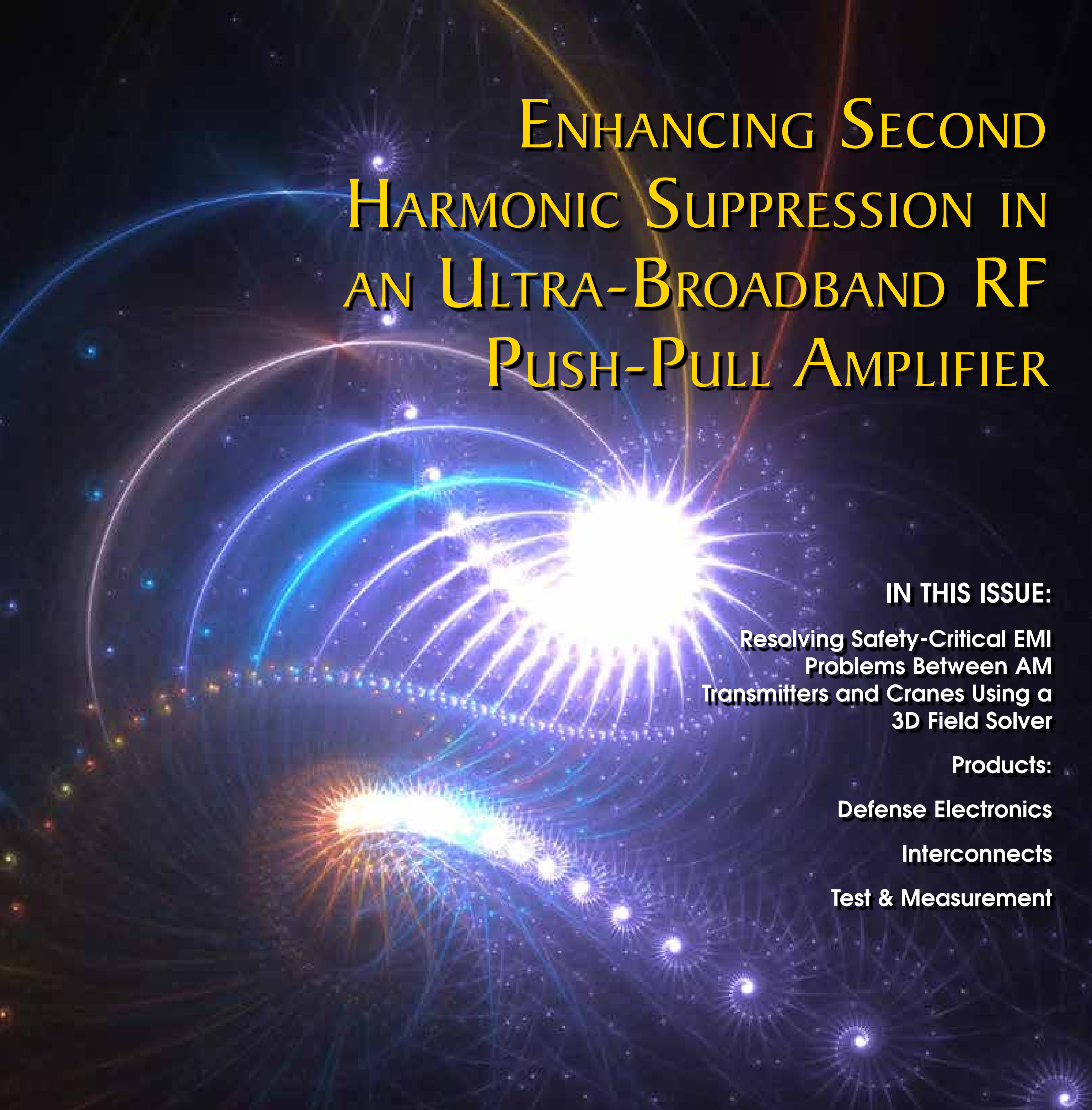
ALSO PUBLISHED ONLINE:
www.highfrequencyelectronics.com

**JANUARY** 2014

# HIGH FREQUENCY ELECTRONICS



## Enhancing Second Harmonic Suppression in an Ultra-Broadband RF Push-Pull Amplifier

**IN THIS ISSUE:**

Resolving Safety-Critical EMI Problems Between AM Transmitters and Cranes Using a 3D Field Solver

Products:

Defense Electronics

Interconnects

Test & Measurement

Ideas for today's engineers: Analog · Digital · RF · Microwave · mm-wave · Lightwave

# One's all battle. One's all business.
# Both are ready to ship.


Whether you're designing for the battlefield or a demanding DAS application requiring reverse polarity, Aeroflex / Inmet has the rugged, low-power attenuator you need, in stock and ready to ship. These new additions to our extensive line of coaxial attenuators feature the same Inmet quality and pricing you've come to expect.

**Attenuation Accuracy:**

| | |
|---|---|
| 0 to 10 dB: | ± 0.5 dB |
| 12, 15, 20 dB: | ± 0.7 dB |
| 30 dB: | ± 0.9 dB |
| 40 dB: | ± 1.5 dB |

**VSWR:** 1.20:1 Max.

**Impedance:** 50 Ohms

They're delivered with high-performance, passivated stainless-steel, SMA connectors featuring gold-plated, beryllium-copper conductors.

Call or visit our website to order today.

**888-244-6638**
**www.aeroflex.com/inmet**

AEROFLEX
A passion for performance.



ALSO PUBLISHED ONLINE AT:
www.highfrequencyelectronics.com

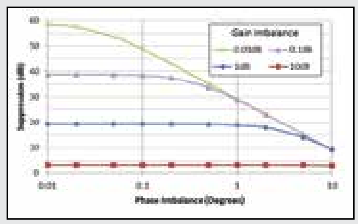
**JANUARY** 2014
Vol. 13 No. 1

# HIGH FREQUENCY ELECTRONICS



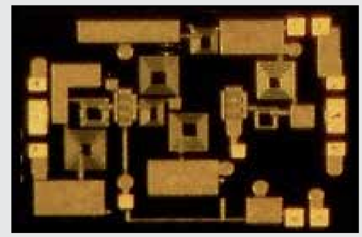

Electromagnetic simulation was used to identify the cause of the problem when conventional on-site analysis approaches failed.






By incorporating an attenuator and delay line in one of the paths the distortion suppression of the amplifier is modified.





Including RFMW, AtlanTecRF, AR RF/Microwave Instrumentation, RLC Electronics, Passive Plus, Precision Devices.

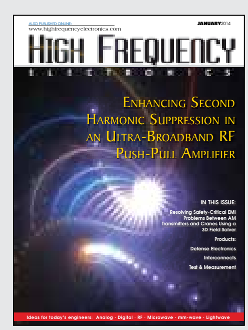



Featuring Micrel, Wurth Electronics Midcom, Pentek, T-Tech, Pro-Comm, ARRA Inc., AMCOM, Quick-Pak, and more.



Highlighting Harold "Deke" Williams, EADS North America, Rohde & Schwarz, Boeing, National Instruments.






Commentary by Senior Tech Editor Tom Perkins.

HIGH FREQUENCY
ELECTRONICS

Vol. 13 No. 1 January 2014

Publisher
Scott Spencer
scott@highfrequencyelectronics.com
Tel: 603-472-8261

Associate Publisher/Managing Editor
Tim Burkhard
tim@highfrequencyelectronics.com
Tel: 707-544-9977

Senior Technical Editor
Tom Perkins
tom@highfrequencyelectronics.com
Tel: 603-472-8261

Vice President, Sales
Gary Rhodes
grhodes@highfrequencyelectronics.com
Tel: 631-274-9530

Editorial Advisors:
Ali Abedi, Ph.D.
Candice Brittain
Paul Carr, Ph.D.
Alen Fezjuli
Roland Gilbert, Ph.D.
Sherry Hess
Thomas Lambalot
John Morelli
Karen Panetta, Ph.D.

Business Office
Summit Technical Media, LLC
One Hardy Road, Ste. 203
PO Box 10621
Bedford, NH 03110

Also Published Online at
www.highfrequencyelectronics.com

Subscription Services
Sue Ackerman
Tel: 651-292-0629
circulation@highfrequencyelectronics.com

Send subscription inquiries and address changes to the above contact person. You can send them by mail to the Business Office address above.

**Our Environmental Commitment**
*High Frequency Electronics* is printed on paper produced using sustainable forestry practices, certified by the Program for the Endorsement of Forest Certification (PEFC™), www.pefc.org

PEFC/29-31-130

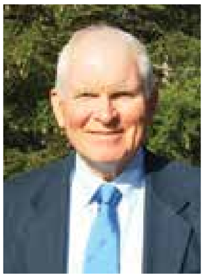
SUMMIT
Technical Media LLC





# Milestone for Experimenters

**Tom Perkins**
**Sr. Technical Editor**



2014 marks the 100th anniversary of the founding of the American Radio Relay League. These days the Connecticut-based organization is more often referred to as ARRL, the national association for AMATEUR RADIO®. This would be because these days messages are rarely relayed across the country by different stations. The "miracle" of the early days of amateur radio is no longer a key service provided by radio amateurs (hams). But ham radio remains a last-resort means of communications "when all else fails". And it continues to be a fun hobby with many aspects for experimenting, learning electronics, both analog and digital, and, in today's parlance, "social networking" with friends and strangers.

ARRL has about 160,000 members, far fewer than the number of hams just in the United States alone. In spite of this there is a formidable influence exerted by the US Federal Communications Commission (FCC) and the International Amateur Radio Union (IARU) and International Telecommunication Union (ITU).

