EVM

The traditional RFIC design flow uses continuous wave (CW) stimulus to evaluate signal integrity, nonlinear terms such as third-order intermodulation products and nonlinear compression points of the subsystem. While CW stimulus provides fast insight into the system's performance, it offers a limited understanding of the impact of nonlinear distortion on modulation accuracy. The use of modulating signals in the RFIC design flow offers an alternative. However, this approach is not widely used due to the long simulation times when a transistor-level design with strong nonlinear characteristics is subject to higher-order modulation. The complexity of the simulation environment also presents a challenge. EVM evaluation is normally performed only after the completion of the design, rather than during the RFIC design flow. By not properly taking EVM analysis into account during the design phase—optimizing circuits to a minimum EVM over a wide range of input power levels and multiple circuit conditions—sub-optimum IC performance in terms of EVM can result.



▲ **Fig. 1 Simplified block diagram of a T/R front-end in a phased array.**

The traditional expression for the third-order intercept point of a cascaded series of components results in poor prediction of the EVM across a wide range of input power levels:

$$I_{P3} = \left[I_{P3,1}^{-1} + \left(\frac{I_{P3,2}}{G_1} \right)^{-1} + \ldots \right]^{-1} \qquad (1)$$

where G_1 is the gain of the first stage and the $I_{P3,i}$ represents the third-order intercept point of the i^{th}-stage.

Consider the simplified block diagram in ***Figure 1*** of a transmitter/receiver (T/R) front-end in a phased array. The nonlinear elements are the power amplifier (PA) and core IC. The latter is responsible for the phase and amplitude control to obtain specific beam-forming characteristics. Rather than the third-order intercept points, the nonlinear behavior of the core IC and PA are described by the AM-AM and AM-PM functions. These functions provide a more accurate description of the nonlinear characteristics of the system. By defining the simple subsystem of Figure 1 in terms of AM-AM and AM-PM distortion, and

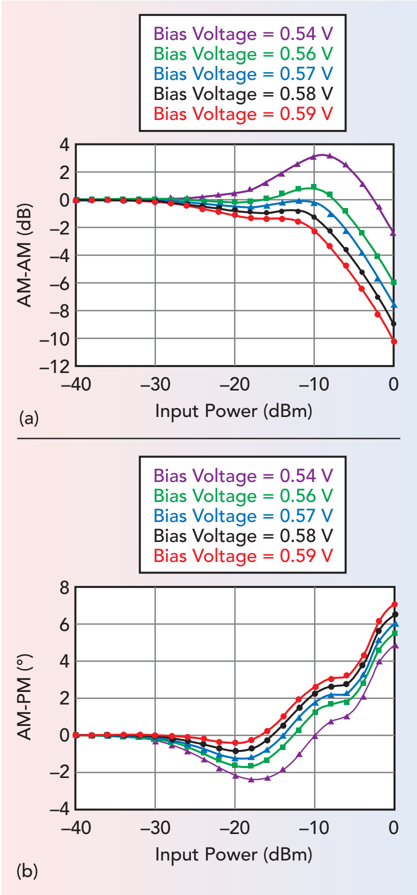
considering that the quiescent points of the core IC and PA stages vary according to the output power level, RF subsystem design for optimum EVM becomes very challenging, in part because multiple combinations of power levels and quiescent currents between the core IC and PA may lead to similar saturation power levels, yet very different EVM performance.

Many modern wireless communication systems employ orthogonal frequency-division multiplexing (OFDM) with 64-QAM or higher modulation and bandwidths of 40 MHz or greater. EVM of 1.8 percent and below is normally required, and this demands careful system optimization. Translating stringent EVM requirements into an actual RFIC design flow is of paramount importance to deliver a system with high-power efficiency and excellent EVM performance.

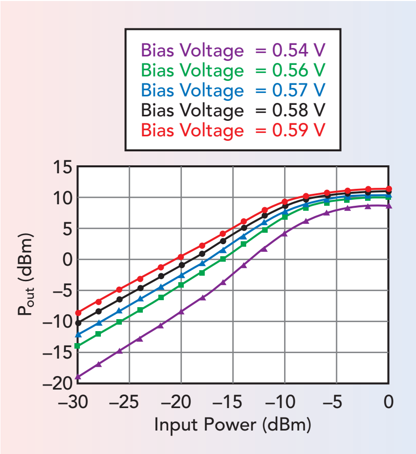
DISTORTION AND EVM

To better understand the AM-AM and AM-PM nonlinear characteristics and their relationship to EVM, refer to Figure 1. The bidirectional T/R front-end comprises a vector modulated phase shifter, a low noise amplifier, a PA and a bidirectional transfer switch. Amplitude control is obtained by varying the gain at the different amplification units of the core IC. A common approach to implementing variable gain amplification at RF frequencies is to change the bias and, therefore, the quiescent current of the device. By varying the quiescent current, the device's transconductance changes and so, too, does the voltage gain. In addition to the amplitude control, the nonlinear characteristics of the core IC also vary with the quiescent current. ***Figure 2*** shows the simulated AM-AM and AM-PM distortions of the 180 nm CMOS core IC versus input power and bias. Inspection of these curves does not provide clear insight into the optimum operating point for EVM over a wide range of input power levels and modulation formats.

The traditional output versus input power characterization, shown in ***Figure 3***, offers even less information about the EVM at different input power levels. A common practice is to roughly estimate the amount of power back-off from the 1 dB compression point to define the maximum linear output power. For example, one could use the curves of Figure 3 and choose 13 dB back-off, which defines an approximate linear input power of -22 dBm for 256-



▲ **Fig. 2** Simulated AM-AM (a) and AM-PM (b) distortion of the core IC.



▲ **Fig. 3** Output vs. input power of the core IC.

Our RF & Microwave Amplifiers Give You An Unfair Advantage

Hybrid Power Solid State Modules & Benchtop Amplifiers

700 MHz to 6 GHz Single Band Units

Now you can have Class A designs when linearity is the driving force, as in EMC and wireless applications OR Class AB designs when increased power and efficiency is paramount for EW applications. Standard 6 GHz modular designs provide up to 50 watts P out while benchtops are capable of delivering up to 500 watts CW.

Dual Band Amplifiers

AR now offers the widest Class A solid state frequency range coverage in a single amplifier housing. Our widest bandwidth designs cover 0.7 to 10.6 GHz in a dual band configuration. These amplifiers come in a band split configuration from 0.7 to 4.2 GHz and 4 to 10.6 GHz. Output powers provide up to 80 watts for the lower band split while the higher band provides up to 40 watts.

Solid State Pulsed Amplifiers

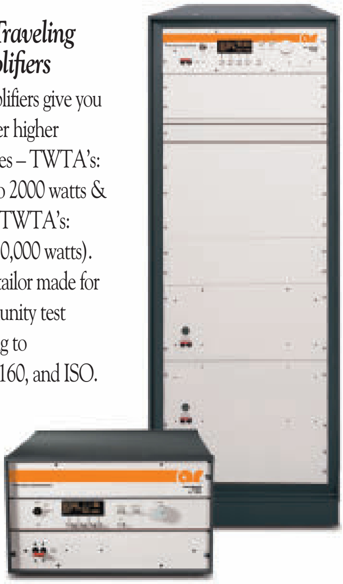
0.8 to 4 GHz Pulse, Up to 150,000 Watts

For automotive and military EMC radiated immunity susceptibility testing, as well as radar and communication applications, there is now a very attractive alternative to Traveling Wave Tube Amplifiers (TWTA's). Octave and sub-octave bands.

AR's new offerings include various frequency ranges and output power levels to meet several standards, or designs can be tailored to suit your specific application.

"T" and "TP" Traveling Wave Tube Amplifiers

AR's microwave amplifiers give you more power and cover higher frequencies ("T" Series – TWTA's: 1- 50 GHz; CW 40 to 2000 watts & "TP" Series – Pulsed TWTA's: 1- 18 GHz; 1000 to 10,000 watts). These amplifiers are tailor made for various radiated immunity test applications to MIL-STD-461, DO-160, and ISO.



Solid State 6 To 18 GHz Amplifiers

Single Band Class A Amplifiers Up to 40 Watts CW

AR's solid-state amplifiers covering the 6 – 18 GHz frequency range. Excellent gain flatness and ∞ to 1 output protection. Output powers of 20 & 40 watts available. Ideal for EW & radiated susceptibility testing.

www.arworld.us/advantage

Come See Us at EMC+SIPI
Gaylord National Resort & Convention Center, Washington, DC
August 7-11, 2017, Booth 401

ISO 9001:2008
Certified

We don't just build great products.
We build great products that last.

rf/microwave instrumentation

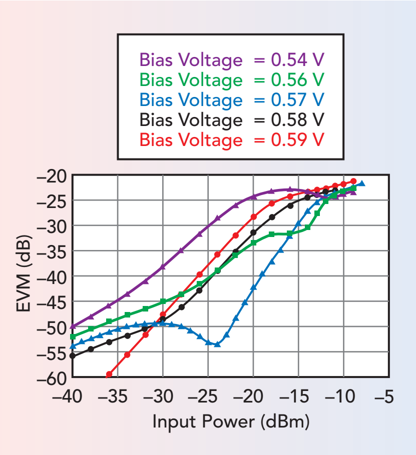
Other ar divisions: modular rf • sunar rf motion • receiver systems • ar europe

USA 215-723-8181. For an applications engineer, call 800-933-8181.
In Europe, call ar United Kingdom +44 1908 282766 • ar France +33147917530 • ar Deutschland +49 6101 80270 0 • ar Benelux +31 172 423000

www.arworld.us
Download the AR RF/Microwave Mobile App: www.arworld.us/arApp

QAM OFDM. Approximately 12 dB gain control is obtained by varying the bias point from 0.54 to 0.59 V.

The simulated EVM of the core IC with 256-QAM and a 40 MHz bandwidth is shown in ***Figure 4***, using the same bias conditions shown in Figures 2 and 3. As the bias voltage approaches the 0.54 V threshold voltage, EVM versus input power degrades and the voltage gain decreases rapidly (see Figure 3). Figure 4 shows how the operating condition affects EVM. At very high input power level, where the core IC operates in compression, the bias point has little impact on EVM. As the input power decreases, lower EVM is obtained with a bias voltage of 0.57 V. For input power levels below -32 dBm, the high bias voltages (0.58 and 0.59 V) provide lower EVM. One conclusion is that determining EVM is almost impossible by merely inspecting the nonlinear characteristics of the IC derived from CW excitation. A thorough EVM analysis, as an integral part of the RFIC design flow, is required to optimize circuit conditions for minimum EVM. Also, subsystem implementations of the T/R front-end in Figure 1 and spatial filters with adjustable weighing functions demand that integrated EVM simulations be part of the RF system design flow.

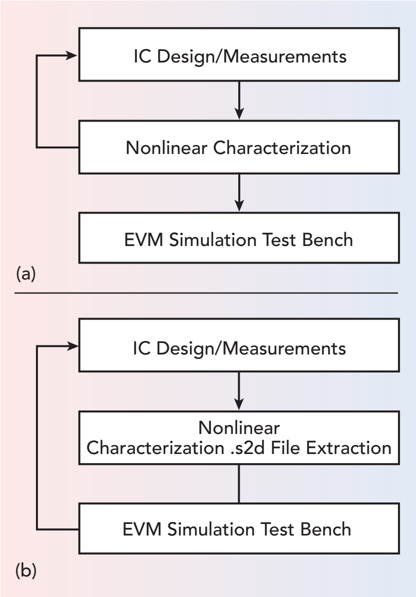


▲ Fig. 4 Simulated EVM of the core IC vs. bias.

EVM IN THE DESIGN FLOW

The previous section described the importance of integrating EVM analysis in the RFIC design flow for higher-order modulations, i.e., 64-QAM and higher, where EVM levels below -30 dB are required. ***Figure 5*** illustrates two RFIC design flows that can be used for EVM analysis. Figure 5a shows the traditional EVM simulation flow. Here, the verification methodology for RFIC design, which includes process-voltage and temperature (PVT) variation analysis at the circuit level, layout verification, functional verification and EVM verification at the system level, is carried out at the end of the design. Performing EVM analysis only in the verification stage, without taking it into account during the design phase, leads to suboptimal design and slows the overall design process. The latter occurs when the circuit must be redesigned because the device's quiescent point has to change to meet EVM performance, which occurs particularly in cases where stringent EVM specifications are demanded.

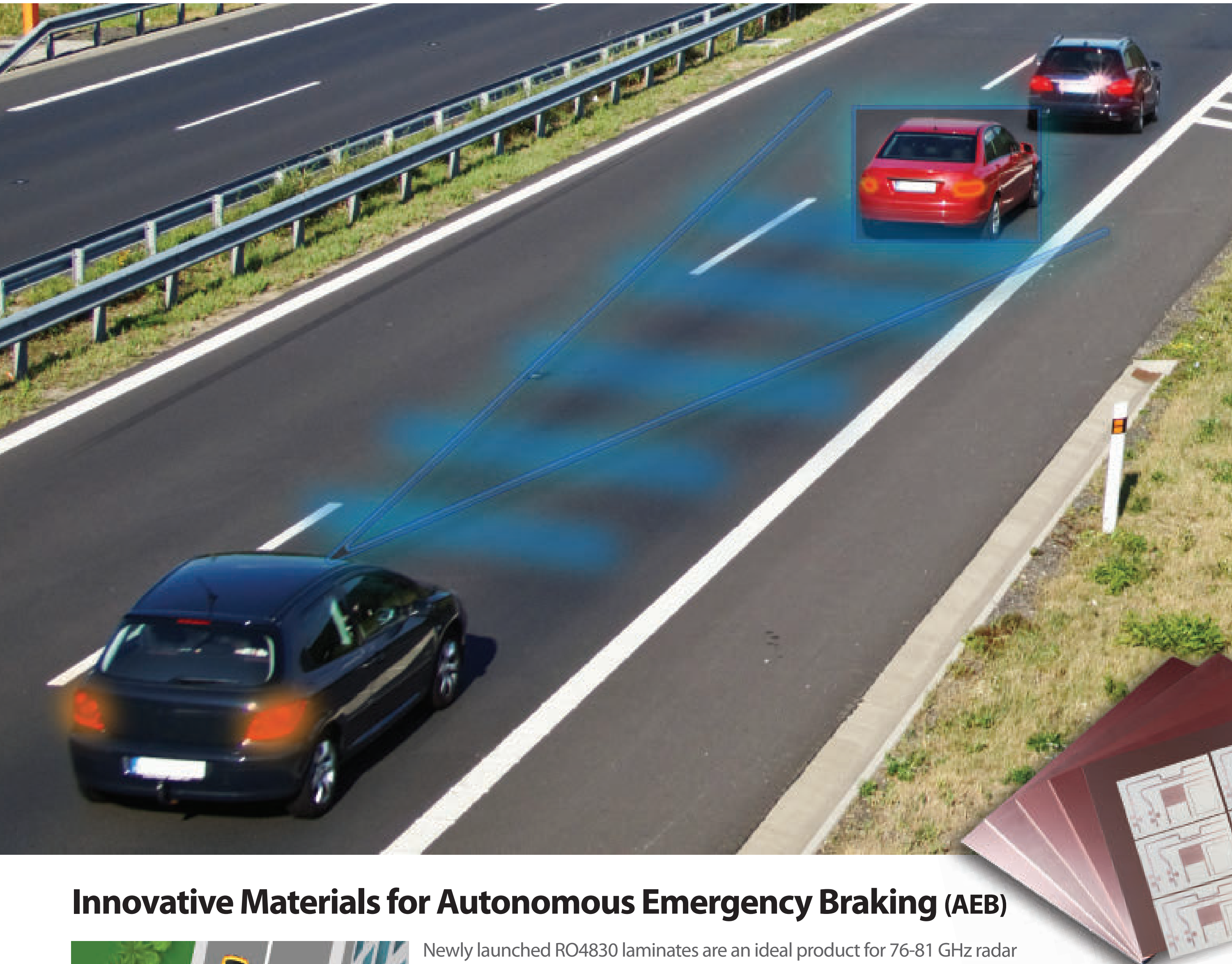
Introducing EVM simulations during the RFIC design flow creates a few difficulties. That is because EVM simulations are slow compared to simulations based on CW stimulus, and the design environment is different than the normal RFIC design environment. A complete transistor-level circuit description for EVM analysis is very time consuming and, ultimately, too complex for EVM



▲ Fig. 5 Traditional design flow (a) and modified flow that integrates EVM analysis (b).

Make Driving Safer with Rogers RO4830™ Laminates

Breakthrough Material for 76-81 GHz Radar Sensors



Innovative Materials for Autonomous Emergency Braking (AEB)

AEB City, AEB Vulnerable Road Users

Newly launched RO4830 laminates are an ideal product for 76-81 GHz radar sensors. Its low dielectric constant matches the most common Dk for radar sensors at this frequency. Combined with its very low insertion loss and easy fabrication of RO4000® products, RO4830 laminates are the most cost-effective choice for designers of 76-81 GHz radar sensors.

RO4830 laminates build upon a Rogers' legacy of excellence in quality and reliability, well known by users of other Rogers' RF/microwave circuit materials, such as RO3003™ and RO4835™ laminates.

Rogers provides leading-edge electrical testing and fabrication support for automotive radar sensor applications at millimeter wave frequencies.

Dk Value: 3.2

Insertion Loss: 2.2 dB/in.

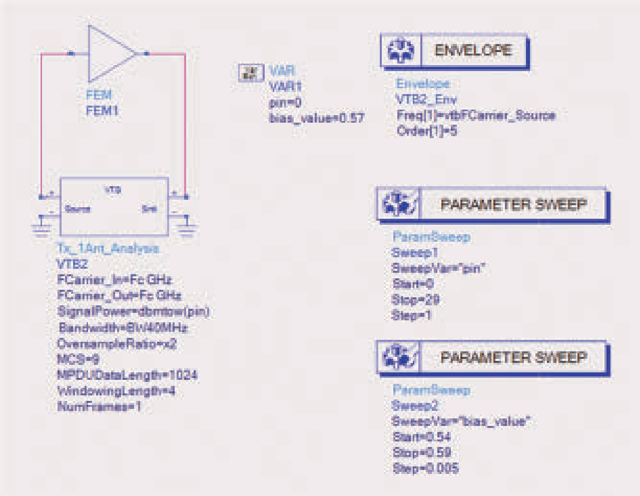
Properties are at 77 GHz. Measured using microstrip differential phase length test method, with 5 mil thick substrate.