When we closely examine the progress made in communications and broadcasting, the advances made in such a short time are mind-boggling. The progress achieved is loaded with idiosyncrasies. AM radio's heyday perhaps only lasted about 20 years, yet it still exists today. Major Edwin Armstrong's development of Frequency Modulation was initially fought by some seeking to reap fortunes in AM radio manufacture. For many years engineers and technicians seeking employment had a distinct advantage in job hunting if they possessed an amateur radio license. Even in wartime, when most ham operations were curtailed, hams were in high demand—not only for their operating skills, but particularly in WWII for providing their equipment for the war effort.

### ARRL Major Happenings

Some Key ARRL milestones extracted from their 2014 Calendar include:

- 1914 - founding of the organization by Hiram Percy Maxim and Clarence D. Tuska,
- 1915 - the first edition of QST, the journal of the ARRL published privately by these same gentlemen in,
- 1926 - the *Radio Amateur's Handbook* first published
- 1928 - first ARRL on-the-air contest International Relay Party
- 1933 - ARRL holds its first Field Day, a nationwide (US and Canada) demonstration of rapid deployment of communications assets in an emergency
- 1935 - Amateur Radio Emergency Service (ARES®) created

• 1936 - W1MK, ARRL station located at Brainard Field near Hartford is destroyed by Spring flood

• 1938 - ARRL station W1AW (deceased H. P. Maxim's call letters) built in Newington, Connecticut

• 1951 - ARRL promotes benefits of single sideband (SSB) voice communications

• 1957 - The International Geophysical Year – ARRL receives contract to conduct propagation studies

• 1963 - ARRL builds new headquarters facility adjacent to W1AW station in Newington

• 1984 - FCC delegates testing and ARRL becomes a Volunteer Examiner Coordinator (VEC)

• 2012 – ARRL starts publishing digital edition of QST magazine

### People and Technology

When I first earned an amateur license in 1957, many of the early pioneers were still alive and active. Many also worked in the field of electronics and would likely have read *HFE* had it existed then. Notable hams include: Chet Atkins, Tex Beneke, Frank Bliley, Walter Cronkite, Arthur Godfrey, Yuri Gagarin, Senator Barry Goldwater, Al Gross, Bob Heil, Walter "Pee Wee" Hunt, Jack Kilby, General Curtis LeMay, Bill Leonard, Roy Neal, Percy L. Spencer (our Publisher's grandfather), Alvino Ray, Jean Shepherd, Phillip H. Smith, Dr. Joe Taylor, King Hussein of Jordan, Dr. Ulrich Rohde, Paul Tibbits, and David Packard.

I regret that as a teenager I did not embrace or cherish the opportunities for dialog with many seasoned mentors to the degree possible. But perhaps many of these folks preferred to look to the future anyhow. And oh, how advances were made. Transistors replaced vacuum tubes, low noise receiver preamplifiers for VHF, UHF, and microwaves evolved, and Earth-Moon-Earth (EME) bounce became commonplace. Various unique propagation phenomena such as sporadic E, aurora, tropospheric bending, and meteor scatter are routinely exploited. Adding to these developments, we have satellite communications, mountaintop repeaters, introduction of integrated circuits, tiny hand-held transceivers, amateur television (slow and fast scan), packet, PSK-31 and other digital techniques, and Software Defined Radio (SDR).

### The Next 100

The next century will be both exciting and challenging as precious frequency spectrum demand continues to grow. Because of its members, ARRL will continue exert influence over the great developments ahead.

Happy New Year!

## Conferences

**January 19 – 23, 2014**
**IEEE Radio and Wireless Symposium**
Newport Beach, Calif.
http://www.radiowirelessweek.org/wisnet/

**January 28 – 31, 2014**
**DesignCon**
Santa Clara, Calif.
http://www.designcon.com/santaclara/

**March 19 – 20, 2014**
**Microwave & RF**
Paris
www.microwave-rf.com

**March 23 – 27, 2014**
**IEEE International Wireless Symposium (IWS 2014)**
Xi'an, China
http://iws-ieee.org/

**May 8 – 9, 2014**
**IEEE MTT-S International Wireless Power Transfer (WPTC 2014)**
Jeju, Korea
**http://www.wptc2014.org/**

**June 1 – 6, 2014**
**IEEE International Microwave Symposium (IMS2014)**
Tampa, Florida
http://ims2014.mtt.org/

## Short Courses

**Besser Associates**
**besserassociates.com**
**Tel: 650-949-3300**

New Courses
Course 227: Wireless LANs
Course 226: Wireless/Computer/Telecom Network Security
Course 228: GaN Power Amplifier Design
Course 223: Fundamentals of LTE, HSPA, & WCDMA
Course 221: BER, EVM, & Digital Modulation Testing for Test & Product Engineers

## Company-Sponsored Training & Tools

**Analog Devices**
Training, tutorials and seminars.
*http://www.analog.com/en/training-tutorials-seminars/resources/index.html*

**AWR**
On-site and online training, and open training courses on design software.
*http://web.awrcorp.com/Usa/News--Events/Events/Training/*

**Linear Technology**
LTSpice IV
LTpowerCAD
LTpowerPlay
Amplifier Simulation & Design
Filter Simulation & Design
Timing Simulation & Design
Data Converter Evaluation Software
http://www.linear.com/designtools/software/

---

**National Instruments**
LabVIEW Core 1
*Online*
*http://sine.ni.com/tacs/app/fp/p/ap/ov/pg/1/*
LabVIEW Core 2
Online
*http://sine.ni.com/tacs/app/fp/p/ap/ov/pg/1/*
*Object-Oriented Design and Programming in LabVIEW*
*Online*
*http://sine.ni.com/tacs/app/fp/p/ap/ov/pg/1/*
Free, online LabVIEW training for students and teachers.
*http://sine.ni.com/nievents/app/results/p/country/us/type/webcasts/*
Webcasts on demand.
*http://search.ni.com/nisearch/app/main/p/bot/no/ap/tech/lang/en/pg/1/sn/catnav:mm,n15:WebcastsOnDemand,ssnav:dzn/*
LabVIEW user groups.
*https://decibel.ni.com/content/community/zone/labviewusergroups*

## Call for Papers

**September 1 – 3, 2014**
**IEEE International Conference on Ultra-WideBand (ICUWB)**
Paris
Abstract submission deadline: March 11, 2014
Final submission deadline: June 6, 2014
Notification of acceptance date: May 12, 2014
http://www.icuwb2014.org/

**September 14 – 19, 2014**
**International Conference on Infrared, Millimeter, and Terahertz waves (IRMMW-THz)**
Tucson, Ariz.
Abstract submission deadline: March 21, 2014
Final submission deadline: May 25, 2014
Notification of acceptance date: April 20, 2014
http://www.irmmw-thz.org/

**October 19 – 22, 2014**
**2014 IEEE Compound Semiconductor Integrated Circuit Symposium (CSISC)**
La Jolla, Calif.
Abstract submission deadline: May 2, 2014
Final submission deadline: July 25, 2014
Notification of acceptance date: June 13, 2014
http://www.csics.org/

# **Micro Lambda's Bench Test Boxes...**
# Simple and Easy to Use!

**MLBS-Synthesizer Test Box – 600 MHz to 20 GHz**
Standard models cover the 0.6 to 2.5 GHz, 2 to 8 GHz, 8 to 20 GHz and 2 to 20 GHz frequency bands. All versions of the MLSP synthesizer product family can be easily inserted into the test box. Tuning consists of a control knob, key pad, USB and Ethernet connections. Units provide +10 dBm to +13 dBm output power levels and are specified over the lab environment of +15°C to +55°C and are CE certified.

Units are provided with a power cord, USB cable, Ethernet cable, CD incorporating a users manual, quick start guide and PC interface software.

**MLBF-Filter Test Box – 500 MHz to 50 GHz**
Standard models utilize any Bandpass or Bandreject filter manufactured by Micro Lambda today. Bandpass filter models cover 500 MHz to 50 GHz and are available in 4, 6 and 7 stage configurations. Bandreject (notch) filter models cover 500 MHz to 20 GHz and are available in 10, 12, 14 and 16 stage configurations. Units are specified to operate over the lab environment of +15°C to +55°C and are CE certified.

Units are provided with a power cord, USB cable, Ethernet cable, CD incorporating a users manual, quick start guide and PC interface software.

**See our complete line of wideband, low noise components**

**MLSP-series Synthesizers**
600 MHz to 20 GHZ

**MLSW-series Synthesizers**
600 MHz to 16 GHz

**MLTO-series TO-8 Oscillators**
2 to 16 GHz

**MLSMO-series Surface Mount Oscillators**
2 to 16 GHz

**www.microlambdawireless.com**

MICRO LAMBDA WIRELESS, INC.

*"Look to the leader in YIG-Technology"*

46515 Landing Parkway, Fremont CA 94538 • (510) 770-9221 • sales@microlambdawireless.com

## Telecom Regulators, Mobile Carriers Step Up Efforts to Repurpose 2G and 3G Spectrum for LTE

Spectrum repurposing is gaining momentum. The launch of Voice-over-LTE (VoLTE) services by major carriers first in South Korea and soon in the United States is part of the effort to move voice calls from the circuit switched 2G and 3G networks to the packet switched LTE networks. To achieve this, operators have built extensive LTE networks, which also serve as a marketing tool to stay in competition.

"For CDMA operators such as Verizon, aggressive LTE deployment is necessary because a VoLTE call cannot fall back to the circuit switched domain," said Ying Kang Tan of ABI Research. "Even for WCDMA operators like AT&T, it makes sense to do likewise because LTE is much more spectral efficient than WCDMA." As such, by the end of next year, when VoLTE has gained more momentum, ABI Research expects more than 93% of the North American population to have access to LTE.

Underlying the adoption of LTE is the support from handset OEMs. "In 2014, LTE handset shipments in Asia-Pacific and North America—the two largest handset markets—will grow by 28% and 25% to reach 150 million and 81 million, respectively," commented Jake Saunders, VP and practice director. "As China joins the VoLTE club next year, more handsets will support this service."

Other devices will increasingly have access to LTE networks as well. Tablets with LTE support will see global shipments jump by 67% in 2014. The growth of 72% is even higher for the United States, which may come as a surprise for this relatively mature market, as consumers take advantage of shared data plans which are gaining popularity.

**—ABI Research**
**abiresearch.com**

## Unmanned Ground Systems: Semi-Autonomy is the Way Forward over the Next 10 Years

Unmanned Ground Vehicles (UGV) represent a tiny proportion of vehicle inventories globally but replacing and complementing manned vehicles with unmanned systems is a powerful opportunity. As yet, it has not been defined how the technology will be best utilized or how new systems will be integrated into force structures. According to Frost & Sullivan in the five-to-ten-year timeframe there will be only a limited proliferation of unmanned technology into the market.

"Currently, the U.S. is at the forefront in terms of integration and acquisition of unmanned systems into its military land vehicle fleet," said Program Manager, Aerospace, Defense & Security, Richard Hilton. "But even the US has dramatically scaled back its intent to integrate unmanned systems in line with wider cut backs and defense sequestration. Moreover, there are no really significant procurement programs for UGVs in any other region."

The commercial automotive industry is leading the way in unmanned vehicle systems. Commercial vehicle manufacturers with a significant defense-industry footprint may be able to migrate technology into military vehicles once costs are driven down through increasingly accessible commercial supply.

**—Frost & Sullivan**
**frost.com**

## DOCSIS 3.0 Broadband CPE Shipments to Grow 14% to 50 Million in 2014

Broadband Customer Premise Equipment (CPE) shipments at the end of 2013 are expected to surpass 147 million, according to ABI Research. The devices counted include modems, wired routers, and gateways. Despite a growing broadband subscriber base and increasing demand for advanced broadband services, broadband CPE shipments are only expected to grow to 150 million in 2014.

"Increasing adoption of fiber-optic broadband services is driving the growth of fiber-optic CPE shipments. Fiber-optic CPE will represent 26% of overall broadband CPE shipped in 2014. Cable and DSL CPE devices will have equal market share of around 37%," comments Jake Saunders, VP and practice director.

As cable broadband operators rapidly extend to DOCSIS 3.0 networks, DOCSIS 3.0 CPE shipment is gaining market share. In 2014, DOCSIS 3.0 CPE devices shipped will reach 50 million, accounting for more than 89% of cable CPE shipments. Total DSL CPE shipments by the end of 2013 are likely to be around 2% lower than total shipments in 2012; mainly due to slow subscriber net addition in DSL broadband service. "However, since DSL operators continue to upgrade to higher speed VDSL services, VDSL CPE shipments are growing stronger. ABI Research expects that VDSL CPE will account for over 25% of DSL CPE device shipments in 2014," adds Khin Sandi Lynn, industry analyst.

ZTE tops broadband CPE shipments in 3Q 2013 with a 13% market share. ARRIS jumped to second place after acquiring Motorola's Home Division in April 2013. Combined shipments of ARRIS and Motorola CPE represents 12% market share, overtaking Huawei which owns 11% market share.

**—ABI Research**
**abiresearch.com**

**Raytheon Co.**, Tucson, Ariz., is being awarded a $35,019,637 modification to previously awarded contract (N00024-10-C-5432) to exercise an option to accomplish fiscal 2014 design agent engineering services for the MK-31 **Rolling Airframe Missile (RAM) Guided-Missile Weapon System** (GMWS) improvement program support, guided-missile round pack support, and guided-missile launching system support. The RAM MK-31 GMWS is a cooperative development and production program conducted jointly by the United States and the Federal Republic of Germany under Memoranda of Understanding.

**Lockheed Martin** Corp., Marietta, Ga., has been awarded up to $169,726,427 not-to-exceed firm-fixed-price contract for advance procurement funding for long lead efforts associated with 18 **C-130J aircraft**. Work will be performed at Marietta, Ga., and is expected to be completed by Oct. 31, 2016. This award is the result of a sole-source acquisition. Fiscal 2013 advance procurement funds in the amount of $169,726,427 are being obligated at time of award. Air Force Life Cycle Management Center/ WLNNC, Wright-Patterson Air Force Base, Ohio, is the contracting activity (FA8625-14-C-6450).

**Bell-Boeing Joint Project Office,** Amarillo, Texas, is being awarded a $15,597,818 firm-fixed-price delivery order (0075) against a previously issued basic ordering agreement (N00019-12-G-0006) in support of the **V-22 aircraft**. This order provides for additional nonrecurring engineering and technical support to forward fit/retrofit engineering change proposal #1007 into the aircraft. This effort will also provide for the delivery of eight helmet mounted display retrofit kits, spares, support equipment, tooling and training devices. Work will be performed at Ridley Park, Pa. (99.9 percent), and Fort Worth, Texas (.1 percent), and is expected to be completed in March 2015.

**General Atomics Aeronautical Systems** Inc., Poway, Calif., was awarded a $40,253,105 modification (P0003) to contract W58RGZ-13-C-0109 for the Gray Eagle full rate production option exercise applicable to the **Gray Eagle Unmanned Aircraft System**. Fiscal 2014 other procurement, Army funds in the amount of $40,253,105 were obligated at the time of the award. Estimated completion date is Sept. 30, 2016. One bid was solicited with one received. Work will be performed at Poway, Calif. Army Contracting Command, Redstone Arsenal, Ala., is the contracting activity.

**EADS North America**, Herndon, Va. was awarded a $33,217,089 firm-fixed-price contract with options for the purchase of six **UH72A Lakota aircraft** and six airborne radio communication 231 radios. Fiscal 2014 other procurement funds in the amount of $33,217,089 were obligated at the time of the award. Estimated completion date is Dec. 31, 2014. Five bids were solicited with three received. Work will be performed in Herndon, Va. Army Contracting Command, Redstone Arsenal, Ala., is the contracting activity (W58RGZ-06-C-0194).

UK engineering support services powerhouse **Babcock International Group** awarded **Rohde & Schwarz** a contract to implement HF military messaging in the UK. The R&S MMHS message handling system from Rohde & Schwarz will be an essential part of the UK Ministry of Defense's naval communications network at their Forest Moor, Kinloss and overseas sites. The contract will be part of the UK MoD's **defense high frequency communications service project** (DHFCS). DHFCS is a public-private partnership (PPP) that was awarded to Babcock in 2003 for a 15 year period. The purpose of the project is to deliver strategic beyond-line-of-site high frequency (HF) and low frequency (LF) communications services to the three branches of the armed forces.

**The Boeing Co.**, St. Louis, Mo., is being awarded $8,481,104 for firm-fixed-price delivery order 2035 against a previously issued basic ordering agreement (N00019-11-G-0001) for follow-on integrated logis-

tics support/engineering services for **Harpoon/SLAM-ER Missile System** and Harpoon Launch Systems for the U.S. Navy and various foreign military sales customers.

**Austal USA** LLC, Mobile, Ala., was awarded an $8,247,342 modification to previously awarded contract (N00024-11-C-2301) on Nov. 27, 2013, to exercise an option for **littoral combat ship** (LCS) core class services. Austal USA LLC will assess engineering and production challenges as well as evaluate the cost and schedule risks from affordability efforts to reduce LCS acquisition and lifecycle costs.