Learn more @
www.rogerscorp.com/RO4830

ROGERS CORPORATION

Advanced Connectivity Solutions

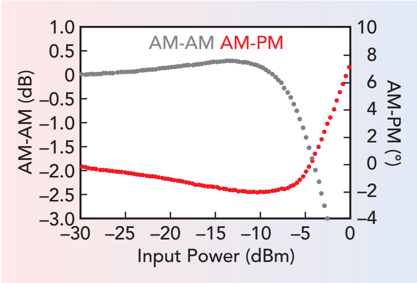
www.rogerscorp.com • USA - AZ, tel. +1 480 961 1382 • EUROPE - BELGIUM, tel. +32 9 235 3611



▲ **Fig. 6** **EVM simulation test bench using Keysight's ADS software.**

analysis. The RFIC design flow in Figure 5b offers a way to overcome these limitations: the nonlinear AM-AM and AM-PM characteristics at various bias conditions are inserted automatically, with additional small-signal and noise parameters, into the GCOMP7 option of the .s2d file format. The resultant .s2d file defines the behavior of a nonlinear amplifier used for EVM simulation.

Figure 6 shows the test bench used for the evaluation of the implemented EVM using Keysight's Advanced Design System (ADS). For the EVM analysis, a 256-QAM, 40 MHz bandwidth signal was used. The input power level and bias voltage were parametrized, comprising 33 power levels simulated over 11 bias conditions, resulting in 363 different conditions for simulation. The EVM simulation based on the .s2d files consumed just a fraction of time compared to the simulation based on the transistor-level design. The latter becomes impractical to analyze in the design flow of Figure 6b due to the complexity of the circuit and the long simulation times required. The same circuit, modeled with .s2d format files, required only a few seconds to analyze the EVM—a substantial reduction in the EVM simulation time that enabled the practical integration of EVM analysis into the RFIC design flow.



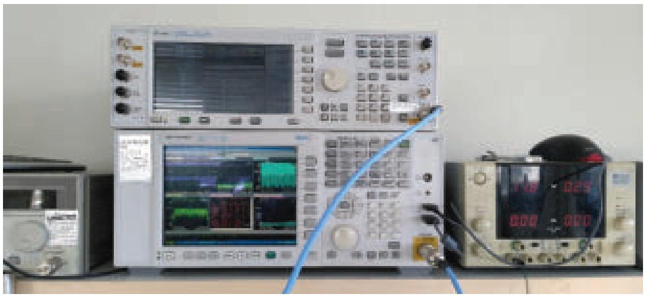
▲ **Fig. 7** **Measured AM-AM and AM-PM distortion of the DUT.**

SIMULATED AND MEASURED RESULTS

Using a circuit representation based on the .s2d file format and the test bench shown in Figure 6, EVM simulations were carried out to compare with the measured EVM. A 256-QAM, 40 MHz bandwidth modulating signal was used for the simulations. The measurements of AM-AM and AM-PM distortion were initially performed using spectrum and network analyzers, prior to EVM evaluation. ***Figure 7*** shows the measurement results of the nonlinear characterization of the device under test (DUT). A .s2d file format was created to describe the small- and large-signal characteristics of the DUT. The GCOMP7 option was used to model the nonlinear behavior.

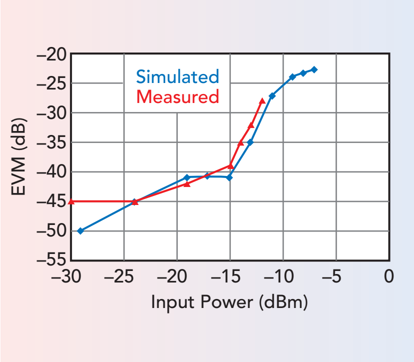
Figure 8 shows the setup for EVM measurement. Power calibration was performed to determine the input power levels during nonlinear characterization of the DUT and EVM measurements. To assure the accuracy of the input power for EVM readings, the output power of the vector signal generator remained constant, while the different input power levels applied to the DUT were varied using an external variable attenuator. Cable losses were extracted and de-embedded from the measurement results.

Both the measurement and simulation of EVM are shown in ***Figure 9***. Excellent agreement was obtained



▲ **Fig. 8** EVM measured using the Keysight E4438C vector signal generator and N9020A signal analyzer.

between simulation and measurement at moderate and high input power. At power levels below −25 dBm, the sensitivity of the measurement equipment limits the ability to measure EVM below −45 dB. The results show the importance of evaluating EVM, particularly at moderate power levels, where the results are highly dependent on the amplitude and phase distortion characteristics of the nonlinear circuit.



▲ **Fig. 9** Simulated vs. measured EVM.

CONCLUSION

The importance of integrating EVM analysis into the RFIC design flow, particularly for systems with EVM specifications below -30 dB, cannot be overstated. Without including EVM in the design flow, the complete RF subsystem can have suboptimal EVM under different input power and bias conditions. Small changes in the bias of an output stage can result in very different EVM over a wide range of input power. Fortunately, a substantial reduction in the simulation time for EVM evaluation can be obtained through AM-AM and AM-PM characterization and by incorporating this into the .s2d file format. Using this methodology for integrating EVM evaluation into the design flow, engineers can simulate EVM that is in excellent agreement with measured EVM—and in a fraction of the time.■

ACKNOWLEDGMENT

The authors would like to thank K. Manin, I. Levie, P. Steinberg and E. Turgerman for fruitful discussions and measurement support.

References

1. R. Hassung et al., "Effective Evaluation of Link Quality Using Error Vector Magnitude Techniques," *Wireless Communication Conference*, pp. 89–94, 1997.
2. P. Naraine, "Predicting the EVM Performance of WLAN Power Amplifiers with OFDM Signals," *Microwave Journal*, May 2004.

INVITED PAPER

A Modified Three-Level Doherty Amplifier for Next-Generation Communication Systems

Mike Roberts
Slipstream Engineering Design Ltd., Shipley, U.K.

A modified three-level Doherty amplifier produces good efficiency over 10 dB of operation using devices of equal periphery. Test results are presented that demonstrate a drain efficiency of greater than 40 percent at 10 dB back-off.

Modern communication systems routinely use complex modulation techniques that result in peak-to-average ratio (PAR) signals of 9 dB and higher. To achieve sufficient linearity, these high PAR levels require a power amplifier (PA) to operate far below the power levels that would yield optimum power-added efficiency. To understand this effect, consider one of the simplest forms of an RF amplifier, the class AB type shown in ***Figure 1***.

Such an amplifier is relatively straightforward to design and manufacture and can easily provide peak drain efficiencies of around 65 percent when operating in the 2 GHz region. One drawback with this type of simple amplifier is that when the RF output signal level is reduced, the output voltage swing decreases and efficiency drops with the square root of the output power. This means that at a quarter of the output power (-6 dB), efficiency is about half of what it is at peak output power, or 32 percent in this example. Clearly, operating at 6 dB back-off and higher with a class AB amplifier results in a significant reduction in efficiency, because the signal is, on average, sitting at a highly inefficient operating point.

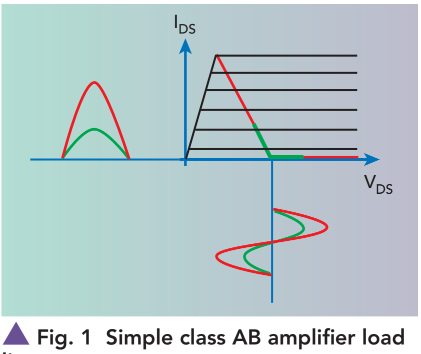


Fig. 1 Simple class AB amplifier load line.

The use of a Doherty amplifier is a well known technique for improving efficiency of a PA in backed-off operation. The standard two-way Doherty amplifier with a peak in efficiency at 6 dB back-off and full power is commonly used and well understood. With the use of increasingly complex signals comes the challenge to move the peak in efficiency to higher levels of back-off while maintaining efficiency up to full power output. This can be achieved with asymmetrical Doherty amplifiers or by utilizing N-way Doherty techniques. This is why the use of Doherty amplifiers in modern code division multiple access (W-CDMA) and long-term evolution (LTE) systems has seen a strong resurgence.

The two-way Doherty amplifier provides an improvement over class AB operation, but with higher levels of PAR being used it is necessary to improve efficiency at back-off levels of 10 dB and higher. The three-level or three-way Doherty amplifier produces peaks in efficiency at 9.5, 4.4 and 0 dB, which is a good fit for LTE transmitters. However, as will be seen later, the conventional approach requires that the two auxiliary amplifiers be twice the periphery of the main amplifier.

This article describes the operation of a modified three-level Doherty amplifier[1] that produces good efficiency over the top 10 dB of operation using devices of equal periphery. Its operation is explained based on an Ampleon (formerly NXP) design that uses three laterally diffused metal oxide semiconductor (LDMOS) transistors of equal size. Design challenges faced with this type of amplifier are presented and compared against the conventional three-way Doherty architecture. Test results are presented that demonstrate a drain efficiency of greater than 40 percent at 10 dB back-off.

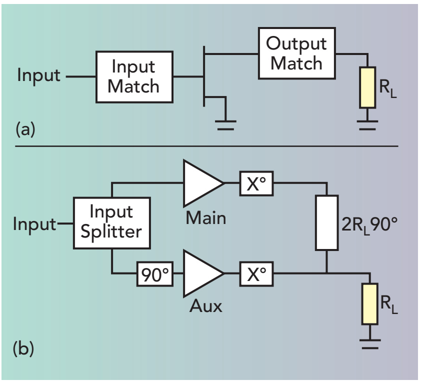
The entire RF design, including layout, is implemented in the NI AWR Design Environ-

ment. Within this software environment, Microwave Office circuit design software and APLAC harmonic balance are used to simulate, in detail, the large-signal effects of the Doherty amplifier's operation. The software's load-pull analysis is used to determine the impact of load impedance on amplifier performance.

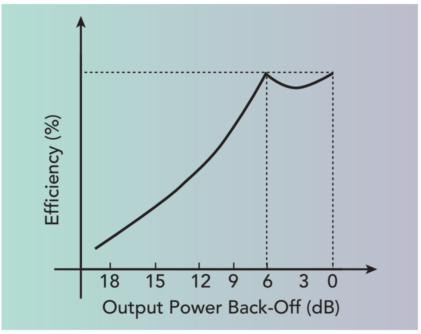
TWO-WAY DOHERTY DESIGN

Although well documented in the literature, it is worth taking a moment to revisit the simple case of the two-way Doherty amplifier to fully understand the three-level configuration. The standard two-way Doherty amplifier works by splitting the amplifier into two equally-sized amplifiers that are half the size of a single-ended class AB amplifier with the same peak power capability (see ***Figure 2***). The basic principle is that when the output signal level is low, only the main amplifier is active. With increasing output levels, the auxiliary amplifier is progressively introduced up to the point where full power is achieved, and both the main and auxiliary amplifiers contribute equally to deliver full power.

The two-way circuit is configured with the main amplifier biased in class AB and the auxiliary amplifier biased in class C. This biasing scheme means that at low input drive levels, the main amplifier conducts and the auxiliary amplifier is off. As input levels are increased, the main amplifier drive level also increases. When the output power is a quarter (-6 dB) of the amplifier maximum, the auxiliary amplifier starts to conduct current. At low signal levels, when the auxiliary amplifier is not active, the main amplifier (assuming R_L = 25 Ω) "sees" 100 Ω. This means that it reaches full voltage swing at half power. Full voltage swing means that the main amplifier provides maximum efficiency at half its output power. At this point, the amplifier, as a whole, is delivering a quarter (-6 dB) of its peak power capability with maximum efficiency. This is the first point on the theoretical efficiency curve in ***Figure 3***.



▲ Fig. 2 Single-ended class AB amplifier (a) and two-way Doherty amplifier (b).



▲ Fig. 3 Theoretical efficiency of a two-way Doherty amplifier.

As input drive level is increased from the 6 dB back-off point, the current contribution into the load from the auxiliary amplifier increases. This increased current injected by the auxiliary amplifier means that the impedance looking into the load increases. The 50 Ω impedance inverter between the load and the main amplifier ensures that the main amplifier sees a reduced load as the current contribution from the auxiliary amplifier increases. So, in this regime, as output power increases, there are two processes taking place. The first is that, due to load modulation from the auxiliary amplifier, the main amplifier is effectively increasing in size; that is, its capability to produce power is increasing during the time it is running at maximum voltage swing and hence maximum efficiency. The other process taking place is that both the main and auxiliary amplifiers contribute to the total output power.

As the drive level increases further, these processes continue to increase until the auxiliary amplifier is at maximum output power (if the devices are equal in size) and the currents into the load from the main and

Planar Monolithics Industries, Inc.

Diplexers / Multiplexers - Filters

- Amplifiers – Solid State
- Attenuators – Variable/ Programmable
- Couplers (Quadrature, 180° & Directional)
- Detectors – RF/Microwave
- DLVAs, ERDLVAs & SDLVAs
- DTOs, VCOs, PLO, DROs, & Frequency Synthesizers
- Filters & Switched Filter Banks
- Form, Fit, Functional Products & Services
- Frequency Discriminators & IFMs
- Integrated MIC/MMIC Assemblies (IMAs)
- IQ Vector Modulators
- Limiters – RF/Microwave
- Log Amplifiers
- Millimeter Wave Components (Up to 50 GHz)
- Miscellaneous Products
- Multifunction Integrated Assemblies (MIAs)
- Phase Shifters & Bi-Phase Modulators
- Power Dividers/Combiners (Passive & Active)
- Pulse Modulators (SPST)
- Rack & Chassis Mount Products
- Receiver Front Ends & Transceivers
- SDLVAs, ERDLVAs & DLVAs
- Single Side Band Modulators
- SMT & QFN Products
- Switch Matrices
- Switched Filter Banks
- Switches – Solid State
- Systems - Radar Sense & Avoid
- Systems – Fly Eye Radars
- Threshold Detectors
- USB Products

PMI offers the highest quality filters, diplexers, multiplexers, switch filter banks, and filter assemblies for industrial and military applications in the DC to 40 GHz frequency range. PMI's specializes in form, fit, and function replacement parts to customers' electrical, mechanical, and environmental specifications. More available at http://www.pmi-rf.com/Products/filters/features.htm

Model: 11DP-11R5/16R5-CD-SFF-1 (Diplexer)

http://www.pmi-rf.com/Products/filters/11DP-11R5-16R5-CD-SFF-1.htm

Center Frequencies, Fo	Low Band: 11.5 GHz High Band: 16.5 GHz
Passband Frequencies	Low Band: 10.75 to 12.25 GHz High Band: 15.75 to 17.25 GHz
Passband Insertion Loss	3 dB Max. - Measured 1.67 dB
Passband VSWR	1.5:1 Max. - Measured 1.4:1
Rejections	Low Band: -50 dBc @ 10.25 GHz - Measured -64 dBc -75 dBc @ 13.75 GHz - Measured -85 dBc High Band: -50 dBc @ 17.75 GHz - Measured -64 dBc -75 dBc @ 14.25 GHz - Measured -85 dBc

Package Size: 3.5" x 1.4" x 0.5"
Connectors: SMA (F) removable

Model: DPX-18G26R5G40G (Diplexer)

http://www.pmi-rf.com/Products/filters/DPX-18G26R5G40G.htm

Insertion Loss (Passband)	2 dB Max. - Measured 1.3 dB
VSWR (Passband)	2.5:1 Max. - Measured 2.4:1
Diplexer K Band 1dB Passband	18.0 GHz, Min., 25.0 GHz Max.
Diplexer Ka Band 1dB Passband	28.0 GHz Min., 40.0 GHz Max.
Crossover Band	25.0 GHz Min., 28 GHz Max
Crossover Excess Attenuation	5 dB Typ. - Measured 4.8 dB
Stopband Attenuation	60 dB - Measured 64 dB
K Band (Stopband)	32.0 GHz - 46.0 GHz
Ka Band (Stopband)	DC - 22.0 GHz

Package Size: 0.8"x 0.6" x 0.38"
Connectors: 2.92mm (F)

Model: DP-5700M-6500M-CD-SFF (Diplexer)

http://www.pmi-rf.com/Products/filters/DP-5700M-6500M-CD-SFF.htm

Low Passband	5.7 to 6.5 GHz Min.
High Passband	13.75 to 14.50 GHz Min.
Passband Insertion Loss	≤ 1 dB @ Low Passband - Measured 0.57 dB ≤ 2 dB @ High Passband - Measured 1.32 dB
VSWR	2.0:1 @ Passbands - Measured 1.37 dB
CH to CH Isolation	≥ 70 dB - Measured 83.19 dB
Power Handling	20 W

Package Size: 2.5" x 1.0" x 0.6"
Connectors: SMA (F)

Model: PTP-1G18G-2G8G-55-S4F (Triplexer)

http://www.pmi-rf.com/Products/filters/PTP-1G18G-2G8G-55-S4F.htm

Insertion Loss	J1 to J2: 1.3 dB Max. @ 1.0 to 1.9 GHz J1 to J3: 1.3 dB Max. @ 2.1 to 7.6 GHz J1 to J4: 1.3 dB Max. @ 8.4 to 18.0 GHz
Out-Of-Band Rejection	J1 to J2: 55 dB Min. @ DC to 0.75 GHz 55 dB Min. @ 2.3 to 18.0 GHz J1 to J3: 55 dB Min. @ DC to 1.7 GHz 55 dB Min. @ 9.2 to 18.0 GHz J1 to J4: 55 dB Min. @ DC to 6.8 GHz 55 dB Min. @ 20.5 to 26.0 GHz
Crossover	J2/J3: 5.5 dB Max. @ 1.98 to 2.02 GHz J3/J4: 5.5 dB Max. @ 7.92 to 8.08 GHz
VSWR	2.0:1 Max.
Input Power	+20 dBm CW

Package Size: 3.0" X 1.8" X 0.5"
Connectors: SMA (F)

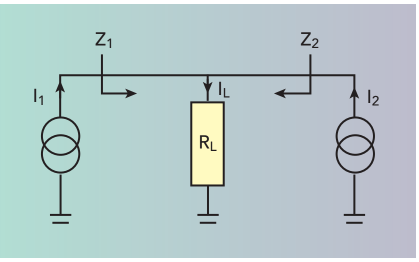
West Coast Operation:
4921 Robert J. Mathews Pkwy, Suite 1
El Dorado Hills, CA 95762 USA
Tel: 916-542-1401, Fax: 916-265-2597

East Coast Operation:
7311-F Grove Road
Frederick, MD 21704 USA
Tel: 301-662-5019, Fax: 301-662-1731

sales@pmi-rf.com • www.pmi-rf.com

ISO9001-2008 REGISTERED

auxiliary amplifiers are equal. At this point the main and auxiliary amplifiers both see 50 Ω. The key concept in the operation of the Doherty amplifier is load modulation. The explanation given by Cripps[2] provides an excellent description of the principles involved. The key elements are summarized here for clarity.