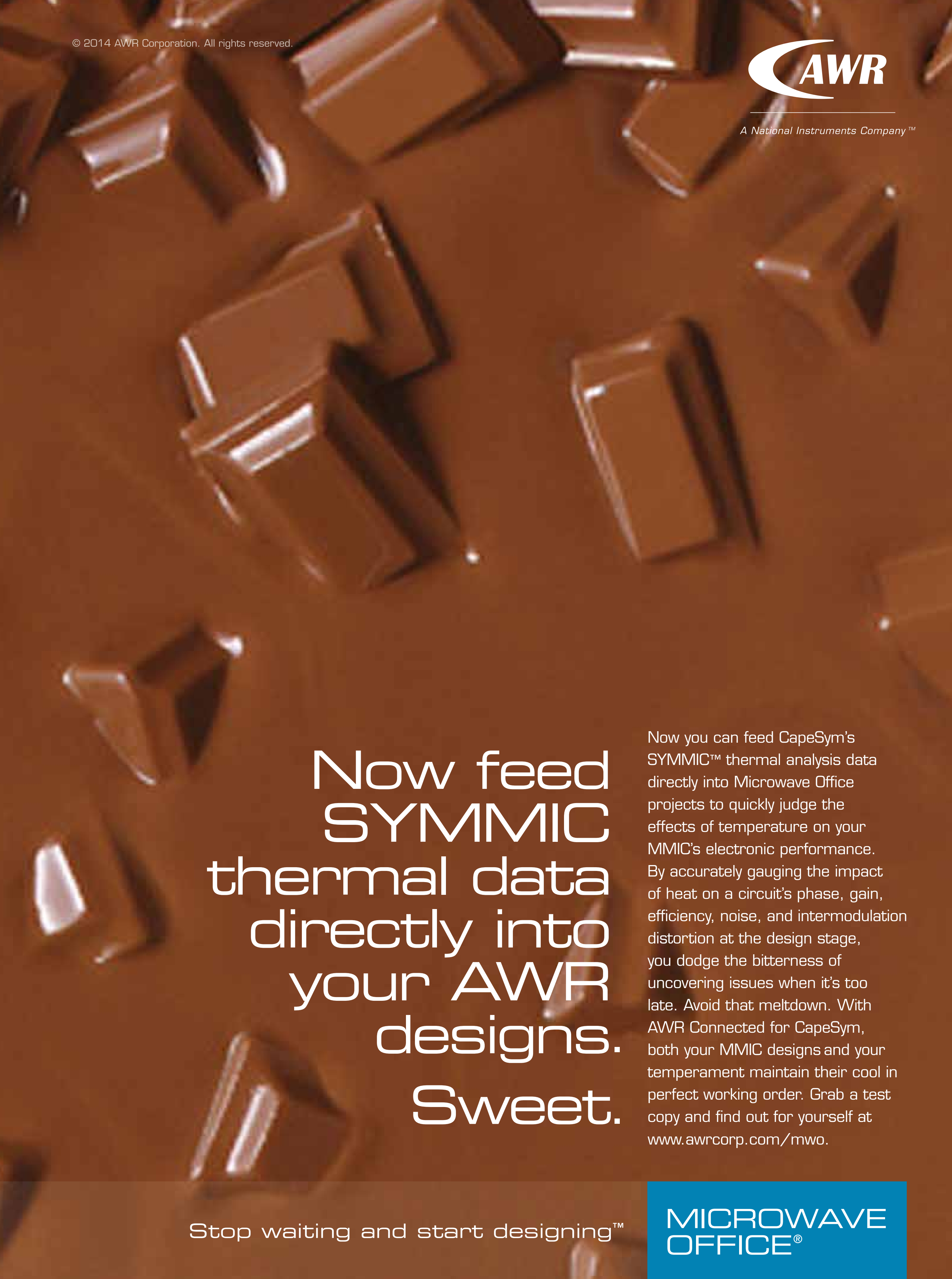
NATIONAL INSTRUMENTS

**National Instruments** concluded its first-ever **NIDays North America** conference series on December 12 with the last of four such 2014 events at the San Jose, Calif. Convention Center. NIDays events were held earlier last year in Boston, Chicago, San Jose, and Washington, DC. Attendees had the chance to network with peers and hear about the latest technology and innovation news from NI.

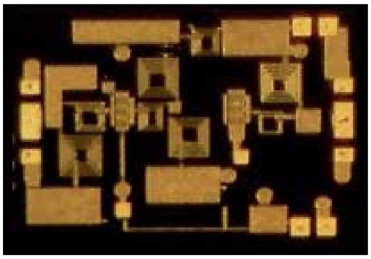

**San-tron, Inc.** achieved **AS9100 certification**, a quality standard for companies that design, develop or produce aerospace products. Developed specifically for the aviation, aerospace and defense industries, AS9100 ensures the safety and reliability of products used throughout these markets. The AS9100 certification provides San-tron with a comprehensive quality management system (QMS), requiring effective product configuration control, product conformance to customer requirements, and product monitoring and measurement for product validation.

**Harold "Deke" Williams**, founder of **Wilmanco**, Los Angeles, passed away in November. He was 73. A cutting-edge electronics innovator, former Marine and devoted husband and father, he is truly missed by his family and friends. Deke accomplished a great deal in his life with his hard-work ethic, self-discipline, generosity, and love for his family. He proudly served his country in the Marine Corps from 1959 to 1963. Upon founding Wilmanco in 1979, he introduced several innovative products to the RF community, and was first to market a patch antenna for use in **GPS receiving equipment.**

**AR RF/Microwave Instrumentation** has broken ground on a **major expansion project** at its headquarters in Souderton, PA, USA. The expansion will add a two story 10,000 sq. ft. addition, increase the power provided to the facility to 2 Megawatts, and give AR the capability to manufacture and test high-power RF amplifiers in excess of 100 kW. This aggressive move further strengthens AR's position as the leader in high power RF amplifiers.


© 2014 AWR Corporation. All rights reserved.
AWR
A National Instruments Company™
Now feed SYMMIC thermal data directly into your AWR designs.
Sweet.
Now you can feed CapeSym's SYMMIC™ thermal analysis data directly into Microwave Office projects to quickly judge the effects of temperature on your MMIC's electronic performance. By accurately gauging the impact of heat on a circuit's phase, gain, efficiency, noise, and intermodulation distortion at the design stage, you dodge the bitterness of uncovering issues when it's too late. Avoid that meltdown. With AWR Connected for CapeSym, both your MMIC designs and your temperament maintain their cool in perfect working order. Grab a test copy and find out for yourself at www.awrcorp.com/mwo.
Stop waiting and start designing™
MICROWAVE OFFICE®

## FEATURED PRODUCTS



### LNA

RFMW announced support for the TGA2611, 2-6 GHz LNA utilizing TriQuint's GaN25 technology. GaN processes provide a highly robust input coupled with low noise figure and high gain, ideal characteristics for S and C-band radar receivers or broadband communication receivers. Small signal gain of the TGA2611 measures 25 dB while mid-band noise figure is 1 dB.

**RFMW**
**rfmw.com**

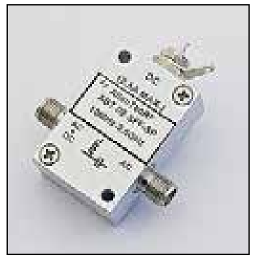
### Combiner

Model SWP-50366308-15-C1 is a V band waveguide eight -way power combiner operates from 50 to 66 GHz. The power combiner exhibits 2.0 dB insertion loss and 18 dB port to port isolations between non-adjacent ports and 13 dB between adjacent ports in the operational bandwidth. The power combiner possesses excellent phase and amplitude balance. The power combiner is equipped with WR-15 waveguides and UG385/U flanges.

**SAGE Millimeter**
**sagemillimeter.com**

### Bias Tees

As a vital link in utilizing a single coaxial cable to carry both RF signals and DC power, the new ABT series of Bias Tees from AtlanTecRF bring this capability to systems operating at frequencies up to 50GHz. With RF connector choices of 2.92mm, SMA and Type N the ac-



tual frequency bands offered range from 10MHz - 2.5GHz through to 50KHz – 50GHz with DC voltage capability to 100 Volts and current capacity to 2.5 Amps.

**AtlanTecRF**
**atlantecrf.com**

### Dividers

Pasternack Enterprises introduced a line of Wilkinson power dividers (also referred to as Wilkinson power splitters). These multi-octave power dividers cover popular communications bands from 0.5 to 2.7 GHz including 3G and 4G, plus WiFi bands and are well suited for applications such as in-building distributed antenna systems (DAS) or test environments.

**Pasternack Enterprises**
**pasternack.com**

### HPM

AR's new Hybrid Power Module (HPM) is a Broadband Power Amplifier, which operates from a single DC voltage and covers 6/18GHz. It delivers a minimum of 5 Watts output power and 42 dB small signal gain with excellent gain flatness and harmonics. The HPM has a built-in over voltage protection and is available in Class A and Class AB. It is extremely load tolerant and can be used as a Microwave Power Amplifier for both the Military and Commercial Industries.

**AR RF/Microwave Instrumentation**
**arworld.us**

### Switch

PMI Model No. P1T-0R5G18G-60-T-512-SFF is a single pole, single throw, absorptive solid state switch that operates over the frequency range of 0.5 to 18.0GHz. This model has a maximum insertion loss of 3.5dB and an isolation specification of 60 dB. It operates at 20 dBm CW and can survive 1 Watt CW, 10 Watts peak for 1 uSec.

**Planar Monolithics Industries**
**pmi-rf.com**

### Switch

RLC Electronics' Micro Miniature Transfer Switch is an extremely compact design. The switch can be provided as either a surface mount design or connectorized unit (SMA connectors standard). These switches offer excellent electrical performance through 26.5 GHz; VSWR 1.7:1 max, Insertion Loss 0.7 dB max and Isolation 50 dB min.

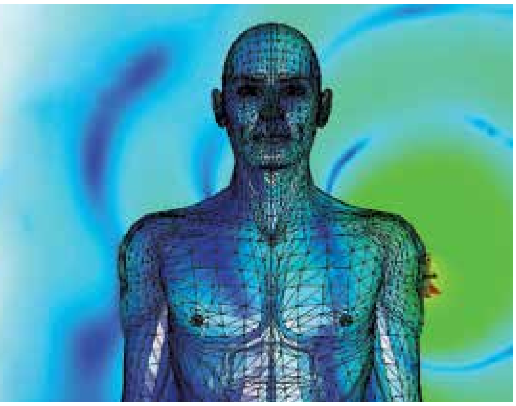
**RLC Electronics**
**rlcelectronics.com**

### VCO

Crystek's CVCO25CL-0902-0928 VCO operates from 902 MHz to 928 MHz with a control voltage range of 0.5V~3.5V. This VCO features a typical phase noise of -108 dBc/Hz @ 10 KHz offset and has excellent linearity. Output power is typically +3 dBm. Engineered and manu-

# Make the Connection

## Find the simple way through complex EM systems with CST STUDIO SUITE



Components don't exist in electromagnetic isolation. They influence their neighbors' performance. They are affected by the enclosure or structure around them. They are susceptible to outside influences. With System Assembly and Modeling, CST STUDIO SUITE helps optimize component and system performance.

Involved in antenna development? You can read about how CST technology is used to simulate antenna performance at **www.cst.com/antenna**.

If you're more interested in filters, couplers, planar and multilayer structures, we've a wide variety of worked application examples live on our website at **www.cst.com/apps**.