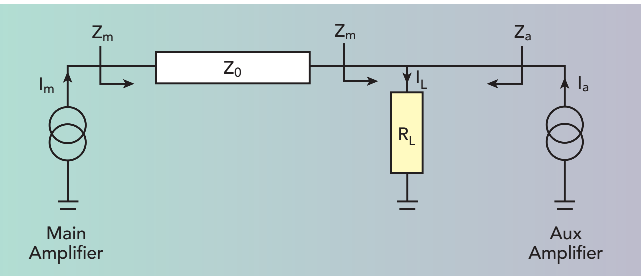


▲ **Fig. 4** Standard two-way Doherty load modulation with the inverter removed.

Figure 4 represents the simplest possible case where two current sources are feeding into a common load. When I_2 = 0, the impedance Z_1 is simply equal to R_L. If a current is injected into the load from I_2 then the impedance Z_1 is modified to:

$$Z_1 = \left(1 + \frac{I_2}{I_1}\right) R_L \tag{1}$$

If I_1 and I_2 are equal, then $Z_1 = Z_2 = 2R_L$. With the addition of an impedance inverter as shown in ***Figure 5***, this circuit becomes the two-way Doherty. The addition of the inverter causes the impedance seen at the main amplifier, Z_m, to decrease when the current from the auxiliary amplifier is injected into the common load. When the auxiliary amplifier is off $Z_m = Z_o^2 / R_L$.



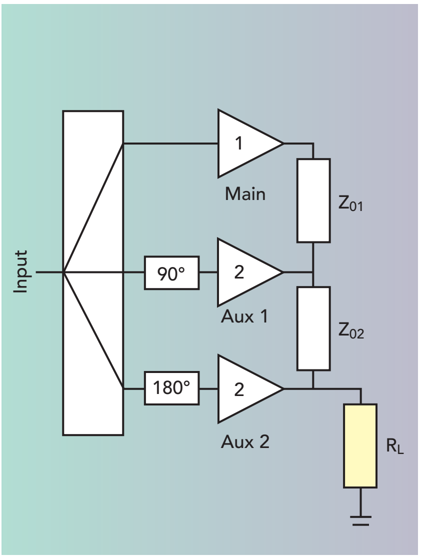
▲ **Fig. 5** Two-way Doherty amplifier.

CONVENTIONAL THREE-LEVEL DOHERTY DESIGN

As shown in ***Figure 6***, the conventional three-level Doherty amplifier is a direct extension of the two-way design. By adjusting the relative device periphery between the main and auxiliary amplifiers, it is possible to achieve a variety of different positions for the efficiency peaks. The designer can use the equations defined by Edmund, et al.[3] to locate the efficiency peaks as required. This article is concerned with signals around 10 dB of PAR. The relative levels of device periphery to achieve an efficiency peak at -9.5, -4.4 and 0 dB for the conventional three-level Doherty is 1:2:2, where the first digit is the main amplifier followed by Aux 1 and Aux 2.

For this configuration, Z_{01} is required to be 70.7 Ω, Z_{02} = 33.3 Ω and R_L = 20 Ω. At the first efficiency peak, the main amplifier sees an impedance of 90 Ω. In order to match the output to 50 Ω, an impedance inverter with a value of $\sqrt{(20*50)}$=31.6 Ω is required. In essence, the conventional three-level Doherty amplifier behaves as a two-way Doherty amplifier up to the second peak (-4.4 dB) in efficiency; then, from the second peak to full power, the main and auxiliary 1 amplifiers behave like a main amplifier that is load modulated by the current contribution from auxiliary 2.

There are two main drawbacks to the conventional three-level



▲ **Fig. 6** Conventional three-level Doherty amplifier.

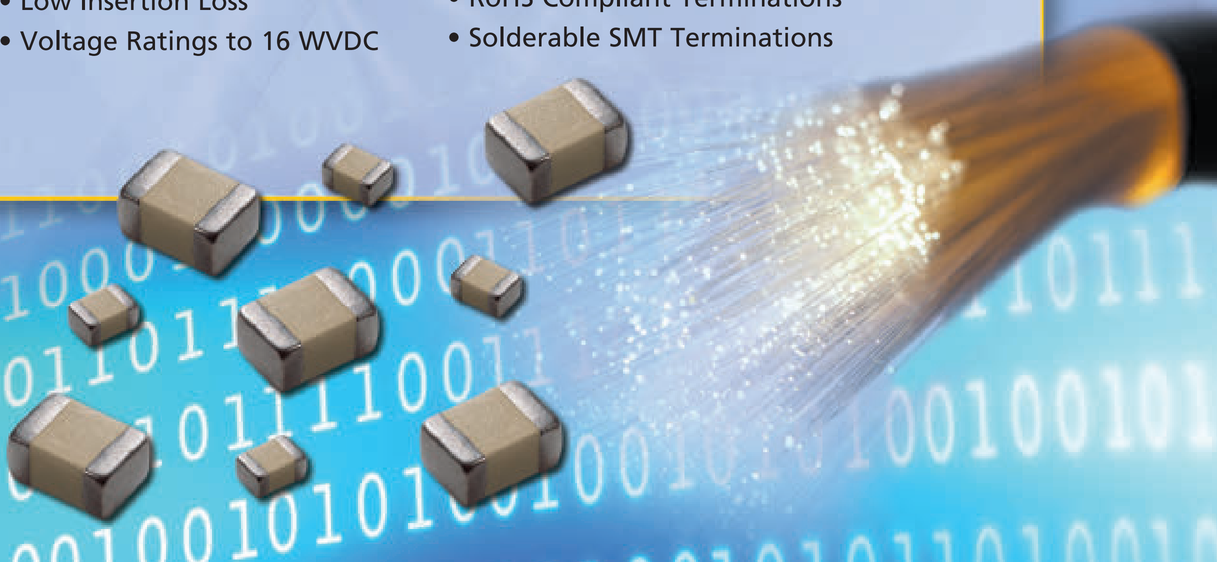
ATC Broadband SMT Capacitor Solutions

Reliable and Repeatable Broadband Performance

ATC's 520 and 530 Series family of Broadband Capacitors exhibit low insertion loss over multiple octaves of frequency spectrum, flat frequency response and excellent return loss. They are ideal for broadband DC blocking, coupling, bypassing, and feedback applications in optical communications systems and equipment using high-speed digital logic.

Attributes

- 0201 and 0402 EIA Case Sizes
- 16 KHz to 20 GHz
- Low Insertion Loss
- Voltage Ratings to 16 WVDC
- Unit-to-Unit Performance Repeatablity
- RoHS Compliant Terminations
- Solderable SMT Terminations



ATC Series	EIA Size	Capacitance	Frequency Range	Insertion Loss	Voltage Rating
520 L	0402	10 nF	160 KHz to 16 GHz	1 dB max.	16 WVDC
530 L	0402	100 nF	16 KHz to 18 GHz	1 dB max.	16 WVDC
530 Z	0201	100 nF	16 KHz to 20 GHz	0.4 dB typ.	10 WVDC

AMERICAN TECHNICAL CERAMICS

ATC North America
sales@atceramics.com

ATC Europe
saleseur@atceramics.com

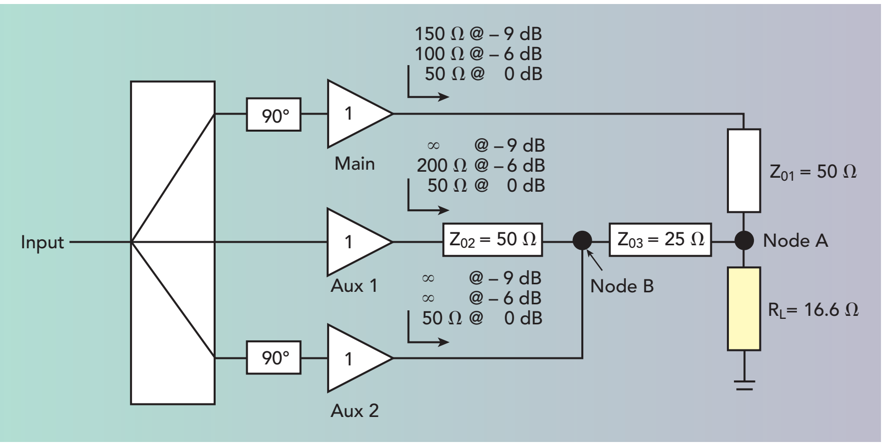
ATC Asia
sales@atceramics-asia.com

THE ENGINEERS' CHOICE®

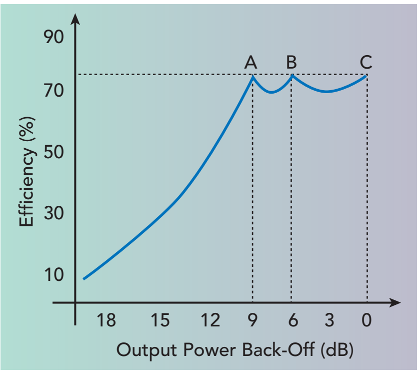
www.atceramics.com

THE ENGINEERS' CHOICE® ISO 9001 REGISTERED COMPANY

RoHS Compliant



▲ **Fig. 7** Modified three-level Doherty amplifier.



▲ **Fig. 8** Theoretical efficiency of a three-way Doherty amplifier.

Doherty amplifier. The first is that different device sizes are required to provide efficiency peaks in the 10 dB back-off region, which leads to added complexity. The second is that the load modulation of the main amplifier stops between the second and final efficiency peaks. This means that the main amplifier is driven into extreme saturation over the last 6 dB of output power.[1]

MODIFIED THREE-LEVEL DOHERTY WITH EQUAL DEVICES

The modified three-level Doherty design[1] achieves similar performance to a conventional three-level Doherty amplifier without having to accommodate output transistors of different sizes. Using transistors of equal size for the main and auxiliary stages has a number of practical benefits, including the use of a single "unit cell" RF design. The basic amplifier unit cell for the main and auxiliaries can be of the same (or very similar) design, which reduces development time. Also, having three of the same part rather than two different parts on the bill of materials results in economies of scale, which is important for what are likely to be the most expensive components in the amplifier. The configuration also provides proper load modulation of the main amplifier, whose load impedance is steadily reduced with increasing drive level. A schematic of the modified three-level Doherty is shown in ***Figure 7***.

The best way to understand the operation is to start at low signal levels, progressively increasing the input drive and discussing the operation at each efficiency peak (see ***Figure 8***). Each unit cell in this example delivers maximum output power when driving a 50 Ω load. The unit cell also contains phase offset lines to ensure that the electrical length of an auxiliary (and main) stage is 180 degrees from the active device at the point where the amplifier is connected into the Doherty combiner circuit. This ensures that when the auxiliary amplifier is switched off, an open circuit is presented to the Doherty combiner and minimum power is dissipated in the auxiliary output matching circuits. The main amplifier is biased in a class AB mode, auxiliary 1 is biased at about 0.7 V, and auxiliary 2 is biased at about 0 V when using enhancement mode LDMOS transistors. These values provide the required progressive switching of the auxiliary amplifiers. Note that the load is 16.7 Ω in this example and

TABLE 1

MODIFIED THREE-LEVEL DOHERTY AT 9 dB BACK-OFF

Stage	Impedance Presented to Unit Cell	Power Delivered to Output Load
Main	150 Ω	33% of $P_{MaxMain}$
Aux 1	Open	0
Aux 2	Open	0
Total Power in Load		11% of P_{Total}
Power Delivered/Total Power Capability (Back-Off Level in dB)		10log(0.33/3) = −9.6 dB

TABLE 2

MODIFIED THREE-LEVEL DOHERTY AT 6 dB BACK-OFF

Stage	Impedance Presented to Unit Cell	Power Delivered to Output Load
Main	100 Ω	50% of $P_{MaxMain}$
Aux 1	200 Ω	25% of $P_{MaxAUX1}$
Aux 2	Open	0
Total Power in Load (Max = 3)		25% of P_{Total}
Power Delivered/Total Power Capability (Back-Off Level in dB)		10log(0.75/3) = −6.0 dB

TABLE 3

MODIFIED THREE-LEVEL DOHERTY AT 0 dB BACK-OFF

Stage	Impedance Presented to Unit Cell	Power Delivered to Output Load
Main	50 Ω	100% of $P_{MaxMain}$
Aux 1	50 Ω	100% of $P_{MaxAUX1}$
Aux 2	50 Ω	100% of $P_{MaxAUX2}$
Total Power in Load (Max = 3)		100% of P_{Total}
Power Delivered/Total Power Capability (Back-Off Level in dB)		10log(1) = 0 dB

transformed up to 50 Ω with a 28.8 Ω quarter-wave inverter.

At low signal levels, in the regime before point A in Figure 8 is reached, only the main amplifier is active. The impedance presented to the main amplifier unit cell at this point is 150 Ω. At point A (9 dB back-off) the conditions shown in ***Table 1*** apply. As the input drive level increases, it moves to the region between points A and B (6 dB back-off) in Figure 8. At point A, auxiliary 1 switches on and starts to deliver current into the common output load R_L. This increase in current into the common load causes the impedance seen from the main amplifier at node A to increase. The action of the inverter Z_{01} in the main path causes the impedance seen by the main amplifier to fall. This reduction in output impedance enables the main amplifier to deliver more power into the common load while remaining in voltage saturation.

As drive level increases, this process continues until the current in the load due to the auxiliary amplifier is half the current in the load due to the main amplifier, and the following condition is reached:

$$\frac{I_{A1}}{I_M} = 0.5 \qquad (2)$$

This condition is point B in Figure 8 and is the second efficiency peak. Applying Equation 1, the imped-

ance seen from the main amplifier looking into node A is given by:

$$Z_{M\_NodeA} = R_L\left(1+\frac{I_{A1}}{I_M}\right) = \frac{3}{2}R_L = 25\ \Omega \qquad (3)$$

So, the impedance seen by the main device looking into the 50 Ω inverter Z_{01} is 100 Ω. Also, the impedance seen from the auxiliary branch looking into node A is given by:

$$Z_{A\_NodeA} = R_L\left(1+\frac{I_M}{I_{A1}}\right) = 3R_L = 50\ \Omega \qquad (4)$$

The impedance at node B looking from the auxiliary 2 amplifier is therefore 12.5 Ω (due to Z_{03}), and the impedance seen by the auxiliary 1 unit cell amplifier is 200 Ω. Since the main and auxiliary 1 amplifiers are both running at voltage saturation, they both deliver maximum efficiency, hence the peak in efficiency. The amplifier parameters at this second efficiency peak are given in ***Table 2***.

Bias of the auxiliary 2 amplifier is set such that it starts to turn on and deliver current into the output load when Equation 2 is satisfied. The increase in current further reduces the main impedance and allows it to deliver more power. The increased current into the load also reduces the load impedance seen by the auxiliary 1 amplifier, so this device delivers more power and further increases load current. This increase in current continues until the contribution from each amplifier is equal and the following is satisfied:

$$I_M = I_{A1} = I_{A2} \qquad (5)$$

The two auxiliary amplifiers deliver a total normalized current of 2 into the load and the main amplifier delivers 1. This is point C in Figure 8. At this point, the impedance from the main branch looking into node A is now

$$Z_{M\_NodeA} = R_L\left(1+\frac{I_{A1}+I_{A2}}{I_M}\right) = 3R_L = 50\ \Omega \qquad (6)$$

The main amplifier sees 50 Ω and delivers full power. The impedance seen from the auxiliary branch looking into node A is given by:

$$Z_{A\_NodeA} = R_L\left(1+\frac{I_M}{I_{A1}+I_{A2}}\right) = \frac{3}{2}R_L = 25\ \Omega \qquad (7)$$

Since Z_{03} is a 25 Ω inverter, the impedance looking into node B is also 25 Ω. This is the correct impedance for two 50 Ω loads in parallel. The parameters for the amplifier at this third and final efficiency peak (0 dB back-off) are given in ***Table 3***.

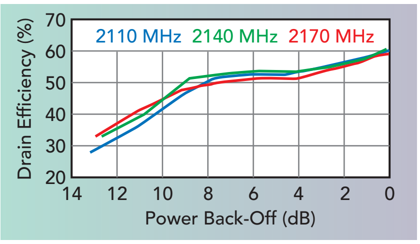
In addition to the design of the output network, there are a number of practical design considerations for this type of amplifier that should be considered. The first is that the gain of the three-level amplifier is inherently quite low because of the three-way input split. This results in the small-signal gain being a minimum of 4.7 dB lower than that obtained from a single-ended device. This is less of an issue at lower cellular bands but can become a problem at higher frequencies, where gain is at a premium. The quarter-wave transformers used extensively throughout

this design limit the bandwidth to about four to five percent maximum, so this approach is only applicable for narrowband applications.