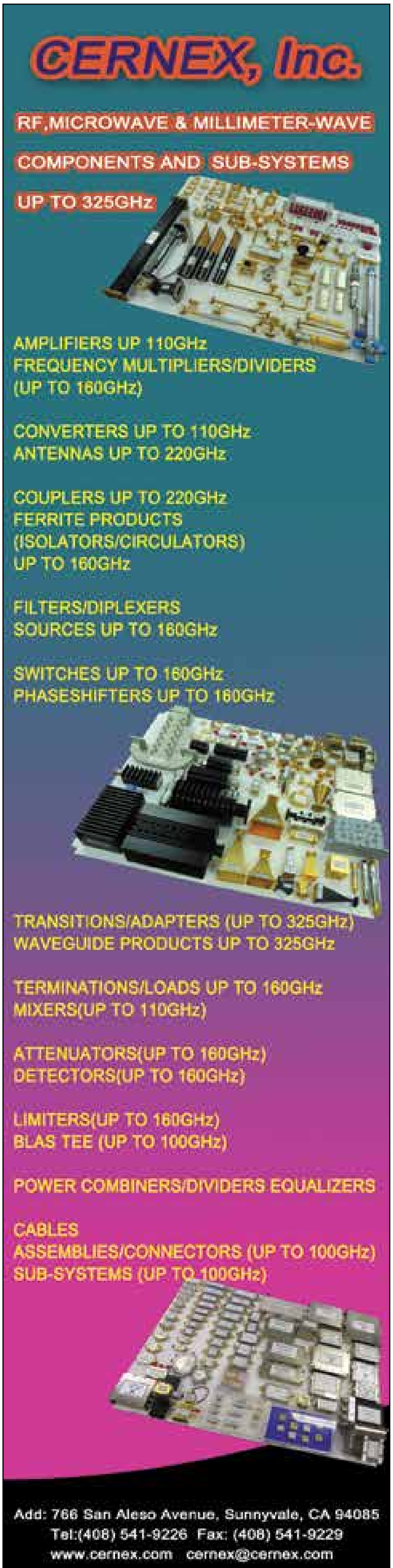
Get the big picture of what's really going on. Ensure your product and components perform in the toughest of environments.

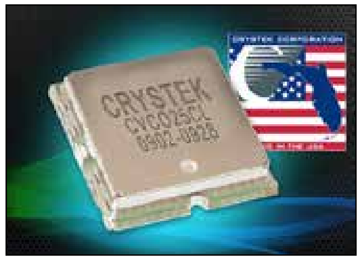
**Choose CST STUDIO SUITE –
Complete Technology for 3D EM.**

CST

CST – COMPUTER SIMULATION TECHNOLOGY | www.cst.com | info@cst.com

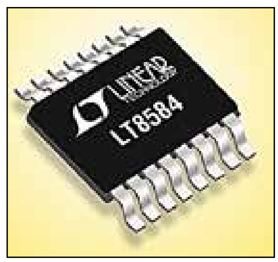
# FEATURED PRODUCTS




factured in the USA, the model is packaged in the industry-standard 0.5 in. x 0.5 in. SMD package.

**Crystek**
**crystek.com**




## DC/DC Converter

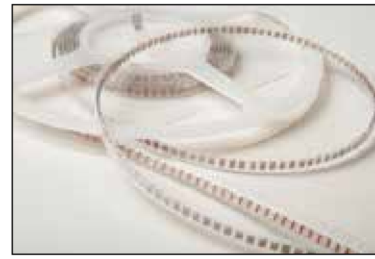
The LT8584 is a monolithic flyback DC/DC converter designed to actively balance high voltage stacks of batteries. These battery stacks are commonly found in electric and hybrid vehicles as well as fail-safe power supplies and energy storage systems. Because these batteries are stacked in series, the lowest capacity battery will limit the entire battery stack's run-time. Ideally, the batteries would be perfectly matched, but this is often not the case and generally gets worse as the batteries age.

**Linear Technology**
**linear.com**

## Filters

RFMW, Ltd. announced design and sales support for 6GHz broadband wireless filters from Sangshin Elecom. The MBP33RC6162S525A is an excellent choice for wireless backhaul applications where flexibility in channel planning and selection is critical. It covers the frequency range from 5.9 GHz to 6.425 GHz in a small 8.5 mm x 5.6 mm package.

**RFMW**
**rfmw.com**



## Capacitors

Passive Plus now offers extended values for the Traditional Hi-Q High Power, Low ESR/ESL, Low Noise, High Self-Resonance ultra-stable performance capacitors. Usually used for wireless broadcasting equipment, mobile base stations, GPS portables, MRI coils, and radar, these capacitors are 100% RoHS and offered in magnetic and non-magnetic terminations. They are designed and manufactured to meet the requirements for MIL-PRF-55681 and MIL-PRF-123.

**Passive Plus**
**passiveplus.com**


## OCXO

Precision Devices Inc. announced the high temperature (to +90°C) VN01 and VN03 series of Oven Controlled Crystal Oscillators (OCXO). This product is ideal for applications like satellite communications and a variety of military systems where extremely high temperature operating environments are the normal.

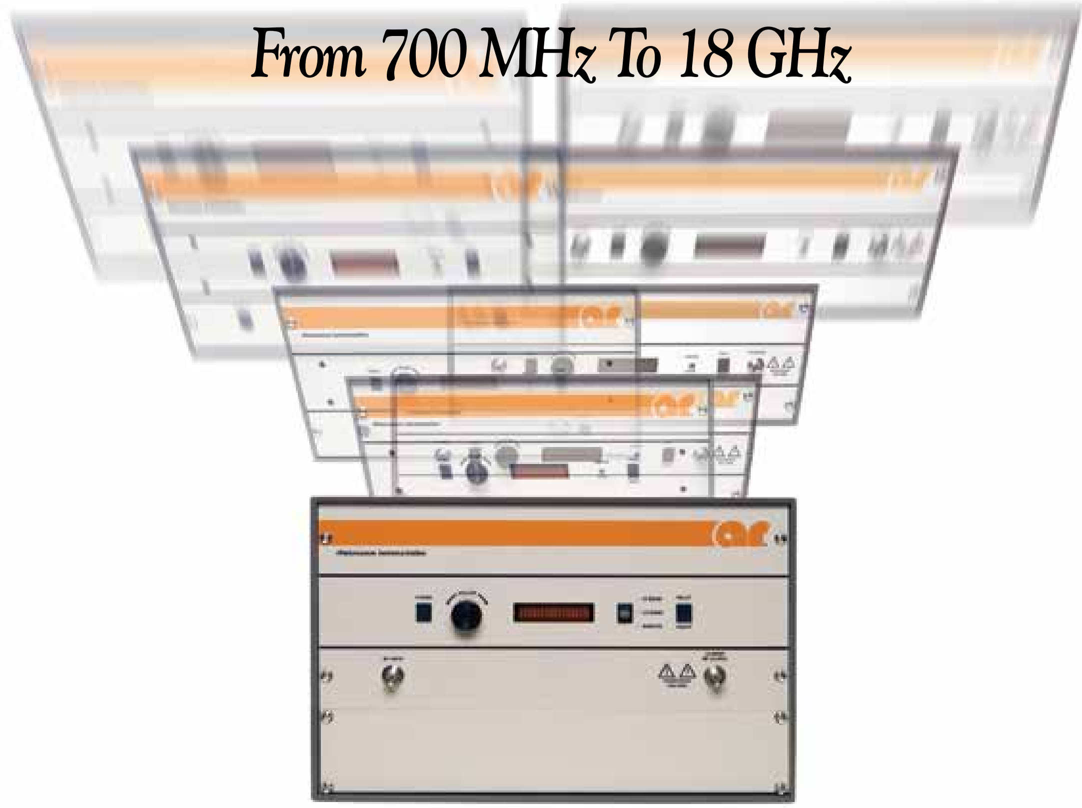
**Precision Devices**
**pdixtal.com**

## Isolator

VidaRF offers 12.0 - 14.5 GHz Coaxial Isolator Model; VCI-120145-1 which is a rugged body with S/Steel SMA connectors, sealed and painted if required. Isolation 20 dB

# New Dual Band Class A Solid State Amplifier Models

## From 700 MHz To 18 GHz



AR now offers the widest Class A solid state frequency range coverage in a single amplifier housing. Our widest bandwidth designs now covers 700 MHz to 18 GHz frequency range in a dual band configuration. These amplifiers come in two different band split configurations from 700 MHz to 4.2 GHz and 4 to 18 GHz up to 80 watts or from 700 MHz to 6 GHz and 6 to 18 GHz up to 50 watts. Other frequency band splits from 700 MHz up to 8 or 10.6 GHz are also available.

You now have freedom like never before. Just pick the power you need in each band from our 40 available models. We build our lower power dual band amplifiers with flexibility to increase the power levels at a later date, because your needs are constantly changing.

Our dual band amplifiers can be used for multiple applications such as EMC, EW and TWTA replacements, because they are linear, very reliable, have great harmonic rejection, and are extremely load tolerant.

*To learn more, visit www.arworld.us/dualband or call us at 215-723-8181.*

ISO 9001:2008
Certified

ar®

**rf/microwave instrumentation**

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

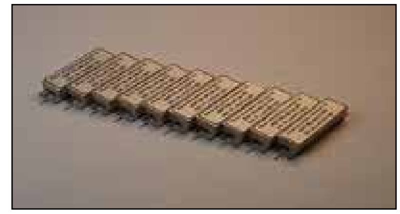
USA 215-723-8181. For an applications engineer, call 800-933-8181.
In Europe, call ar United Kingdom +44 1908 282766 • ar France +33147917530 • ar Deutschland +49 6101 80270-0 • ar Benelux +31 172 423000

www.arworld.us

min, insertion loss of 0.4 dB or less, VSWR of 1.25:1, temp -54 to +85C. Other frequencies and connector configurations available per request in this package .50 x .67x .50".