EXPERIMENTAL RESULTS

To demonstrate the concept, a 2.14 GHz version of the Ampleon three-level amplifier was designed and manufactured by Slipstream Engineering Design. A photograph of the amplifier is shown in ***Figure 9***. The three-way input split (-4.7 dB) is achieved by using a 5 dB directional coupler cascaded with a 3 dB hybrid coupler. The transistors used are twin LDMOS devices running at 28 V bias (normally used for push/pull or balanced applications) with one of the transistors unused in the upper device. Results are presented as back-off levels from the full output power of 150 W, which in this case is defined as about 2 dB out-

▲ **Fig. 9** **Slipstream Engineering's 2.14 GHz three-way Doherty amplifier.**



▲ **Fig. 10** **CW drain efficiency vs. back-off vs. frequency. Full power is 150 W.**

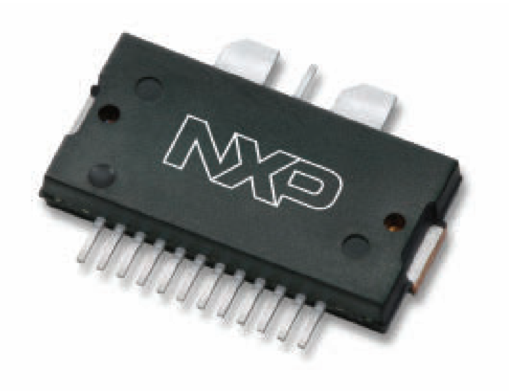
put compression (see ***Figure 10***). As can be seen, the design objective of 40 percent drain efficiency at 10 dB back-off is achieved over the band of interest. The small-signal gain of this amplifier is about 16 dB, with a power gain at full power of 14 dB.

CONCLUSION

This article presented an overview and explanation of the operating principles for a modified Ampleon three-level Doherty amplifier[3] that produces good efficiency over the top 10 dB of operation using devices of equal periphery. Design challenges faced with this type of amplifier were discussed and compared with those of a conventional three-way Doherty architecture. Experimental results demonstrate a drain efficiency of greater than 40 percent at 10 dB back-off.■

References

1. R. Gajadharsing, W. C. E Neo, M. Pelk, L. C. N. De Vreede and J. Zhao, "3-Way Doherty Amplifier With Minimum Output Network," *U.S. Patent US20100315162*, issued December 16, 2010.
2. S. Cripps, "RF Power Amplifiers for Wireless Communications," *Artech House*, Norwood, Mass., April 1999.
3. W. C. Edmund Neo, J. Qureshi, M. J. Pelk, J. R. Gajadharsing and L. C. N. de Vreede, "A Mixed Signal Approach Towards Linear and Efficient N-Way Doherty Amplifiers," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 55, No. 5, May 2007.



Two-Stage, 48 V, LDMOS Driver IC for Cellular

NXP Semiconductors
Chandler, Ariz.

The transition from analog to digital over-the-air television broadcasting in the U.S. and Europe is freeing up significant amounts of spectrum. Digital video compression allows up to eight digital TV channels to transmit in the same amount of spectrum required by only one analog channel. Digital signals do not require the wide guard bands needed by their analog counterparts for interference protection. Collectively, the digital transition has made spectrum available for use by wireless services in the U.S. and Europe, called the first and second "digital dividends." Although the second digital dividend that makes spectrum between about 600 and 700 MHz available is still in the making, it will allow frequency harmonization between the U.S., Europe and other markets. When compared with its higher frequency counterparts, greater distances can be covered with fewer base stations in the 600 to 700 MHz region. This makes serving rural areas much less expensive and provides better penetration of buildings and other structures.

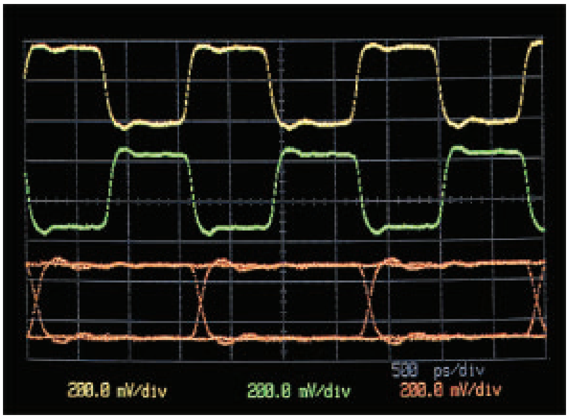
Carriers are moving toward multiband and wideband applications to reduce operating costs, and adopting carrier aggregation (CA) to increase data rates. CA is a key capability of LTE-Advanced that allows mobile network operators to combine up to five (currently) carriers, typically non-contiguous, in the downlink to increase peak data rates and overall capacity. The simultaneous transmission requirement of CA is especially important below 1 GHz, where base stations cover more area.

To serve these new spectrum deployments and CA needs, NXP Semiconductors has introduced the A2I09VD030N very high voltage (VHV), two-stage driver integrated circuit. It is the first commercially available product of its type, operating at 48 VDC and integrating two amplification stages rather than the usual one. Since inception, cellular systems have typically used a 28 VDC supply voltage, but a transition to 48 VDC is occurring, initially below 1 GHz. Raising the voltage effectively doubles the power density of the devices in the amplifier chain. The A2I09VD030N's higher voltage operation and two stages of amplification enable smaller devices to produce a specific RF output power, reducing the size of the base station power amplifier, which allows the size of the base station to be smaller. This supports current market needs, as wireless carriers strive to deploy smaller base stations, especially remote radio heads where the power amplifier is at the top of the tower.

This new NXP IC is a broadband amplifier, operating from 575 to 960 MHz. The gain of the two-stage A2I09VD030N is greater than 31 dB; coupled with a final amplifier gain of about 19 dB, the total lineup has 50 dB gain. Consequently, a base station requires only two devices, instead of three, to achieve the required gain of 45 dB with suf-

2 GHz Clock Generator

- ***Square wave clocks from DC to 2.05 GHz***
- ***Random jitter <1 ps (rms)***
- ***80 ps rise and fall times***
- ***16-digit frequency resolution***
- ***CMOS, LVDS, ECL, PECL, RS-485***
- ***Phase adjustment & time modulation***



Plot shows complementary clocks and PRBS (opt. 01) outputs at 622.08 Mb/s with LVDS levels. Traces have transition times of 80 ps and jitter less than 1 ps (rms).

The CG635 generates clock signals—flawlessly. The clock signals are fast, clean and accurate, and can be set to standard logic levels.

How fast? Frequency to 2.05 GHz with rise and fall times as short as 80 ps.

How clean? Jitter is less than 1 ps and phase noise is better than –90 dBc/Hz (100 Hz offset) at 622.08 MHz.

How accurate? Using the optional rubidium timebase, aging is better than 0.0005 ppm/yr, and temperature stability is better than 0.0001 ppm.

You would expect an instrument this good to be expensive, but it isn't. You no longer have to buy an rf synthesizer to generate clock signals. The CG635 does the job better—at a fraction of the cost.

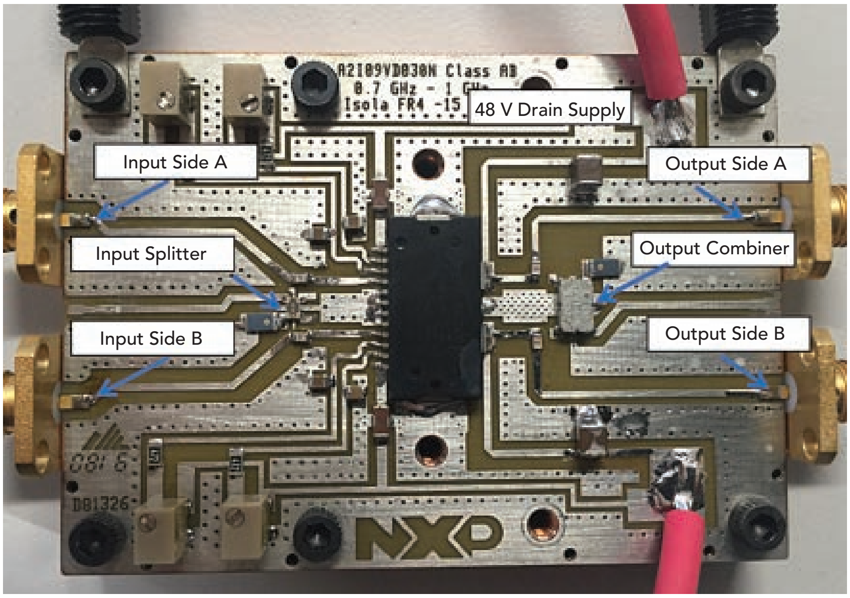
Stanford Research Systems

Phone: (408)744-9040 • Fax: (408)744-9049 • info@thinkSRS.com • **www.thinkSRS.com**

ficient margin. The A2I09VD030N is also a dual-path device, so it can be used in different amplifier architectures: combined with a 3 dB hybrid (see ***Figure 1***), used as two separate drivers or combined in a Doherty configuration as the final stage driver. Operating from 920 to 960 MHz, the A2I09VD030N produces 40 W of peak power with 34 dB of gain and 20 percent efficiency at a 10 dB output back-off. Adjacent channel power ratio (ACPR) is about -44 dBc (see ***Table 1***). The device is an excellent driver for several NXP high-power VHV transistors, including the A2V09H525-04N and A2V07H525-04N, which forms an 80 W base station amplifier lineup.

The A2I09VD030N is in production, and NXP is working on smaller and higher power versions, to offer a more complete portfolio.

The digital dividends are a bonus for the cellular industry, enabled by the adoption of digital television technology. Although the new spectrum in the U.S. is not yet deployed, the "reverse" auction has completed, and the FCC has established a timeline for implementing the new mobile frequencies—which are in the "sweet spot" where signal propagation is well-suited for wireless communications. The new NXP IC is designed to optimize performance at these frequencies. By operating at 48 V, base station power amplifiers can be created with fewer RF power devices, consuming less power and reducing size.



▲ **Fig. 1 A dual-path amplifier using the A2I09VD030N IC. The hybrid splitter on the input and combiner on the output can be connected for single-path operation.**

TABLE 1
A2I09VD030N DRIVER IC SPECIFICATIONS

Frequency (MHz)	Gain (dB)	Power-Added Efficiency (%)	ACPR (dBc)
920	34.4	19.9	−45.0
940	34.5	20.0	−44.6
960	34.3	19.8	−44.3

Test Conditions: Single-Carrier W-CDMA, Input PAR = 9.9 dB at 0.01% probability on CCDF. Average P_{out} = 4 W. V_{DD} = 48 V, I_{DQ} (A+B) = −46 mA, I_{DQ2} (A+B) = 154 mA

NXP Semiconductors
Chandler, Ariz.
www.nxp.com/RF

Vector Network Analysis for the Many

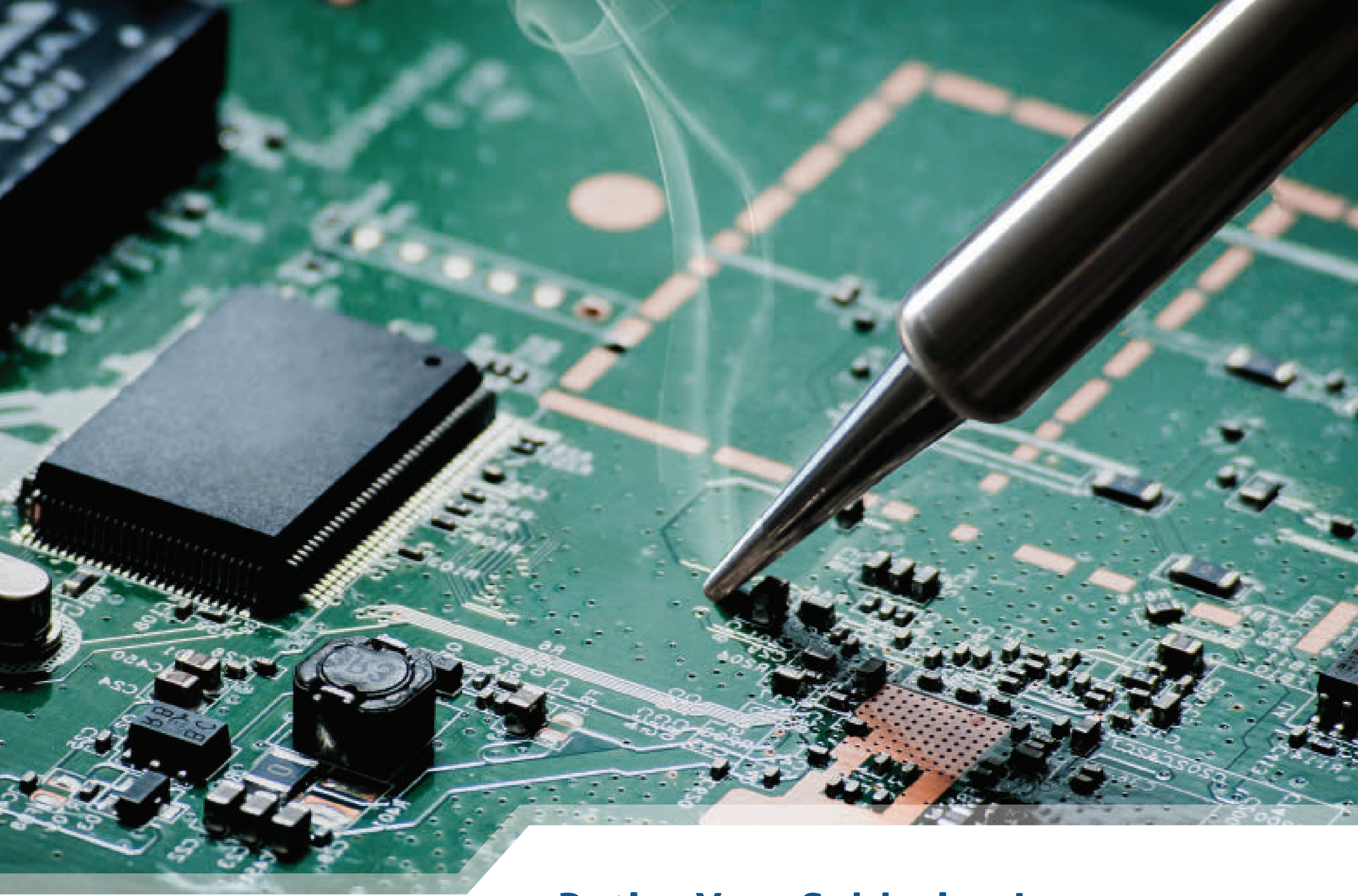
Pico Technology
St Neots, U.K.

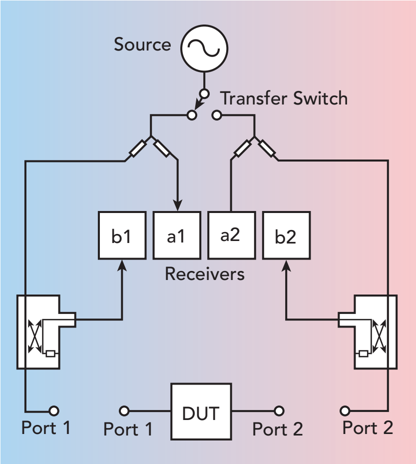
Behind the high speed data, communications and computing developments of recent decades, the need to characterize high frequency interfaces, devices, multi-path interconnects and antennas has proliferated dramatically. Once the domain of an elite few, these microwave measurements have migrated out of the laboratory, away from the specialist, into the lives of technicians, educators, researchers, doctors, manufacturers, inspectors and repairers across a plethora of industries. Increasingly used by non-specialists and systems integrators, microwave measurement needs to be straightforward, convenient, accurate, fast, compact, portable and affordable, as well as supporting proliferating applications and technologies such as 5G, IoT, radar and tissue and materials imaging.

Despite its core measurement role, vector network analysis has clung to the bounds of the expert user and the deep pockets of established business, stubbornly refusing to fall within easy reach and adoption of the wider markets, embedded applications and the less familiar user. Fortunately, Pico Technology has risen to the challenge and produced the PicoVNA 106—a USB-controlled, professional and laboratory grade 300 kHz to 6 GHz vector network instrument that offers performance, portability, ease of use and affordability.

Despite its simple form, small footprint and low cost, the instrument boasts a full-function, minimal-error, four-receiver architecture named "Quad RX." This supports both 8- and 12-term calibration with none of the uncorrectable errors, delays and possible fragilities of traditional three receiver arrangements that do not remove switch errors. The PicoVNA 106 enables convenient calibration methods such as "enhanced isolation correction" and use of the "unknown thru."

The highly compact PicoVNA 106 boasts a dynamic range of up to 118 dB at 10 Hz and only 0.005 dB RMS trace noise at its maximum operating bandwidth of 140 kHz. It can also gather all four S-parameters in just 190 μs per frequency point—a 500 point 2-port S2P Touchstone file compatible with test, math, view and electronic design automation (EDA) simulation tools in less than a tenth of a second. This performance is claimed to be competitive with expensive instruments, yet its low price means the PicoVNA 106 could be considered as a cost-attractive, high dynamic range scalar network analyzer or a highly competitive single-port vector reflectometer, let alone the full,





▲ Fig. 1 Quad RX architecture, including bias tee blocks.

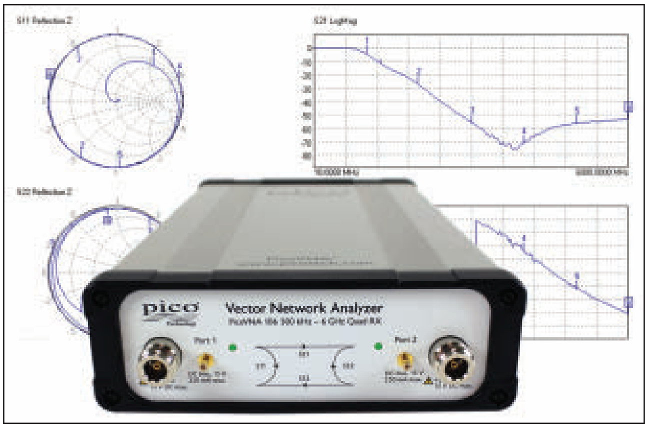
dual-port, dual-path vector network solution that it actually is!

This makes the solution affordable in the classroom, for small business and even the amateur workshop, yet competent to meet the needs of all, right up to the microwave laboratory engineer and expert. Often excluded from lower cost models, bias tees are included for convenient injection of test bias or stimulus. ***Figure 1*** shows the Quad RX architecture.