**VidaRF**
**vidarf.com**





## Bandpass Filter

PMI Model No. 4BP160-40-2A-PP is an LC Bandpass filter centered at 160 MHz with PC pins in and out.

**Planar Monolithics Industries**
**pmi-rf.com**


## Filter

The BPF-A1600+ is a 50Ω bandpass filter fabricated using SMT technology. This bandpass filter covers from 1400- 1800 MHz. It is built with high Q capacitors and air-coil inductors for superior performance. This filter is developed for square kilometer array telescope systems for radio astronomy. It has repeatable performance across lots and consistent performance across temperature.

**Mini-Circuits**
**minicircuits.com**

## Splitter/Combiner

Mini-Circuits SYPJ-2-33+ is a wideband, 2 way, 180° surface mount splitter/combiner. This model provides very low amplitude and phase unbalance with good isolation and insertion loss over the full frequency range. It handles up to 0.5W of input power and comes in a small plastic case with excellent thermal performance (- 40°C to 85°C operating).

**Mini-Circuits**
**minicircuits.com**

# Resolving Safety-Critical EMI Problems Between AM Transmitters and Cranes Using a 3D Field Solver

**By Marcelo Bender Perotoni and Roberto Menna Barreto**

Electromagnetic simulation was used to identify the cause of the problem when conventional on-site analysis approaches failed.

Electromagnetic fields from two high-power AM transmitters close to a construction site induced dangerously high voltages in crane booms, damaging equipment and injuring workers. With construction halted, a solution was urgently required. Electromagnetic simulation was used to identify the cause of the problem when conventional on-site analysis approaches failed, and allowed the engineers to compare possible countermeasures quickly. The chosen solution, a large inductive coupling to the ground, was successfully implemented and construction was able to continue.

## Background

Electromagnetic interference (EMI) is a problem that can affect devices at all scales, and can pose serious risks to workplace safety and the reliability of equipment. While techniques exist for designing countermeasures against expected EMI problems, the unique properties of each operating environment mean that unforeseen issues can arise in operation.

One example of such an EMI problem arose on a building site in the urban coastal area of Rio de Janeiro. Two cranes – a large crawler crane on caterpillar tracks (Figure 1a) and a smaller truck-based crane (Figure 1b) – were deployed to the site to help to construct a pier


**Figure 1• The two cranes used on the construction site.**

Figure 2 • Detail of the burnt pulley, showing the damage to the sheave and cables.

for oil transport. However, once on site, both cranes became victims of severe EMI issues.

Workers using the cranes reported moderate and intense electrical shocks from the equipment, strong enough even to cause skin burns when the boom was touched with bare hands. In addition, the operators of the truck-based crane reported that its electronic systems became inoperative. The intensity of these electrical shocks was dependent on the orientation of the boom, time of the day and atmospheric conditions, becoming stronger as the booms were extended. The induced voltages were so great that the pulley on top of the boom caught fire (Figure 2). The cables and the structure were both damaged and had to be replaced.

Construction was halted, due to the clear risks to worker safety and equipment reliability. Due to the major financial losses involved, the problem had to be solved as quickly as possible, both in respect to the construction of the pier itself, and its subsequent operation.

| AM station #1 | AM station #2 |
|---|---|
| Frequency: 1,280 kHz | Frequency: 900 kHz |
| Power: 100 kW (day) and 50 kW (night) | Power: 100 kW (day) and 50 kW (night) |

Table 1. Details of the AM stations.

The source of the interference was quickly identified: two AM transmitters located approximately 230 meters from the construction site (Table 1, Figure 3). The antennas operated at 100 kW and the maximum radiation direction from the antennas was directed towards the construction site.

The obvious first solution was to ground the whole vehicle using a thick chain connected to the crane structure. However, this did not alleviate the problem. Keeping the booms retracted was also not an option, since they had to be extended for the crane to be able to move and carry its load. Therefore, other alternatives were sought.

Searching through the literature showed that while the problem of electromagnetic induction in cranes is known, studies are limited, and most of the suggested countermeasures are designed for much higher frequencies. Very little information was found about induction caused by AM radio.

This meant that an in-depth study of the problem was necessary. In-site analysis was limited and compli-

Figure 3 • The antenna towers as seen from the construction site.

cated to the difficulty of access, and the large number of possible real world scenarios (for example, different crane positions and boom inclinations) ruled out practical evaluations. For this reason, computer simulation was employed to model the situation. Electromagnetic simulation allowed multiple scenarios to be evaluated, and offered understanding of the fundamental physics pertinent to the problem.

### Computer Simulation

Objects resonate at integer multiples of the wavelength, as well as at geometric fractions of the wavelength (½ wavelength, ¼ wavelength and so on). AM station #1 transmits at the frequency of 1,280 kHz, which corresponds to a wavelength of 234.4 m. The fractional resonant lengths for this frequency are 117.2 m, 58.6 m and, crucially, 29.3 m – a critical length for the cranes. At this length, the cranes behave as an antenna, capturing the incoming RF energy.

The first stage of characterizing the coupling between the cranes and the antennas is to calculate whether the crane lies in the antenna's farfield. The transmitting antennas are considered as monopoles, since they are vertical and the ground (which in this case includes the sea) is considered a good conductor in this frequency range.

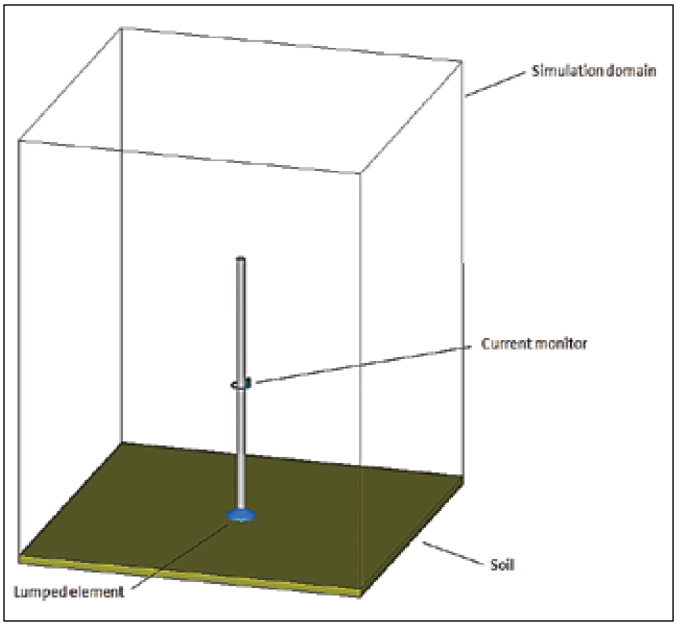



**Figure 4 • The initial crane model.**

For a monopole, the farfield limit $d$ is given by Balanis [1] as:

$$d = \frac{2D^2}{\lambda},$$

where $D$ is the largest antenna dimension and $\lambda$ is the wavelength in question. The results of this calculation for the AM stations are shown in Table 2:

| | Wavelength $\lambda$ (m) | $D$ (m) | $d$ (m) |
|---|---|---|---|
| Station #1 | 234 | 59 | 29 |
| Station #2 | 333 | 83 | 42 |

**Table 2 • Farfield distances of the AM stations.**

Since the cranes are both around 230 m from the antennas, they can be considered as residing in the antenna's farfields. This means that the analysis focused on treating the crane as a resonant structure.

The simulated model is shown in Figure 4. The crane was modeled in CST MICROWAVE STUDIO® (CST MWS) [2] as a simple vertical metallic cylinder, 1 meter from the ground, with a radius of 1 m. The cylinder has a height of 60 m. The ground is modeled as sandy soil, using the electrical properties from the CST MWS material database. Because the crane is located in the antenna's farfield, the excitation is modeled with a plane wave. The soil has a depth of 2 meters, with open boundaries to model an infinite expanse. The open top face was set as a normal perfect matched layer (PML).


WHEN EVERY CONNECTION COUNTS...
COUNT ON DELTA.