Readily hand carried or stowed, the PicoVNA 106A's small size, weight and cost and its high performance make it suitable for field service, installation test, embedded and training applications. Its remote automation interface suits it to test automation, perhaps as a reflectometry or transmission measurement core for embedded roles. Test environments include broadband interconnect, cable and harness, antenna, component and subsystem assembly, installation and fault-over-life monitoring, as well as the manufacturing, calibration, distribution and service industries. Scientific applications extend into the materials, geological and life sciences and to food and tissue imaging and penetrating scans.

FUNCTIONALITY AND ACCURACY

The PicoVNA 106 comes with all the functionality and versatility that would be expected from a modern vector network analyzer (VNA), comparable to or beyond more costly USB instruments and the even more costly and bulky benchtop options.



▲ Fig. 2 PicoVNA 106 with PicoVNA 2 software.

▲ Fig. 3 Calibration standards and test leads.

The VNA is supplied with Windows software that outputs in one, two or four measurement channels all the familiar measurement and plot formats to be expected for the four dual-port S-parameters or the two single-port parameters: logarithmic and linear magnitude and phase, real and imaginary, Smith and linear polar, SWR and group delay (see ***Figure 2***). These can be saved or exported in various graphic and tabular formats, including Touchstone, for compatibility with a wide variety of viewers, domain converters, math and EDA simulation applications.

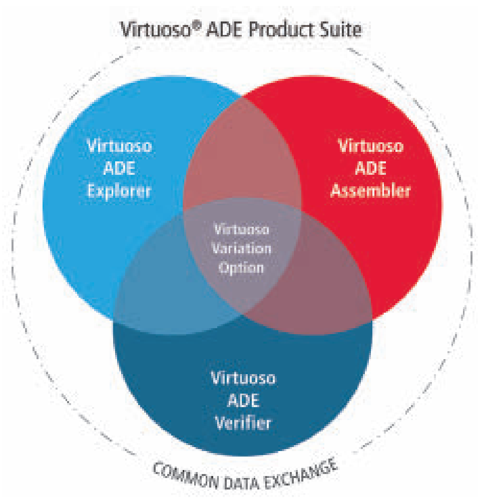
Pico Technology's VNA software also includes Fourier transformation to the time domain. This adds convenient distance-to-fault capability or pulse response determination. In all cases, nominal impedance transformation is available (10 to 200 Ω), mathematical or via port matching pads and comprehensive limits tests can be applied to the cartesian plot formats.

Unwanted measurement contributions from feed lines, probes or test jigs can be eliminated using manual or automatic reference plane offset, including fully independent offset for each S-parameter when required. Alternatively, independent networks can be embedded or de-embedded at each port from a Touchstone representation of each—measured or synthesized. Unusual for any VNA, embedding or de-embedding is interpolated when measurement and network datasets do not share the same frequency points.

The company has also included in its PicoVNA 2 software two utilities to tackle the often complex distortion measures of gain compression and AM to PM. Both of these use a port power sweep at each test frequency, and both measurements are extracted using second-order interpolation. The company is maintaining its long-held tradition of free software provision. All features are included without additional charge, and this will extend to future enhancements and upgrades.

Addressing test leads and calibration standards, Pico offers PC3.5 and SMA male and female test ports using flexible and flex-formable, phase and flatness stable test leads. Four mating calibration standards, with traceable data, are assembled into convenient male and female SOLT housings. ***Figure 3*** shows the calibration standards and test leads. Like the test leads, the SMA and PC3.5 calibration standards all use robust, high-precision stainless steel connectors.

Pico Technology
St Neots, U.K.
www.picotech.com



Virtuoso ADE Refresh Provides New Tools for Complex RF Designs

Cadence Design Systems Inc.
San Jose, Calif.

One of the challenges of emerging technologies—5G and IoT are good examples—is the need for increased integration and functionality to meet the performance and cost requirements of these applications. This increased integration raises a new problem for RF and microwave designers: how to verify the integration. Fortunately, verification of complex designs is a problem that analog and mixed-signal designers have struggled with for years, and the best design practices have been automated in the Cadence® Virtuoso® Analog Design Environment (ADE).

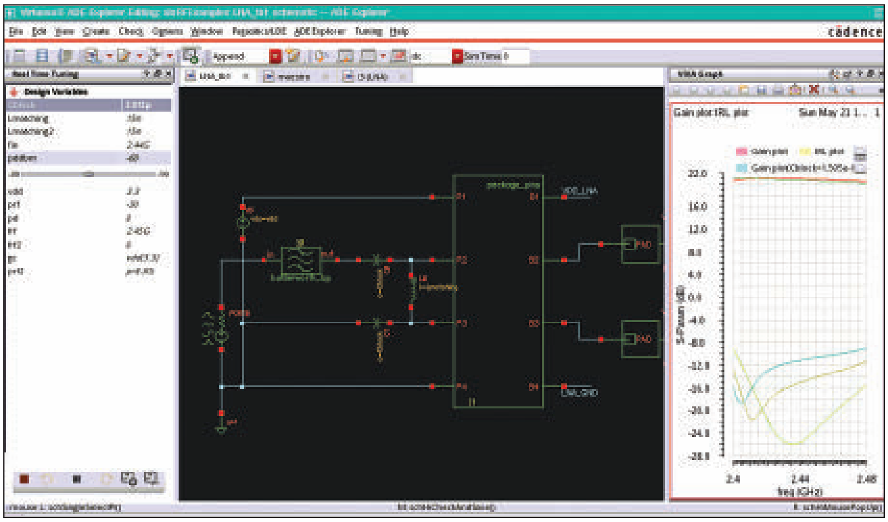


Fig. 1 Real-time tuning in ADE Explorer.

The Virtuoso platform celebrated its 25th anniversary in 2016. Over that time, Virtuoso ADE became the standard design environment for custom IC design by automating the methodology for front-to-back custom IC block realization, including parasitic closure. In the latest refresh (IC6.1.7), ADE has been enhanced to focus on optimized solutions for each design phase.

The Virtuoso ADE Product Suite has been organized into three tiers: Virtuoso ADE Explorer, Virtuoso ADE Assembler and Virtuoso ADE Verifier.

- ADE Explorer is an interactive design environment that includes basic variation analysis and new tools for debugging and design tuning
- ADE Assembler is also an interactive environment used for design validation under a multitude of different conditions, and
- ADE Verifier maps design requirements from customers to the tests being performed in the regression suite to verify that the requirements are satisfied.

For analog and mixed-signal designers, Spectre® APS is the simulator of choice for design and verification. The Spectre RF option makes the Spectre APS technology accessible to RF and microwave designers by providing de-

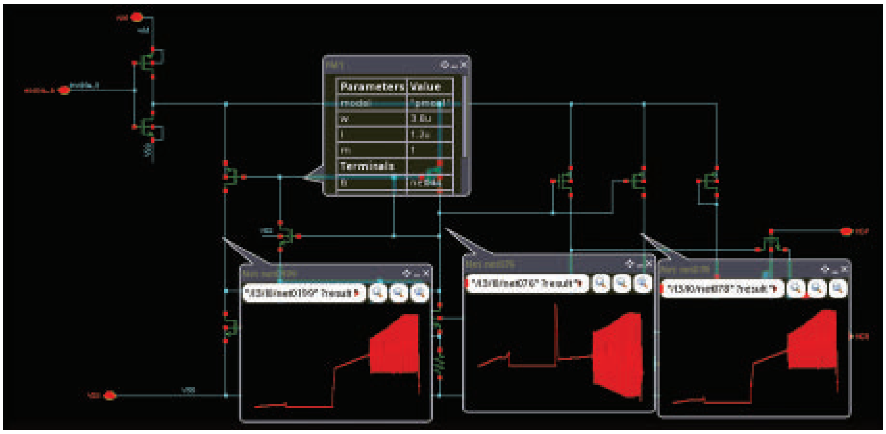


Fig. 2 Interactive debugging in ADE Explorer.

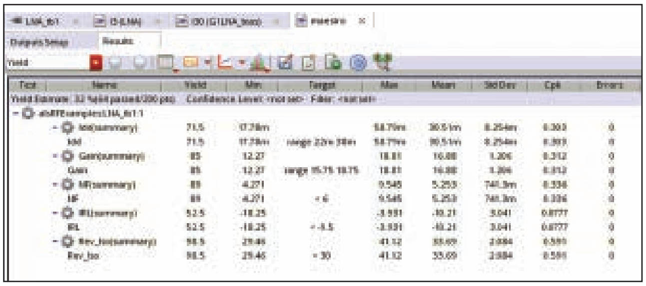


Fig. 3 Monte Carlo analysis example.

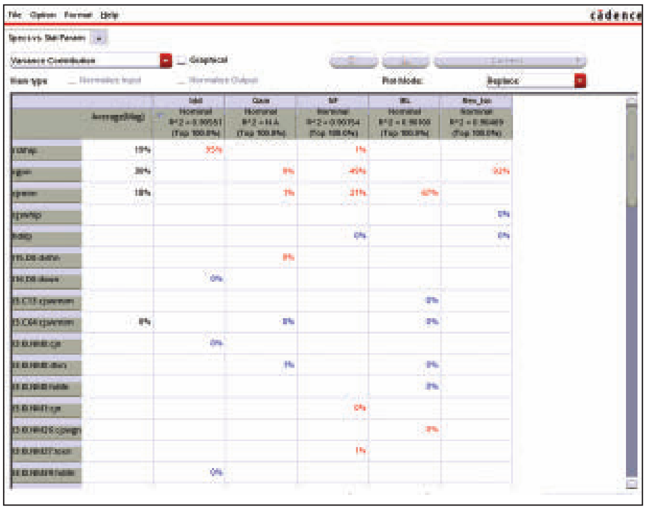


Fig. 4 Contribution analysis example.

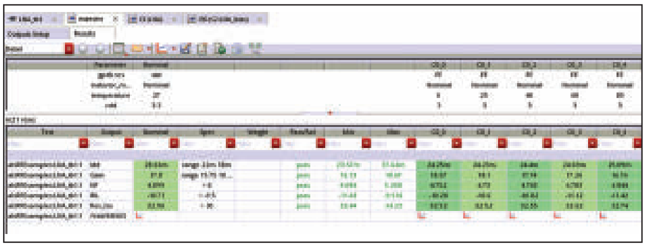


Fig. 5 Corner analysis example.

signers fast and high capacity harmonic balance analysis. This integration of RF analyses with advanced analog and mixed-signal design tools supports the needs of RF designers who are challenged with high frequency designs using planar CMOS processes.

NEW EXPLORER TOOLS

Looking at some of the new features of Virtuoso ADE in IC6.1.7, in the first example, ADE Explorer is used to design a low noise amplifier (LNA). ADE Explorer has been developed based on extensive interactions with designers to optimize their use model for interactive design. Overlaid on top of this environment are tools for RF designers such as real-time tuning and specialized measurements. Consider the problem of tuning an input matching network to optimize S_{11} (see ***Figure 1***). Designers can use slider bars to interactively explore the design space and compare the current results with the previous results. In addition to real-time tuning, designers also have access to Explorer's new interactive debugging capabilities. Suppose that the LNA stops working. A designer can add waveform bubbles to the schematic to monitor key nodes in the circuit, identifying at which node the design "stops wiggling." Once the designer identifies where the issue is, the operating point information can be displayed in a table by simply hovering over the devices (see ***Figure 2***).

Another significant new feature in Virtuoso ADE Explorer is support for process corners and statistical variation simulation. Two options are provided for Monte Carlo analysis: choosing the number of iterations or using Monte Carlo analysis with auto-stop (see ***Figure 3***). Virtuoso ADE also provides advanced tools to analyze the relationship between statistical variation and circuit performance. The Virtuoso Variation option provides contribution analysis. Contribution analysis replaces sensitivity analysis and maps the linear and nonlinear input variations to the output variations (see ***Figure 4***). For example, from the Monte Carlo results, the power supply current (I_{dd}) has a second-order dependency on variation, and the dominate source of variation in the power supply current is rshhip, the sheet resistivity of the high resistance polysilicon. Other views of the data can show other dependencies, for example, which blocks are the source of variation. As designs become more complex, the relationship between cause and effect becomes more difficult for designers to readily identify, and contribution analysis provides a useful tool to identify the core trouble area faster. Back to real-time tuning, contribution analysis can be used to define the parameters to be tuned. The final block-level verification can be run and specification compliance verified (see ***Figure 5***).

ADE ASSEMBLER AND VERIFIER

Virtuoso ADE Assembler provides significant new functionality for design validation, particularly the ability of run plans to run multiple variants of a test bench. For example, to characterize the signal-to-noise + distortion ratio (SINAD) of an analog-to-digital converter (ADC) may require measuring distortion across process, voltage and temperature (PVT) corners and the effect of capacitor mismatch using Monte Carlo analysis. Another common application of Virtuoso ADE Assembler is to validate digitally assisted designs. For example, suppose the designer is using an integrated channel filter for a receiver. The bandpass filter is implemented with five bi-quad sections. The channel filter needs to be controlled to ±1 percent, but the process variation of the on-chip R and C components is 30 percent. The solution is to tune the R and C values in the design to compensate for process variation. Using calibration, we get all the advantages of an off-chip filter with an integrated component. Regular calibration means that the effects of phenomena such as temperature drift are eliminated. In the example shown in ***Figure 6***, the last resonator in a bandpass filter is turned into an oscillator, and the frequency of the oscillator is tuned (see Figure 6c). Tuning is achieved by replacing the capacitor in the filter with capacitor digital-to-analog converters (DAC). Digital control is used to tune the CAPDAC value to the target frequency and then code all the bi-quad sections to be set to the tuned value. An example of tuning the filter is shown in Figure 6d. The filter frequency and filter bandwidth meet the specification after tuning.

Virtuoso ADE Verifier addresses long-standing gaps in the existing design methodologies. ADE Verifier provides requirements management, allowing project managers to visualize the completeness of product validation (see ***Figure 7***). Automotive standards such as ISO26262 and equivalent standards for medical and military/aerospace applications require mapping the system-level requirements to product-level requirements, then showing how the requirements will be tested and compliance validated. Going back to the ADC example discussed earlier, the system-level requirement may be to achieve a SINAD of 60 dB or better at the Nyquist frequen-

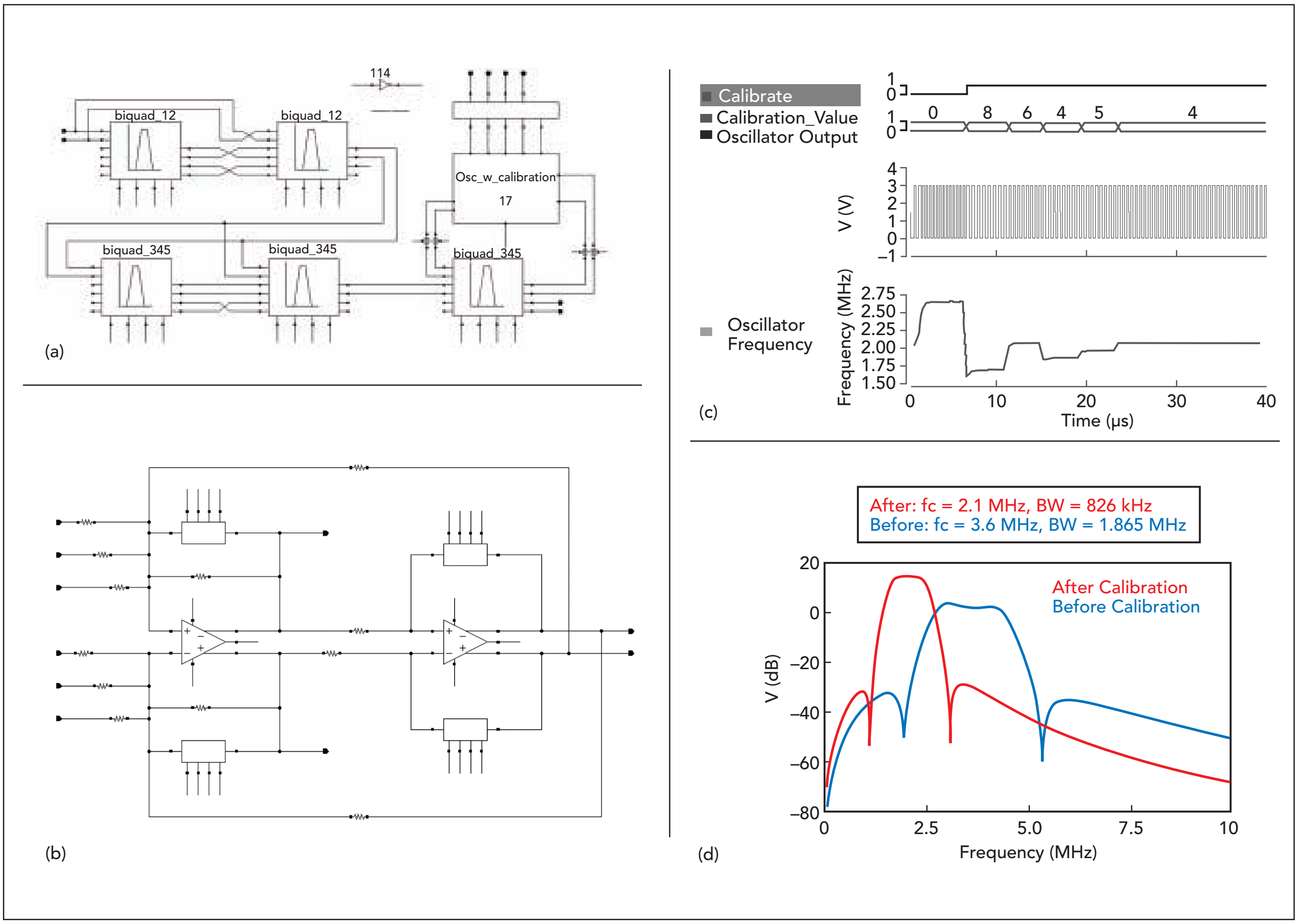


Fig. 6 Channel filter with calibration (a) and bi-quad section with calibration (b). Tuning the oscillator frequency (c), tuning the frequency filter response (d).

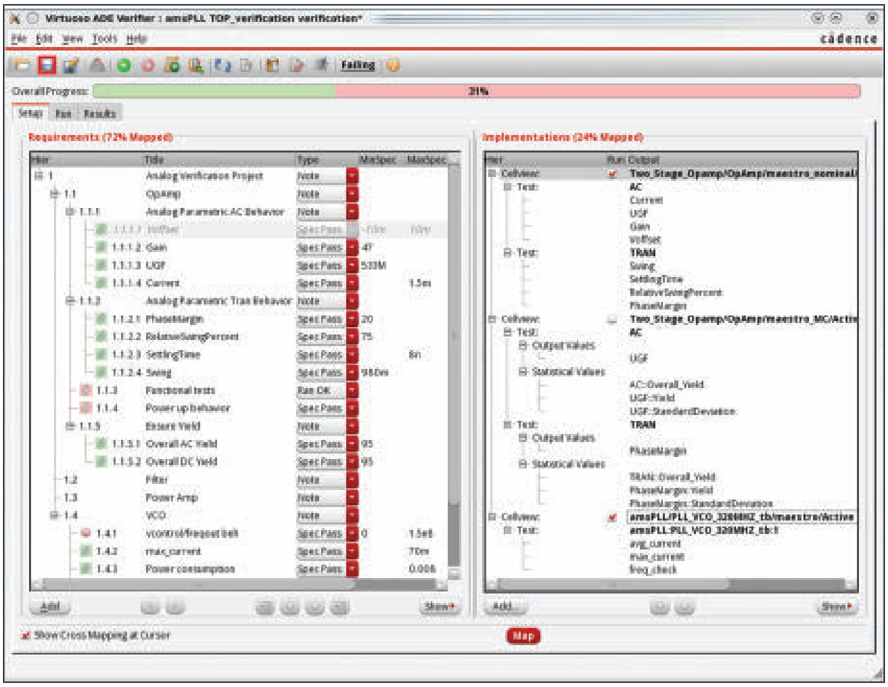


Fig. 7 Virtuoso ADE Verifier.

cy. To calculate the SINAD, several simulations may be required: distortion across PVT corners, comparator noise across process variation, capacitor mismatch across mismatch and others. Virtuoso ADE Assembler provides the first solution for automating the tracking of requirements and the status of a project.

Release IC6.1.7 of Virtuoso ADE brings new technologies that RF and microwave engineers can use to address the challenge of designing and validating 5G and IoT designs. The three new tools—ADE Explorer for design, ADE Assembler for validation and ADE Verifier for oversight—enable product development to be better managed and accelerated.

Cadence Design Systems Inc.
San Jose, Calif.
www.cadence.com

SIX DAYS ■ THREE CONFERENCES ■ ONE EXHIBITION

EUROPEAN MICROWAVE WEEK 2017
NÜRNBERG CONVENTION CENTER,
NUREMBERG, GERMANY
8TH - 13TH OCTOBER 2017

A PRIME YEAR FOR A PRIME EVENT

EUROPEAN MICROWAVE WEEK
NÜRNBERG CONVENTION CENTER
NUREMBERG, GERMANY
8TH-13TH OCTOBER 2017
www.eumweek.com

EUROPEAN MICROWAVE WEEK 2017

REGISTRATION INFORMATION

EUROPE'S PREMIER MICROWAVE, RF, WIRELESS AND RADAR EVENT

REGISTER ONLINE AT:

www.eumweek.com

EuMA European Microwave Association

Organised by: horizon house

Official Publication: Microwave Journal

Co-sponsored by: IEEE

Co-sponsored by: MTT-S

Supported by: IET

Supported by: VDE ITG

EuMIC 2017
The 12th European Microwave Integrated Circuits Conference
Co-sponsored by: GAAS, Electron Devices Society

47TH EUROPEAN MICROWAVE CONFERENCE 2017
The 47th European Microwave Conference
Co-sponsored by: APS, EurAAP, APMC 2017

EuRAD 2017
The 14th European Radar Conference
Co-sponsored by: APS, EurAAP, AESS

EUROPEAN MICROWAVE WEEK
NÜRNBERG CONVENTION CENTER
NUREMBERG, GERMANY
8TH-13TH OCTOBER 2017
www.eumweek.com
A PRIME YEAR FOR A PRIME EVENT

EUROPEAN MICROWAVE WEEK 2017

THE ONLY EUROPEAN EVENT DEDICATED TO THE MICROWAVE AND RF INDUSTRY

The EuMW 2017 team are excited to return to Nuremberg, a uniquely fascinating European city, full of medieval charm. Bringing industry and academia together, European Microwave Week 2017 is a SIX day event, including THREE cutting edge conferences and ONE exciting trade and technology exhibition featuring leading players from across the globe. Concentrating on the needs of engineers, the event showcases the latest trends and developments that are widening the field of applied microwaves. It also offers you the opportunity for face-to-face interaction with those driving the future of microwave technology.

EuMW 2017 will see an estimated 1,700 - 2,000 conference delegates, over 4,000 visitors and in excess of 300 international exhibitors (inc. Asia & US).

REGISTRATION TO THE EXHIBITION IS FREE!

Pivotal to the week is the European Microwave Exhibition, which offers YOU the opportunity to see, first hand, the latest technological developments from global leaders in microwave technology.

The exhibition will provide an unrivalled opportunity for visitors to view and ask questions related to the latest products, components and materials from our extensive selection of international exhibitors. It will also feature exhibitor demonstrations, Industrial Workshops and the annual European Microwave Week Microwave Application Seminars (MicroApps).

- **International Companies** - meet the industry's biggest names and network on a global scale
- **Cutting-edge Technology** - exhibitors showcase the latest product innovations, offer hands-on demonstrations and provide the opportunity to talk technical with the experts
- **Technical Workshops** - get first hand technical advice and guidance from some of the industry's leading innovators

BE THERE

Exhibition Dates	Opening Times
Tuesday 10th October	09:30 - 18:00
Wednesday 11th October	09:30 - 17:30
Thursday 12th October	09:30 - 16:30

FAST TRACK BADGE RETRIEVAL

Entrance to the Exhibition is FREE and attending couldn't be easier.

VISITORS

Registering for the Exhibition

- Register as an Exhibition Visitor online at **www.eumweek.com**
- Receive a confirmation email with barcode
- Bring your barcode with you to the Exhibition
- Go to the Fast Track Check In Desk and print out your visitor badge
- Alternatively, you can register onsite at the self service terminals during the Exhibition

Please note NO visitor badges will be mailed out prior to the Exhibition.

EUROPEAN MICROWAVE WEEK
NÜRNBERG CONVENTION CENTER
NUREMBERG, GERMANY
8TH-13TH OCTOBER 2017
www.eumweek.com
A PRIME YEAR FOR A PRIME EVENT

EUROPEAN MICROWAVE WEEK 2017
THE CONFERENCES

Don't miss Europe's premier microwave conference event. The 2017 week consists of three conferences and associated workshops:

- **European Microwave Integrated Circuits Conference (EuMIC) 9th - 10th October 2017**
- **European Microwave Conference (EuMC) 10th - 12th October 2017**
- **European Radar Conference (EuRAD) 11th - 13th October 2017**
- **Plus Workshops and Short Courses (From 8th October 2017)**
- **In addition, EuMW 2017 will include for the 8th year, the Defence, Security and Space Forum on 11th October 2017**

The three conferences specifically target ground breaking innovation in microwave research through a call for papers explicitly inviting the submission of presentations on the latest trends in the field, driven by industry roadmaps. The result is three superb conferences created from the very best papers. For a detailed description of the conferences, workshops and short courses please visit www.eumweek.com. The full conference programme can be downloaded from there.

FAST TRACK BADGE RETRIEVAL

Register online and print out your badge in seconds onsite at the Fast Track Check In Desk

CONFERENCE PRICES

There are TWO different rates available for the EuMW conferences:

- **ADVANCE DISCOUNTED RATE** – for all registrations up to and including 8th September
- **STANDARD RATE** – for all registrations made after 8th September

Please see the Conference Registration Rates table on the back page for complete pricing information. All payments must be in € Euro – cards will be debited in € Euro.

Online registration is open now, up to and during the event until 13th October 2017

DELEGATES

Registering for the Conference

- Register online at **www.eumweek.com**
- Receive an email receipt with barcode
- Bring your email, barcode and photo ID with you to the event
- Go to the Fast Track Check In Desk and print out your delegate badge
- Alternatively, you can register onsite at the self service terminals during the registration opening times below:

  - Saturday 7th October (16:00 - 19:00)
  - Sunday 8th October (07:30 - 17:00)
  - Monday 9th October (07:30 - 17.00)
  - Tuesday 10th October (07:30 - 17.00)
  - Wednesday 11th October (07:30 - 17.00)
  - Thursday 12th October (07:30 - 17.00)
  - Friday 13th October (07:30 - 10.00)

Once you have collected your badge, you can collect the conference proceedings on USB stick and delegate bag for the conferences from the specified delegate bag area by scanning your badge.

CONFERENCE REGISTRATION INFORMATION

EUROPEAN MICROWAVE WEEK 2017, 8th - 13th October, Nuremberg, Germany

Register Online at www.eumweek.com

ONLINE registration is open from 1st June 2017 up to and during the event until 13th October 2017.
ONSITE registration is open from 16:00 on 7th October 2017.
ADVANCE DISCOUNTED RATE (up to and including 8th September) STANDARD RATE (from 9th September & Onsite).

Reduced rates are offered if you have society membership to any of the following*: Eu*M*A, GAAS, IET or IEEE.

Eu*M*A membership fees: Professional € 25/year, Student € 15/year.

If you register for membership through the EuMW registration system, you will automatically be entitled to discounted member rates.

Reduced Rates for the conferences are also offered if you are a Student/Senior (Full-time students 30 years or younger and Seniors 65 or older as of 13th October 2017).

The fees shown below are invoiced in the name and on behalf of the European Microwave Association. Eu*M*A's supplies of attendance fees in respect of the European Microwave Week 2017 are exempted from German VAT under Article 4 no. 22a German VAT Act.

ADVANCE REGISTRATION CONFERENCE FEES (UP TO AND INCLUDING 8TH SEPT.)

CONFERENCE FEES	ADVANCE DISCOUNTED RATE			
	Society Member (*any of above)		Non Member	
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.
EuMC	€ 470	€ 130	€ 660	€ 190
EuMIC	€ 360	€ 120	€ 510	€ 170
EuRAD	€ 320	€ 110	€ 450	€ 160
2 Conferences				
EuMC + EuMIC	€ 670	€ 250	€ 940	€ 360
EuMC + EuRAD	€ 640	€ 240	€ 890	€ 350
EuMIC + EuRAD	€ 550	€ 230	€ 770	€ 330
3 Conferences				
EuMC + EuMIC + EuRAD	€ 810	€ 360	€ 1140	€ 520

STANDARD REGISTRATION CONFERENCE FEES (FROM 9TH SEPT. AND ONSITE)

CONFERENCE FEES	STANDARD RATE			
	Society Member (*any of above)		Non Member	
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.
EuMC	€ 660	€ 190	€ 930	€ 270
EuMIC	€ 510	€ 170	€ 720	€ 240
EuRAD	€ 450	€ 160	€ 630	€ 230
2 Conferences				
EuMC + EuMIC	€ 940	€ 360	€ 1320	€ 510
EuMC + EuRAD	€ 890	€ 350	€ 1250	€ 500
EuMIC + EuRAD	€ 770	€ 330	€ 1080	€ 470
3 Conferences				
EuMC + EuMIC + EuRAD	€ 1140	€ 520	€ 1600	€ 740

WORKSHOP AND SHORT COURSE FEES (ONE STANDARD RATE THROUGHOUT)

FEES	STANDARD RATE			
	Society Member (*any of above)		Non Member	
	Standard	Student/Sr.	Standard	Student/Sr.
Half day WITH Conference registration	€ 100	€ 80	€ 130	€ 100
Half day WITHOUT Conference registration	€ 130	€ 100	€ 170	€ 130
Full day WITH Conference registration	€ 140	€ 110	€ 180	€ 130
Full day WITHOUT Conference registration	€ 180	€ 140	€ 240	€ 170

Other Items

STATE RECEPTION – 11TH OCT 2017

Tickets for the State Reception are free, but are limited. They are available for delegates on a first-come, first-served basis.

Proceedings on USB Stick

All papers published for presentation at each conference will be on a USB stick, given out FREE with the delegate bags to those attending conferences. The cost for an additional USB stick is € 50.

International Journal of Microwave and Wireless Technologies (8 issues per year)

International Journal combined with Eu*M*A membership:
€ 67 for Professionals or € 57 for Students.

Partner Programme and Social Events

Full details and contacts for the Partner Programme and other Social Events can be obtained via the EuMW website www.eumweek.com.

EUROPEAN MICROWAVE WEEK WORKSHOPS & SHORT COURSES

SUNDAY 8th October		
Half Day	SS-01	EuMC
Full Day	WS-01	EuMC
Full Day	WS-02	EuMC/EuMIC
Full Day	WS-03	EuMC
Full Day	WS-04	EuMC
Full Day	WS-05	EuMC/EuMIC
Full Day	WS-06	EuMC/EuMIC
Full Day	WS-07	EuMC
Full Day	WS-08	EuMC/EuMIC
Full Day	WS-09	EuMC/EuMIC
Full Day	WS-10	EuMC
Full Day	WS-11	EuMC
Half Day	WS-12	EuMC
Full Day	WS-13	EuMC
Half Day	WS-14	EuMC
Half Day	WS-15	EuMC

MONDAY 9th October		
Full Day	WM-01	EuMC
Full Day	WM-02	EuMC
Full Day	WM-03	EuMC
Half Day	WM-04	EuMC
Half Day	WM-05	EuMC
Half Day	WM-06	EuMC
Half Day	WM-07	EuMC
Full Day	WM-08	EuMC

TUESDAY 10th October		
Full Day	WTu-01	EuMC/EuMIC

WEDNESDAY 11th October		
Half Day	SW-01	EuMC/EuRAD
Half Day	WW-01	EuMC
Half Day	WW-02	EuMIC/EuRAD
Half Day	WW-03	EuMC/EuMIC

THURSDAY 12th October		
Half Day	WTh-01	EuMC/EuRAD
Full Day	WTh-02	EuRAD
Full Day	WTh-03	EuMC/EuMIC

FRIDAY 13th October		
Full Day	SF-01	EuRAD
Half Day	SF-02	EuMC/EuRAD
Half Day	SF-03	EuRAD
Full Day	WF-01	EuRAD
Half Day	WF-02	EuMC
Half Day	WF-03	EuMC/EuRAD
Half Day	WF-04	EuRAD
Full Day	WF-05	EuMC
Full Day	WF-06	EuMC/EuRAD
Half Day	WF-07	EuMC/EuRAD
Half Day	WF-08	EuMC/EuRAD

SPECIAL FORUMS & SESSIONS

Date	Time	Title	Location	No. of Days	Fee	
Wednesday 11th October	08:30 - 18:30	Defence, Security & Space Forum	St. Petersburg	1	€ 20 for delegates (those registered for EuMC, EuMIC or EuRAD)	€ 60 for all others (those not registered for a conference)
Monday 9th - Wednesday 11th October	08:30 - 17:50	European Microwave Student School	Neu Delhi	3	€ 40	
Monday 9th - Wednesday 11th October	08:30 - 17:50	European Microwave Doctoral School	Singapur	3	€ 80	

5 MHz to 40 GHz Signal Source Analyzer

The Berkeley Nucleonics BNC 7340 signal source analyzer performs a wide range of amplitude and phase measurements, with its core function a phase noise analyzer. Covering 5 MHz to 40 GHz, the 7340 was designed to evaluate signal sources such as crystal oscillators, phase-locked loop synthesizers, clocks, phase-locked or free-running voltage-controlled oscillators (VCO), dielectric resonator oscillators (DRO), SAW and YIG oscillators. It measures absolute and residual phase noise, pulsed phase noise, amplitude noise and performs time domain transient and spectrum analysis. It can be used as a VCO test bench to measure tuning, pushing, phase noise, current and power.

The analyzer comprises a two-channel cross-correlation system with two internal tunable references sources, with the capability to use external references. The architecture enables the 7340 to perform cross-correlation fast Fourier transform (FFT) analysis of signals. The unit includes an integrated frequency counter, power detector, two programmable low noise DC supplies (up to 14 V and 600 mA) and three low noise tuning voltages (−5 to +22 V).

The 7340 reflects BNC's philosophy of using a PC and an intuitive graphical user interface to control the instrument and display the measurement results. An external PC reduces the cost of entry, provides measurement flexibility and simplifies software upgrades. Computer interfaces include LAN (VXI-11), USBTMC or, optionally, GPIB. A powerful SCPI (standard commands for programmable instruments) command language set is available for controlling the instrument and automating test routines. Combining the 7340's hardware design with BNC's API library enables toolsets for many device types and measurements, and the fast analysis time increases test capacity for production applications.

The BNC 7340 signal source analyzer reflects BNC's reputation for technical excellence and customer service.

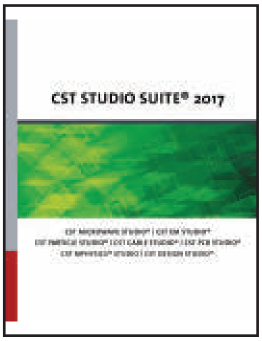
VENDORVIEW

Berkeley Nucleonics Corp.
San Rafael, Calif.
www.berkeleynucleonics.com

CatalogUpdate

CST STUDIO SUITE 2017® Brochure

VENDORVIEW



The latest brochure for CST STUDIO SUITE 2017® is now available. It provides a comprehensive overview of the company's solvers, as well as the applications and markets for which CST STUDIO SUITE® 2017 is an indispensable tool. With CST's signature visuals you can see how simulation can be used to improve the design process, allowing you to anticipate issues before prototyping even begins. To learn more, visit their website and download a digital version of the brochure.

Computer Simulation Technology
www.cst.com/products/csts2

New Corporate Capabilities Catalog

VENDORVIEW

Empower RF Systems is the technological leader in smart power amplifier solutions for EW, threat simulation, radar, communications, EMC and product test. Incorporating the latest semiconductor and power combining technologies with a patented architecture, Empower RF builds the most sophisticated and flexible COTS system amplifiers in the world. In addition to best-in-class SWaP, their next generation amplifiers have sophisticated RF detection to maximize efficiency for a variety of modulation schemes including QAM-xx, OFDM, multi-tone, pulse, AM, FM and more.