SMP/SMPM
Connectors

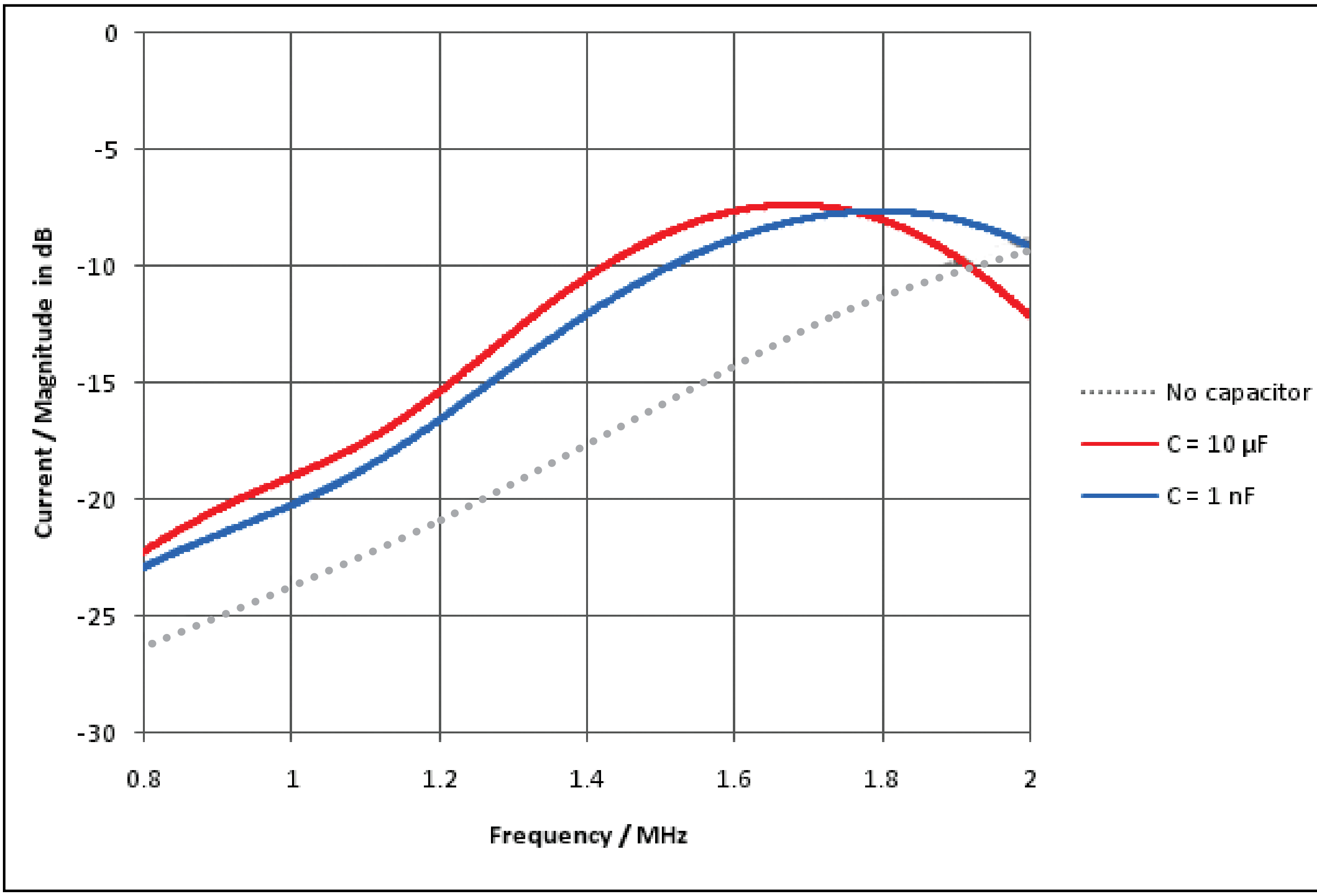



**Figure 5 • Received spectrum power (in dB) of the current measured on the probe placed on the boom. The frequency spans 800 kHz to 2 MHz.**

More sophisticated mechanical models were not available, and because of the urgency of the situation, a simplified model was deemed sufficient for the analysis.

Since the problem was caused by the size of the crane structure, the obvious approach was to decrease the boom size. Although it is impossible to shorten the mechanical structure, it is possible to make it electrically smaller. To do this, additional elements can be added between the boom and the ground, causing the boom to resonate at higher frequencies.

By analogy with standard antenna theory, the first element investigated was a capacitor. The capacitance was implemented with a lumped element, as shown in Figure 4, and the current was measured at a probe on the boom. The results from this study are shown in Figure 5.

From the results, it's clear that adding a capacitance actually increases the circulating current in this part of the radio spectrum. Attention therefore turned to the dual element of the capacitor, the inductor. Figure 6 shows the results for two different inductor values. These provided a reasonable decrease in induced current magnitude at around 1 MHz, suggesting that an inductor is the element of choice for alleviating the problem.

The next numerical evaluation analyzed the scenario where the hook was hanging, forming a loop. Loops are well known for their capacity for picking up magnetic fields, and so the combination of the crane boom and the dangling cable represents a potential problem. Figure 7 shows a simple 3D model taking into account the hook hanging 40 meters from the boom top, where the green dot is a probe that records the electrical field at 20 cm away from the cylinder.

As illustrated in Figure 8, the presence of a loop creates a resonance. As the loop area becomes larger, so do the electric fields. Further simulations showed that with larger areas, the maximum electric field amplitudes corresponded with lower resonances, increasing the levels of hazardous electric fields on the structure.

### Practical Implementation

Once simulation had established that adding an inductor offered a solution to the problem, attention

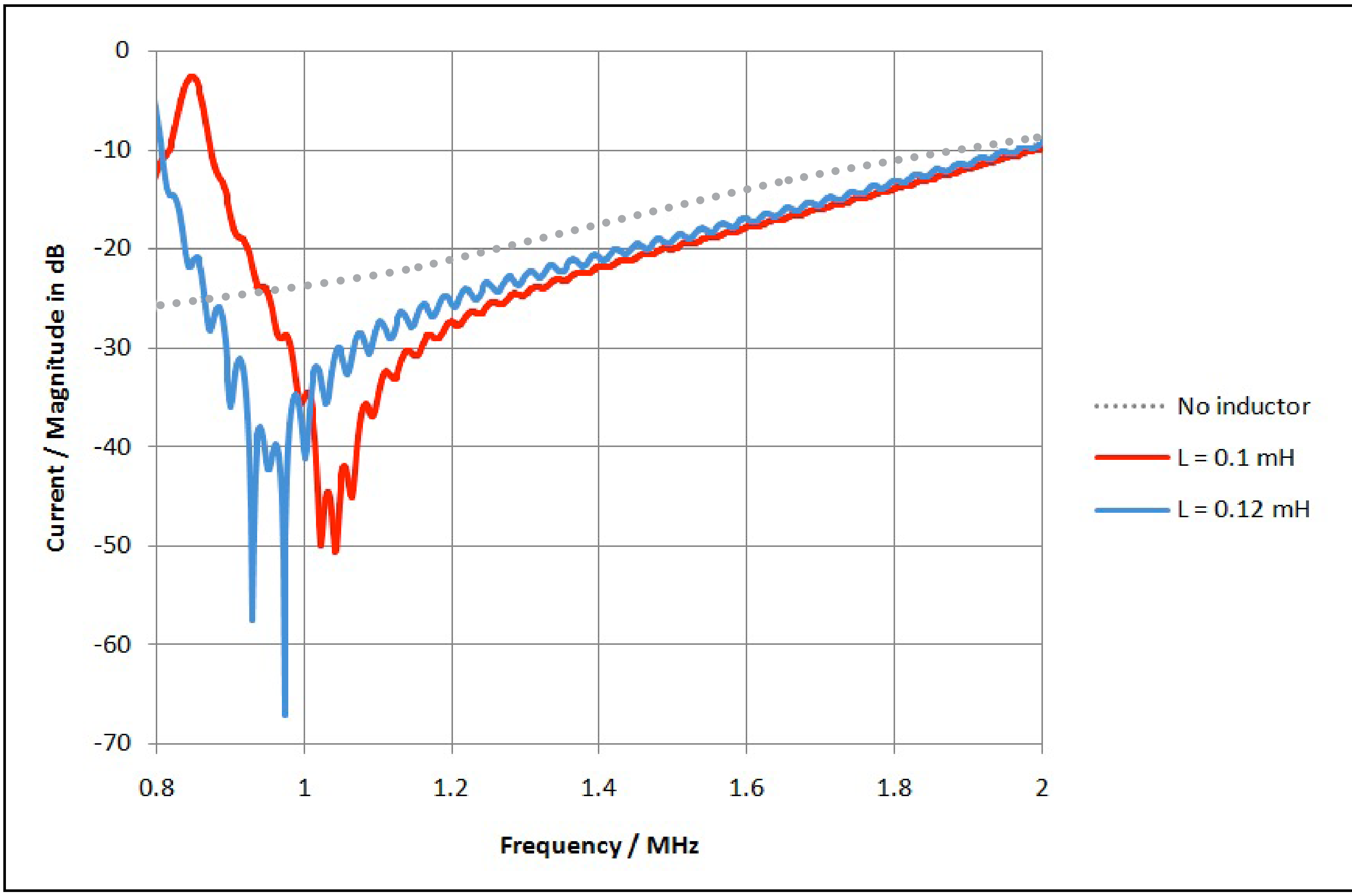



**Figure 6 • Received spectrum power (in dB) as in Figure 5, with an inductor in place of the capacitor.**

turned to implementing this solution in the real world. Due to physical constraints and the quick and dirty modeling, the exact value of inductance found in the simulation was not important. More important was the principle revealed: that an inductive coil can inhibit resonances in the AM frequency bands.

The chosen implementation is shown in Figure 9. 85 meters of cable with cross-section 2.5 mm$^2$ were wound around the hydraulic jack of the crane. This acted as the ferrite core of an inductor, giving the coil the correct inductance level to prevent the EMI problems. One end of the coil was connected to the hook, and the other grounded to a suitable point nearby. During operation, the wire between the hook and the coil forms a catenary, whose length and shape can be manually controlled by the operators down on the ground.

Tests were performed with the boom angled to produce the maximum induced voltage. These proved that the implemented modifications worked, allowing safe, shock-free operation. The site was officially deemed safe

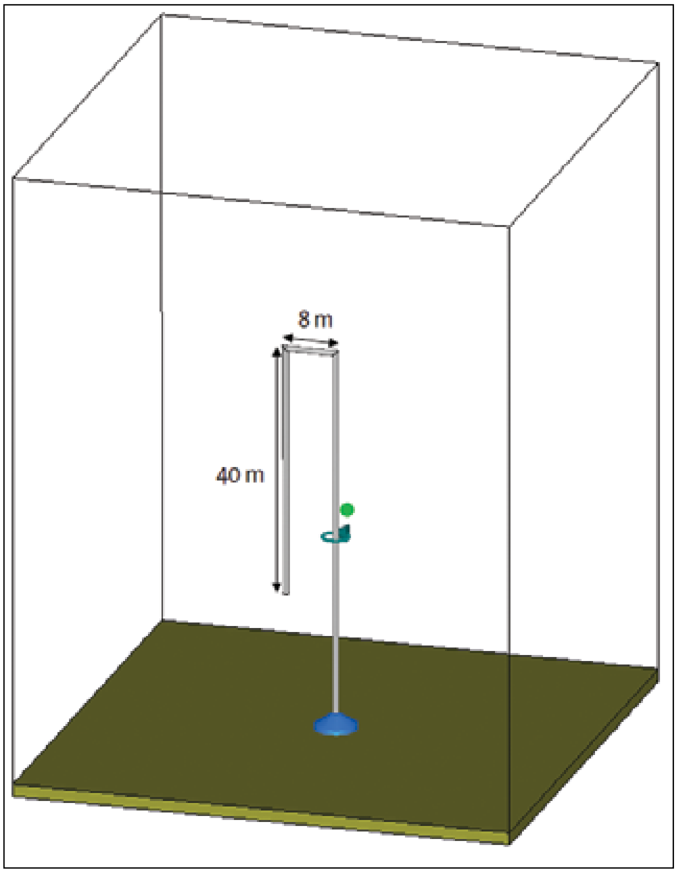



Figure 7 • The loop model. The green dot highlights the position of the field probe.

again and construction resumed, with no further financial or schedule losses.