Empower RF Systems
www.empowerrf.com/download/Empower_Catalog_2017.pdf

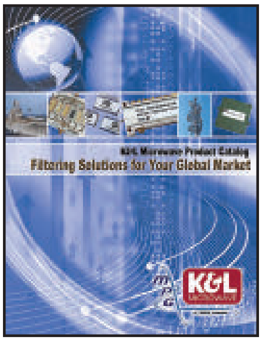
Updated Catalog with New Solutions

VENDORVIEW

HUBER+SUHNER offers a wide range of RF connectors for various applications. The products are used in markets like radio base stations, medical, space, defense and other industries. The product portfolio is being constantly refined. Additionally, HUBER+SUHNER supports its customers worldwide with application engineers, helping the customers in selecting the right product for each specific application.

HUBER+SUHNER
https://literature.hubersuhner.com/Technologies/Radiofrequency/RFConnectorsEN/

K&L Microwave Catalog Update



K&L designs and manufactures a full line of RF and microwave filters, duplexers and subassemblies, including ceramic, lumped element, cavity, waveguide and tunable filters. The catalog shows filter responses, loss calculations and standard packages for all products. K&L supplies many of today's most significant military and homeland security electronics programs. Applications include space flight, radar, communications, guidance systems and mobile radio base stations, as well as air traffic communication and control. Visit their website to download the complete catalog.

K&L Microwave
www.klmicrowave.com

Test Solutions Product Guide

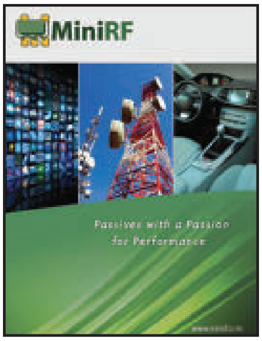
VENDORVIEW

Rapid growth in the number and variety of wireless applications and connected devices in the market has driven the need for more innovative and highly customized test solutions. Customers are looking for equipment to multiplex application-specific test systems across multiple DUTs, which requires signal routing, distribution and conditioning functions in a variety of configurations. This 2017 Test Solutions Product Guide showcases some of the company's newest, most advanced and most popular test systems developed to date.

Mini-Circuits
www.minicircuits.com

2017 Catalog Announcement

VENDORVIEW



MiniRF is dedicated to providing quality RF passive components at competitive prices for existing and emerging broadband/CATV and wireless communications systems. MiniRF is a proven leader in supplying high performance surface mount passive components. MiniRF components are found in the products of many of the world's largest suppliers of communications products with nearly a billion units shipped.

MiniRF
www.minirf.com

EDI CON Electronic Design Innovation Conference & Exhibition

Where high frequency meets high speed.

September 11-13, 2017
Hynes Convention Center
Boston, MA

EDI CON USA BY THE NUMBERS

We've promised you great education, training and networking at the 2017 Electronic Design Innovation Conference (EDI CON) USA. But don't just take our word for it! Let data from last year's inaugural event do the talking.

1,400 Attendees

15 Countries and **35** US States

REPRESENTED

"Excellent show layout. Easy to find exhibitors. You had a lot of major companies that make it worthwhile coming to the show floor."

95% Rated as Good or Excellent

"It is wonderful to have so many specialists in one place. You can get your problems solved. This is a great conference."

117 Sessions/ Workshops

"Great show. Different from other ones because the sessions were not full of marketing information, but real useful information."

96 Industry Expert Speakers

"The sessions were well planned and well attended."

149 Exhibitors

Join the Industry Revolution and Register Now
www.ediconusa.com

NEW PRODUCTS

FOR MORE NEW PRODUCTS, VISIT WWW.MWJOURNAL.COM/BUYERSGUIDE
FEATURING VENDORVIEW STOREFRONTS

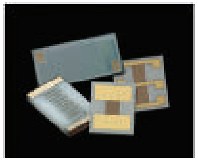
COMPONENTS

5G IPD RF Filters

3D Glass Solutions Inc., a world-class expert on the fabrication of electronic packages and devices using photo-definable glass-ceramics, announced the development and production of the highest efficiency 5G integrated passive devices (IPD) for radio frequency (RF) filters. These RF filters have been designed to operate as bandpass filters for frequencies at 5 and 28 GHz with less than 1 dB of insertion loss. 3DGS' 5G RF filters are manufactured using APEX® Glass, a material which has significant benefits over legacy PCB materials.

3D Glass Solutions
www.3dglasssolutions.com

Wire-Bondable and Edge-Terminated Resistors



For years our customers asked us to bring our short lead times, outstanding customer service and quality focus to the thin film resistor industry. As is the Compex way, we listened. Compex is excited to announce it now offers a full line of wire-bondable and edge-terminated resistors built to its customer's exact specifications. Available alternatives include single, dual, center-tap, array and custom configurations. Compex would be happy to provide samples to ensure you have the right parts for your needs.

Compex Corp.
www.compexcorp.com

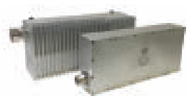
Multiposition Switches

Dow-Key® Microwave, the world's largest manufacturer of electromechanical switches, provides an extensive selection of multiposition switches for a variety of ATE applications ranging from SP3T to SP14T. Characteristics include a standard design of 1 million life cycles; 2 million for 5 x 5 series and 5 million for Reliant SP6T. Coil voltages of 12, 24 and 28 V are available and operate from DC to 26.5 GHz. Various control options are offered and may also be designed with RoHS compliance.

Dow-Key Microwave
www.dowkey.com

3 dB Low PIM Attenuators

VENDORVIEW

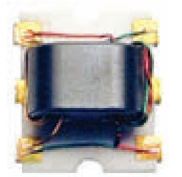


MECA also offers low PIM 3 dB attenuators in both 50 and 100 W models with a typical PIM spec of 161 dBc. They feature a variety of connector styles and configuration within series and between series configurations in: 4.1/9.5, 7/16 and type N as well as 4.3/10.0 DIN connectors, while handling full rated power to +85°C. All of the terminations operate covering 0.698 to 2.7 GHz frequency bands, VSWR = 1.10:1 Typ./1.20:1 Min. Made in the U.S. and 36-month warranty.

MECA Electronics Inc.
www.e-MECA.com

Transformer

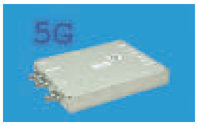
VENDORVIEW



The MRFXF5702 transformer is designed for applications that require very small, low cost and highly reliable surface mount components. Applications may be found in broadband, wireless and other communications systems. These units are built lead-free and RoHS compliant and feature welded wire construction for increased reliability. S-Parameters are available on request.

MiniRF
www.minirf.com

Down Converter



Norden Millimeter's down converter converts 26 to 50 GHz down to 4 to 18 GHz to extend the range of lower cost test equipment. Norden can add gain, inter-stage filtering and bypass switching stages to the custom assemblies. Norden Millimeter continues as the leader in components used in the 5G market. Norden products can be used to quickly and cost effectively, build mmWave system prototypes which demonstrate the viability and feasibility of the technology.

Norden Millimeter
www.NordenGroup.com

Waveguide Electromechanical Relay Switches

VENDORVIEW

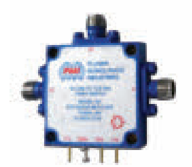
Pasternack has introduced 28 new waveguide electromechanical relay switches that offer full waveguide performance covering C, X, Ku, K and Ka frequency bands from 5.85 to 40 GHz. They are ideal for applications that include electronic warfare, electronic countermeasures, microwave radio, VSAT, SATCOM, radar, research and development, space systems and test instrumentation. Pasternack's new waveguide electromechanical relay switches are configured for single-pole double-throw (SPDT) operation with latching self-cut-off actuators, TTL logic and position indicators with manual override.

Pasternack
www.pasternack.com

2-Way High-Power Switch

VENDORVIEW

PMI Model No. PDT-8G12G-40-515-SFF is an 8 to 12 GHz, 2-way high-power switch that



has an insertion loss of 2 dB maximum and a VSWR of 1.8:1 maximum. The operating power is +40 dBm CW average, +57 dBm 1 µs, 1 percent duty cycle with an isolation of 40 dB minimum. Switching speed 200 ns maximum - measured 100 ns, power supply requirements +5 V at 100 mA and -15 V at 60 mA.

Planar Monolithics Industries Inc.
www.pmi-rf.com

Electro-Mechanical Switch

RF-Lambda multiport switch improves insertion loss repeatability and isolation, which is necessary for higher performance test systems. The repeatability and reliability of this switch is vital to ATS measurement accuracy and can cut the cost of ownership by reducing calibration cycles and increasing test system up time. The RF-Lambda terminated multiport switch provides the long life and reliability required for automated test and measurement, signal monitoring and routing applications. Highly repeatable switching capability is made possible through RF-Lambda's rigorous design and tight manufacturing specifications.

RF-Lambda
www.rflambda.com

6-Bit Digital Attenuator

VENDORVIEW

RFMW Ltd. announces design and sales support for Qorvo's TGL2226-SM, a 6-bit, digital attenuator. With frequency coverage from 100 MHz to 15 GHz, the TGL2226-SM provides 0.5 dB least significant bit size for a range of 31.5 dB. Serving diverse markets such as radar, electronic warfare, satellite and point-to-point communication systems, this digital step attenuator is offered in a 3 mm x 3 mm QFN package for surface mount designs. Control voltage is -3 to -5 V.

RFMW Ltd.
www.rfmw.com

Absorptive Bessel Filters to 30 GHz

RLC Electronics' 4th Order Absorptive Bessel Filters provide the excellent group delay response of Bessel filters, while maintaining impedance matching far into the stopband. Resistive elements are designed into these filters, resulting in a response that closely mimics the classic Bessel in both amplitude and phase. These filters are used in digital systems where truthful reproduction of waveforms is important. These filters are now available with -3 dB cut off frequencies as high as 30 GHz. A surface mount configuration is available to 4 GHz.

RLC Electronics Inc.
www.rlcelectronics.com

Wideband Small Size 2-Way Power Divider

The SDL-100 is a RoHS surface mount 2-way power divider operating in the frequency range of 2 to 1000 MHz. This device combines wide bandwidth and high performance in a compact size, 0.300 in × 0.385 in × 0.200 in and operates in the temperature range of -40°C to 85°C. Product features include input power of 1 W (Max.), insertion loss of 1.2 dB (Typ.)/1.5 dB (Max.), an isolation of 23 dB (Typ.)/17 dB (Min.), amplitude unbalance of 0.6 dB (Max.) and phase unbalance of 4 degrees (Max.) in the band of 500 to 1000 MHz with better performance in the lower part of the frequency band.

Synergy Microwave Corp.
www.synergymwave.com

CABLES & CONNECTORS

SUCOFLEX

VENDORVIEW

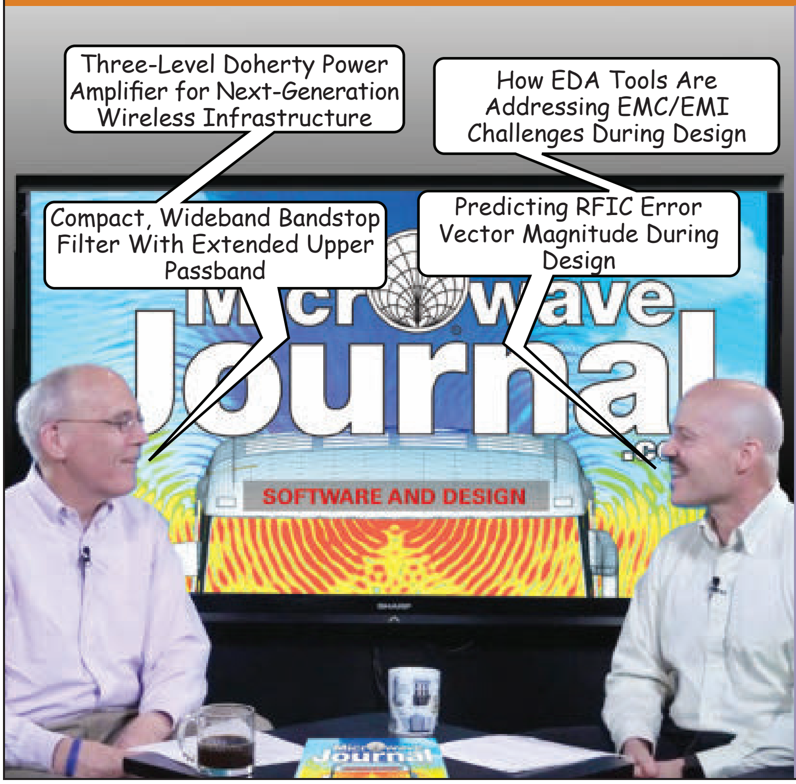
HUBER+SUHNER has developed the SUCOFLEX 526S top performance cable assembly for various applications in its test laboratories. When it comes to test and measurement, SUCOFLEX 526S assemblies guarantee the highest level of satisfaction. Thanks to their unique cable and connector design, they deliver best-in-class phase and amplitude stability vs. flexure in combination with excellent return and insertion loss up to 26.5 GHz.

HUBER+SUHNER
www.hubersuhner.com

110 GHz Cable Assemblies

MegaPhase offers its Mega110 products with 1 mm connectors in both semi-rigid and flexible cable assemblies. Its light-weight 110 GHz cable assemblies are specifically designed for the demands of high-bandwidth applications such as automotive radar, probe stations and mobile backhaul. Visit MegaPhase's website to review its data sheets.

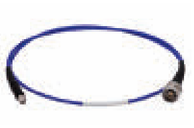
MegaPhase
www.megaphase.com/rf/110



Ultra-Flexible SMA-M to N-M Test Cables, DC to 18 GHz

VENDORVIEW

Mini-Circuits' ULC-2FT-SMNM+ ultra-flexible test cable provides low insertion loss (0.3 to 1.5 dB) and excellent return loss (18 to 24 dB) for a wide range of test applications from DC to 18 GHz. These cables are specially designed for stability of phase and amplitude versus flexure in bend radii as tight as 2 in (2.0 in minimum dynamic bend radius, 0.7 in minimum static bend radius), making them ideal for demanding lab environments where frequent bending is common.



Mini-Circuits
www.minicircuits.com

SPINNER EasyDocks Now Even Better

VENDORVIEW

A new, improved SPINNER EasyDock version is now available for you to take advantage of. The older version had to be slid onto the DUT first and then locked in a second step. The advantage of the new version is that it does both at the same time: it locks the moment you slide it home, without the need to apply pressure in a different place in a second step. Its design has also been made more ergonomic for easier holding and use, thus reducing fatigue.

SPINNER
www.spinner-group.com

Tin-Dipped Surface Mount and Edge Launch Connectors

SV Microwave now offers tin-dipped surface mount and edge launch connectors that make the soldering process fast and easy. These surface mount and edge launch PCB connectors also provide increased solder joint durability while preventing rust, corrosion and oxidization. Connectors' part numbers are denoted with a "-TD". Readily available through distribution.

SV Microwave
www.svmicrowave.com

DC to 50 GHz Vertical Launch Connectors

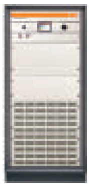
The new vertical launch connectors are specially designed for solderless vertical PCB launch on test and measurement boards. They are claimed to have excellent electrical transition performance up to 50 GHz. The connectors also reduce installation time by eliminating soldering. As well as test and measurement boards another key application is high speed digital test boards.

Withwave
www.with-wave.com

AMPLIFIERS

Single Band Amplifiers Cover 0.7 to 6 GHz Frequency Band

VENDORVIEW



The new 60S1G6 and 500S1G6 are 60 and 500 W CW solid-state amplifiers that have 48 and 57 dB gain, respectively. Both deliver 100 percent rated output power without foldback over the instantaneous 0.7 to 6 GHz band and can survive ∞:1 output VSWR. Applications include radiated susceptibility testing, EW jammers and wireless system and device stress screening tests.

AR RF/Microwave Instrumentation
https://www.arworld.us/html/0.7to6GHz.asp

Wideband Low Phase Noise Amplifier

VENDORVIEW

Custom MMIC, a leading developer of performance driven monolithic microwave integrated circuits (MMIC), has added a new category to their rapidly expanding standard product

offerings. Custom MMIC's new GaAs MMIC low phase noise amplifier family offers previously unattained phase noise performance. Phase noise is a critical requirement which defines the performance level of most radars and communications systems. The five product family achieves phase noise performance as low as -165 dBc/Hz at 10 kHz offset.
Custom MMIC
www.custommmic.com

0.01 to 20 GHz RF Power Amplifier Module

Richardson RFPD Inc. announced the availability and full design support capabilities for a new ultra-wideband power amplifier module from Analog Devices Inc. The HMC-C582 is a GaAs MMIC PHEMT power amplifier in a miniature, hermetic module with replaceable SMA connectors that operates between 0.01 GHz and 20 GHz. The device typically provides 24 dB of gain, up to +36 dBm output IP3, and up to +26 dBm of output power at 1 dB gain compression.
Richardson RFPD
www.richardsonrfpd.com

SEMICONDUCTORS

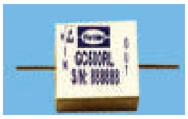
Schottky Detector Diodes

VENDORVIEW

SemiGen Inc., an ISO and ITAR registered RF/microwave assembly, automated PCB manufacturing and RF supply center, has added a series of new Zero Bias Schottky Detector Diodes to its expanding product offerings. SemiGen's SZB900 series of Zero Bias Schottky Detector Diodes are catered to perform as components of video detectors and power monitors, eliminating the need for external DC biasing. This series of schottky diodes features low junction capacitances, high voltage sensitivity, uniform video resistances and high sensitivity, all without external bias circuitry.
SemiGen Inc.
www.semigen.net

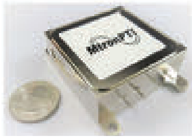
SOURCES

Expanded Pre-Amp Comb Generator



Herotek's new 0.750 in (N3 package) long surface mount package for convenient placement on PCB Boards. Excellent for frequency multipliers, frequency synthesizers and built-in test source. GCA Series requires only +10 or 0 dBm input for input frequency ranges from 250 to 2000 MHz. The company's GC Series (without preamp) also is offered in its "L" package which is 0.53 in long.
Herotek
www.herotek.com

Low G-Sensitivity OCXO



MtronPTI announced XO5503 Series low G-sensitivity OCXO with vibration compensation for military and radar application. XO5503 is designed for application where superior performance is required under high vibration environment. In military communications and radar applications, reliability comes first. The communication link must stay up; the picture must be clear even when conditions are less than ideal.
MtronPTI
www.mtronpti.com

New**Products**

W-Band Varactor Tuned Gunn Oscillator

VENDORVIEW

For communication, radar and test applications, SAGE Millimeter has released a new W-Band varactor tuned Gunn oscillator. Model SOV-94306310-10-G1 utilizes a high-performance GaAs Gunn diode and proprietary cavity design to deliver +13 dBm typical power. The oscillator features a Varactor tuning range of ±3 GHz and delivers low AM/FM noise and harmonic emissions. Compared to its counterparts, such as multiplier based sources, the Gunn oscillator is a lower cost and cleaner source.

SAGE Millimeter
www.sagemillimeter.com

SOFTWARE

COMPLETE Library Release v17.0

VENDORVIEW

Modelithics Inc. announced the latest release, of the Modelithics® COMPLETE Library version 17.0 for use with the Keysight EEsof EDA Advanced Design System (ADS) simulation software. This release marks another big milestone with over 15,000 commercial electronic components from over 65 different vendors now represented in the COMPLETE Library of advanced simulation models. The version 17.0 release contains 34 new models, in addition to the already extensive collection of high accuracy, scalable parasitic simulation models.

Modelithics Inc.
www.modelithics.com

ANTENNAS

5G Phased Array Active Antenna

VENDORVIEW

Anokiwave Inc., an innovative company providing highly integrated IC solutions for mmW markets and active antenna based solutions, announced the introduction of the first in a family of phased array antenna innovator's kits, the AWMF-0129, driven by the Anokiwave AWMF-0108 28GHz 5G Quad Core IC with embedded functions for remote telemetry and low-latency steering™. The AWMF-0129 is a 64-element, single polarization 5G phased array antenna designed to cover the 27.5 to 30 GHz frequency band.

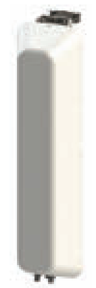
Anokiwave Inc.
www.anokiwave.com

MICRO-ADS

NewProducts

S- & C-Band MIMO Sector Antenna

VENDORVIEW



Southwest Antennas' new S- and C-Band MIMO sector antenna feature 120 degrees of horizontal beamwidth, allowing for wide area coverage. 45 degree left/right slant polarization provides polarization and spatial diversity for connected radios. Designed for 2 × 2 MIMO radio systems, these sector antennas are offered in 2.2 to 2.5 GHz S-Band and frequency options, for ISM / broadcast video and law enforcement use. The antenna features 12 dBi of minimum gain across the entire operating band.

Southwest Antennas
www.southwestantennas.com

TEST EQUIPMENT

VNA Microwave/RF Test Assemblies

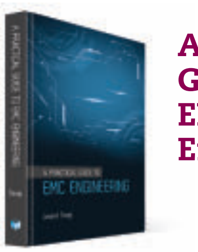
W. L. Gore & Associates has expanded the functional frequency range of its "FF series" GORE® VNA Microwave/RF test assemblies, now offering stable, reliable performance up to 70 GHz. This upgrade addresses industry requirements for enhanced performance in the 60-70 GHz range where there is increased need to maintain measurement accuracy, especially in Vector Network Analyzers (VNAs), communication testing, and mm-wave to name a few key applications.

W. L. Gore & Associates
www.gore.com

ERRATUM

The article "Network Synthesis and Power Amplifiers: So Much More than Impedance Matching," written by Gayle Collins and published in the June 2017 issue, should include the following reference to the author's paper at the 2015 IEEE MTT-S International Microwave Symposium:

20. G. F. Collins, "Network Synthesis of Power Amplifier Matching Circuits - Standing on the Shoulders of Giants," 2015 IEEE MTT-S International Microwave Symposium, Phoenix, Ariz., 2015, pp. 1-3.



A Practical Guide to EMC Engineering

Levent Sevgi

With the explosive growth of wireless and the attendant complexity of wireless systems, electromagnetic compatibility (EMC) has metaphorically moved from a seat at the back of the room to sitting at the table with the other development disciplines. Fortunately, the evolving capability of electromagnetic (EM) software has strengthened EMC engineering so it is not strictly "magic," yet mastering it—if that is possible—requires extensive experience.

Levent Sevgi, who has worked with electromagnetics for almost three decades, wrote this book to address the breadth of EMC engineering topics that are not covered by more specialized texts: market control, accreditation, calibration, EMC testing and measurement and mitigation. The 10 chapters are organized to address 1) basic concepts, governing bodies and standards; 2) accreditation; 3) EM modeling; 4) circuit modeling, including grounding; 5) antennas and their calibration; 6) noise and frequency analysis; 7) EMC test and measurement environments; 8) EMC test and measurement devices; 9) EMC tests and measurements; and 10) mitigation of potential EMC problems (i.e., filtering, screening, cabling, grounding and impedance matching). Each chapter concludes with an extensive list of references, enabling readers to delve into any of the topics. The book contains practical design tips and more than 20 MATLAB scripts to help readers implement the concepts.

Slightly paraphrasing what Sevgi tells students of his EMC courses, "I'm not going to solve your problems; you're going to do that! What I'll do is mostly fill in the gaps of your knowledge and experience. I'm going to revisit everything you learned in your university education and teach you how to look at them with the eye of an EMC engineer. I'm quite sure that at the end of the course you will learn how to diagnose and solve your problem. That would be the success of the course." That would also be the success of this book.

To order the book:

Published by Artech House
www.artechhouse.com
ISBN: 978-1-63081-383-3
316 pages
$159, Print or eBook

E LEARNING CENTER

Presented by: Microwave Journal

July Short Course Webinars

Technical Education Training.............................. 7/25

Technology and Market Outlook for Next Generation MilSatComs

Sponsored by: Rohde & Schwarz and Wolfspeed

Register to attend at mwjournal.com/webinars

Past Webinars On Demand

MIMO Radars and Their Conventional Equivalents

Sponsored by: ROHDE&SCHWARZ

Presented by: Dr. Eli Brookner

microwavejournal.com/events/1636

Design Considerations and Tradeoffs for Microstrip, Coplanar and Stripline Structures at Millimeter-Wave Frequencies

Sponsored by: ROGERS CORPORATION

microwavejournal.com/events

Getting to Know 5G: New Radio and the Race to Standardization

Sponsored by: NATIONAL INSTRUMENTS

microwavejournal.com/events

Countering the UAS Challenge

Sponsored by: ROHDE&SCHWARZ

microwavejournal.com/events

Demystifying 5G – Numerology and Initial Access Concept for 5G NR

Sponsored by: ROHDE&SCHWARZ

microwavejournal.com/events

New Connectors for High-Speed Applications

Sponsored by: CST

signalintegrityjournal.com/events

Advertising**Index**

Sales Representatives

Frequency Matters.

Eastern and Central Time Zones
Chuck Boyd
Northeast Reg. Sales Mgr.
(New England, New York, Eastern Canada)
685 Canton Street
Norwood, MA 02062
Tel: (781) 619-1942
FAX: (781) 769-5037
cboyd@mwjournal.com

Michael Hallman
Eastern Reg. Sales Mgr.
(NJ, Mid-Atlantic, Southeast, Midwest, TX)
4 Valley View Court
Middletown, MD 21769
Tel: (301) 371-8830
FAX: (301) 371-8832
mhallman@mwjournal.com

Pacific and Mountain Time Zones
Brian Landy
Western Reg. Sales Mgr.
(CA, AZ, OR, WA, ID, NV, UT, NM, CO, WY, MT, ND, SD, NE & Western Canada)
144 Segre Place
Santa Cruz, CA 95060
Tel: (831) 426-4143
FAX: (831) 515-5444
blandy@mwjournal.com

International Sales
Richard Vaughan
International Sales Manager
16 Sussex Street
London SW1V 4RW, England
Tel: +44 207 596 8742
FAX: +44 207 596 8749
rvaughan@horizonhouse.co.uk

Germany, Austria, and Switzerland (German-speaking)
WMS.Werbe- und Media Service
Brigitte Beranek
Gerhart-Hauptmann-Street 33,
D-72574 Bad Urach
Germany
Tel: +49 7125 407 31 18
FAX: +49 7125 407 31 08
bberanek@horizonhouse.com

Korea
Young-Seoh Chinn
JES Media International
2nd Floor, ANA Bldg.
257-1, Myungil-Dong
Kangdong-Gu
Seoul, 134-070 Korea
Tel: +82 2 481-3411
FAX: +82 2 481-3414
yschinn@horizonhouse.com

China
Shenzhen
Michael Tsui
ACT International
Tel: 86-755-25988571
FAX: 86-10-58607751
michaelt@actintl.com.hk

Shanghai
Linda Li
ACT International
Tel: 86-21-62511200
lindal@actintl.com.hk

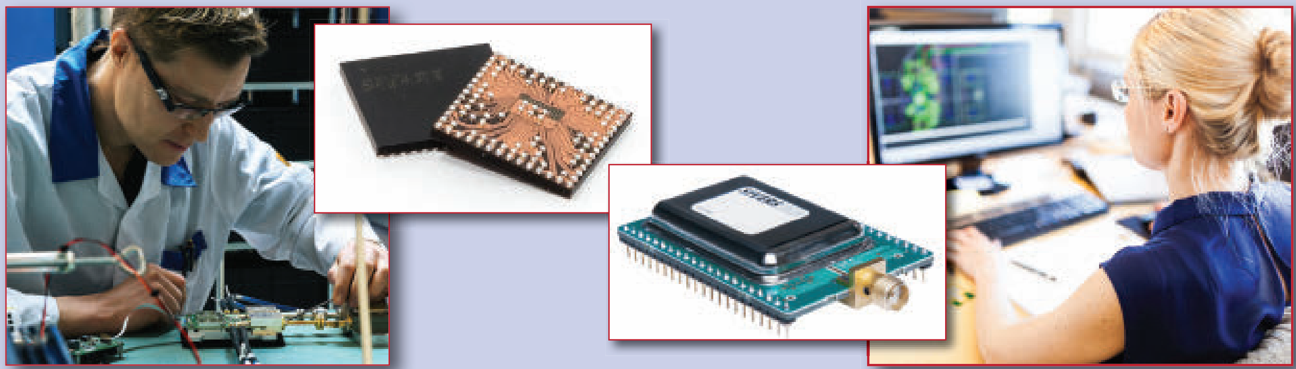
Beijing
Cecily Bian
ACT International
Tel: +86 135 5262 1310
cecilyb@actintl.com.hk

Hong Kong, Taiwan, Singapore
Mark Mak
ACT International
Tel: 852-28386298
markm@actintl.com.hk

Japan
Katsuhiro Ishii
Ace Media Service Inc.
12-6, 4-Chome,
Nishiiko, Adachi-Ku
Tokyo 121-0824, Japan
Tel: +81 3 5691 3335
FAX: +81 3 5691 3336
amskatsu@dream.com

Ed Kiessling • Traffic Manager/Inside Sales • 685 Canton Street Norwood, MA 02062 • Tel: (781) 619-1963 FAX: (781) 769-6178 • ekiessling@mwjournal.com

Sivers IMA–Developing Advanced Millimeter Wave Technology



Sivers IMA is a leading developer and manufacturer of microwave and millimeter wave (mmWave) products with more than 60 years of accumulated innovation. The Sivers story began in 1951 when a Swedish engineer, Carl von Sivers, who had a passion for and a belief in microwave and mmWave technology, founded Sivers Lab AB in Stockholm. The company's development attracted outside interest and Philips, Sweden acquired Sivers Lab AB in 1960, adding active circuits and signal sources to the product line.

In 1983, Philips, Sweden acquired IMA AB, another Stockholm-based company, which produced microwave components, hybrid products and high stability local oscillators for radars, merging it with Sivers Lab to form Sivers IMA. The Sivers Lab part was later acquired by Cobham.

In 1990, the decision was taken for Sivers IMA to approach the market as an independent supplier. SI Holding AB was created from a management buy-out from Philips. A year later, Sivers IMA took up residence in its present headquarters in the Kista district of Stockholm, where the management, research and development and sales and marketing are based. Facilities include a 200 square meter laboratory for prototyping and small volume production, and a clean room of around 270 square meters.

Sivers IMA has an additional sales office and R&D department in Gothenburg that houses a 140 square meter laboratory. The company has also established itself as a global player in the mmWave sector, which, in part, is serviced by high volume production partners in Asia.

The business is currently divided into three product categories. The first is converters and customized transceivers, including mmWave products for E- and V-Band radio links and WiGig products. In the radar sensors sector, the company is developing its radar product offering to include signal processing, with the third category being signal sources.

Sivers IMA serves the worldwide market with reliable products through the development of advanced technology. It is at the forefront of innovation, with an example being the introduction last year of a fully integrated V-Band transceiver RFIC in an advanced low-cost SiGe technology. Another stepping stone in the technology development of Sivers IMA´s products is the beamforming WiGig transceiver RFIC, which is currently being validated.

Throughout the company, the emphasis is on quality. Sivers IMA is ISO 9001:2008 certified and its quality system is an integral part of the management methodology. Quality improvements are actively pursued through programs aimed at enabling each employee to do her or his job right the first time and every time.

Scandinavia has a reputation for "green" policies, and the environment is a key consideration for Sivers IMA. During design, product development and production, the company actively seeks to minimize resource usage and hazardous substances, reduce energy consumption during use of the products themselves and endeavors to reduce the environmental impact and conserve natural resources by minimizing waste and emissions and reusing and recycling materials.

Sivers IMA has a legacy of innovative technology going back to the early 1950s that it has nurtured and developed. In April 2017, the company also acquired all shares in CST Global, a privately held company that designs, manufactures and supplies III-V compound semiconductors. Sivers IMA's strategy is not just to be a developer and manufacturer of advanced microwave and mmWave semiconductors but also for optical semiconductors. The company is now in a position to exploit the development of mmWave technology as well as optical semiconductors, which are both going to play an increasingly significant role in satisfying the communications-driven and Gigabit-hungry needs of society.

www.siversima.com

WERLATONE®

We Are High Power

Test & Measurement Directional Couplers

Up to 1000:1 Bandwidth • Low Insertion Loss • Covering DC-6.5 GHz!

Directional Couplers

Model	Type	Frequency (MHz)	Power (W CW)	Coupling (dB)	Insertion Loss (dB)	VSWR (ML)	Flatness (± dB)	Size (Inches)
C6021	Dual	0.01-1000	500	40	0.45	1.30:1	0.5	6.7 x 2.27 x 1.69
C5725	Dual	0.1-1000	500	40	0.5	1.25:1	0.5	5.2 x 2.67 x 1.69
C9688	Dual	1-1000	800	40	0.5	1.20:1	1.0	6 x 2.2 x 2.2
C7734	Dual	30-2500	100	43	0.35	1.25:1	1.5	3.5 x 2.6 x 0.7
C8188	Uni	30-3000	20	20	2.4	1.35:1	1.0	6 x 1.5 x 1.1
C3910	Dual	80-1000	200	40	0.2	1.20:1	0.3	3 x 3 x 1.09
C8373	Bi	100-2500	200	20	0.8	1.25:1	1.75	9.58 x 1.48 x 0.88
C7711	Dual	100-3000	100	40	0.35	1.25:1	1.0	3 x 2.2 x 0.7
C7058	Bi	200-2000	200	10	0.3	1.25:1	1.0	6.4 x 1.6 x 0.72
C8060	Bi	200-6000	200	20	1.1	1.40:1	2.25	4.8 x 0.88 x 0.5
C7248	Bi	300-3000	100	6	0.35	1.25:1	1.0	6 x 2 x 0.85
C8000	Bi	600-6000	100	30	0.4	1.25:1	1.0	1.8 x 1 x 0.56
C8214	Bi	700-2500	100	6	0.35	1.25:1	1.0	6 x 2 x 0.85
C10462	Dual	700-4200	250	40	0.2	1.30:1	1.0	2 x 2 x 1.06
C10525	Dual	700-4200	700	50	0.2	1.35:1	1.0	2.15 x 2 x 1.36
C10537	Dual	700-4200	700	60	0.2	1.35:1	1.0	2.15 x 2 x 1.36
C10536	Dual	700-4200	1000	50	0.2	1.35:1	1.0	2.15 x 2 x 1.36
C10751	Dual	700-4200	1000	60	0.2	1.35:1	1.0	2.15 x 2 x 1.36
C10006	Dual	700-4200	2000	50	0.2	1.35:1	1.0	3 x 3 x 1.59
C10117	Dual	700-6000	250	40	0.2	1.30:1	1.0	2 x 2 x 1.06
C10364	Dual	700-6000	500	50	0.2	1.35:1	1.0	2.15 x 2 x 1.36
C10762	Dual	1000-6000	300	40	0.2	1.30:1	0.5	2 x 2 x 1.06
C10958	Dual	1000-6000	400	40	0.2	1.35:1	0.5	2 x 2 x 1.06
C10761	Dual	1000-6000	600	40	0.2	1.35:1	0.5	2.15 x 2 x 1.36
C8644	Bi	1800-6100	60	20	0.4	1.25:1	1.0	1.1 x 0.75 x 0.48
C10743	Dual	2000-6000	500	40	0.2	1.30:1	0.5	2.15 x 2 x 1.36
C10746	Dual	2000-6500	500	50	0.2	1.35:1	1.0	2.15 x 2 x 1.36
C10748	Dual	2000-6500	500	60	0.2	1.35:1	1.0	2.15 x 2 x 1.36

Werlatone, Inc.
17 Jon Barrett Road
Patterson, NY 12563
T 845 278 2220
F 845 278 3440
sales@werlatone.com
www.werlatone.com