### RF Frequency Considerations

The stopgap solution detailed above allowed construction to resume. However, the actual operation of the finished pier also needed to be examined in detail. As well as the electric shock risk, other considerations included the protection of electronic systems against EMI, the exposure of workers to non-ionizing radiation and interference with transmissions from the radio stations.

The main exposure hazard for RF energy is the heating of body tissues. At FM radio frequencies (around 90 MHz), the dimensions of the body mean that it acts as a good antenna. For lower frequencies such as the AM radio band, this effect is almost negligible, since the AM wavelength is so much larger than a human body.

Instead the biggest concern to take account for the protection of workers in the pier was electrostimulation—the effect of an electrical current passing through the body. If the voltage between the structure and the worker is high enough, arcing can occur, causing burns.

Protective measures against these currents include insulating boots and gloves for workers who interact with the crane or suspended cargo, and appropriate training for involved staff.[3] To help avoid shocks and burns, the voltage of metal parts should be verified before they are touched. As an example, the United

Figure 9: (a) The implemented coil and (b) the wire connecting the hook to the coil.

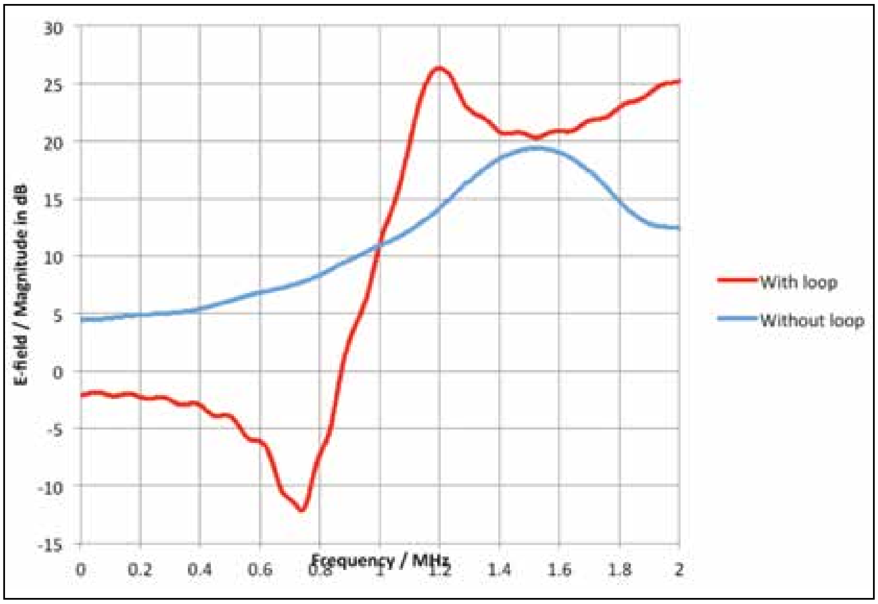



**Figure 8 • The response (absolute electric field measured at the probe position) for the cases with loop (red curve) and without loop (blue curve).**

States Navy has adopted 140 V as a maximum allowable voltage across the body in this frequency range.[4]

The voltages pose particular risk to the crane operator. While the crane cabin should be grounded for various reasons, this will have little influence on the high voltages at the bottom of the crane. Instead, the best solution is to isolate the operator from the voltage on the crane and load. This can be done by isolating the driver from metallic parts such as the control pedals, by replacing the cables or hooks with non-conductive materials such as nylon and Kevlar which are strong enough to support the load from the hook, and operating the crane remotely using a wireless control system.

### About the Authors:

Marcelo Bender Perotoni is a Professor, UFABC, Brazil. Email: Marcelo.perotoni@ufabc.edu.br. Roberto Menna Barreto is Managing Partner, QEMC – Engenharia, Qualidade e Compatibilidade Eletromagnética Ltda, Brazil. Email: menna@qemc.com.br.

### References

[1] C. Balanis, *Antenna Theory: Analysis and Design*

[2] CST - Computer Simulation Technology, www.cst.com

[3] R. Stricklan, "Safety Training for Workers in High-RF Environments", Above Ground Level (AGL) magazine, March 2010, Vol. 7, No. 3

[4] R. Olsen, J. Schneider, R. Tell, "Radio Frequency Burns in the Power System Workplace", IEEE Transactions on Power Delivery, January 2011, Vol. 26, No. 1

# Enhancing Second Harmonic Suppression in an Ultra-Broadband RF Push-Pull Amplifier

**By Gavin T. Watkins**

By incorporating an attenuator and delay line in one of the paths the distortion suppression of the amplifier is modified.


### Abstract

An ultra-broadband push-pull amplifier operating over a bandwidth of two and a half octaves from 50 MHz to 300 MHz is described here. The broadband second harmonic distortion suppression of the amplifier is characterized in terms of gain and phase imbalance between the two amplifier paths. By incorporating an attenuator and delay line in one of the paths the distortion suppression of the amplifier is modified so that greater than -45 dBc is achieved over the whole band. Up to 11 dB improvement in suppression was achieved using this method.


### Introduction

In low power and broadband applications where amplifier efficiency is noncritical, shunt-series feedback is often used [1]. At high powers this is impractical due to the low efficiency and the parasitic strays of resistive elements used in the feedback network. Transformer-coupled push pull amplifiers are capable of efficient operation at medium and high output power levels. Since transformers can provide a purely resistive impedance transformation over their operating range, broadband operation of 1:250 is possible [2]. Some less traditional applications have also emerged like envelope tracking where extremely wide operation is again required [3].

### Transformer Coupled Push-Pull Amplifier

A push-pull amplifier generally consists of four main elements: an input transformer connected in anti-phase, two single ended amplifiers (SEAs) and an output transformer to combine the outputs of the SEAs in anti-phase as shown below in Fig. 1 (a).

The output spectrum of each SEA consists of a fundamental tone and harmonically related distortion products as shown by the Volterra series:

$$y(t) = a_1\, x(t) + a_2\, x(t)^2 + a_3 x(t)^3 + a_4 x(t)^4 \ldots \tag{1}$$

where x(t) is the input signal and y(t) the output. Because the center tap of input transformer's secondary is grounded, one SEA will see x(t) as its input and the other –x(t). Since the $(-x(t))^2$ is equal to $(-x(t))^2$, the output $y_1(t)$ of path one and $y_2(t)$ of path two will be:

$$y_1(t) = a_1\, x(t) + a_2\, x(t)^2 + a_3\, x(t)^3 + a_4\; x(t)^4 \ldots \tag{2}$$

$$y_2(t) = -a_1 x(t) + a_2\, x(t)^2 - a_3\, x(t)^3 + a_4\; x(t)^4 \ldots \tag{3}$$

$y_1(t)$ and $y_2(t)$ are combined in anti-phase resulting in the fundamental components (FUN) and odd order harmonics adding, whereas the even order harmonics cancel [4].

*UP TO* **100 Watt**

# AMPLIFIERS

**NOW!** **100 kHz to 18 GHz**

from **$945** ea. qty. (1-9)

**High-powered performance, across wide frequency ranges.** These class A linear amplifiers have set a standard throughout the RF & microwave industry. Rugged and reliable, they feature over-voltage and over-temperature protection, including the ability to withstand opens and shorts! And they're all in stock, whether with a heat sink/fan (for design labs and test benches), or without (for quick integration into customer assemblies). Go to minicircuits.com, and it's easy to select the models that meet your needs, including new features like TTL-controlled RF output. Place an order today, and you can have them in your hands as soon as tomorrow—or if you need a custom model, just give us a call for an engineer-to-engineer discussion of your requirements!

| Model (*with heat sink/fan**) | Frequency (MHz) | Gain (dB) | Pout @ Comp. 1 dB (W) | Pout @ Comp. 3 dB (W) | $ Price (Qty. 1-9) *with* heat sink | $ Price (Qty. 1-9) *without** heat sink |
|---|---|---|---|---|---|---|
| LZY-22+ | 0.1-200 | 43 | 16 | 32 | 1495 | 1470 |
| ZHL-5W-1 | 5-500 | 44 | 8 | 11 | 995 | 970 |
| • ZHL-100W-GAN+ | 20-500 | 42 | 79 | 100 | 2395 | 2320 |
| • ZHL-50W-52 | 50-500 | 50 | 40 | 63 | 1395 | 1320 |
| • ZHL-100W-52 | 50-500 | 50 | 63 | 79 | 1995 | 1920 |
| LZY-1+ | 20-512 | 43 | 37 | 50 | 1995 | 1895 |
| • ZHL-20W-13+ | 20-1000 | 50 | 13 | 20 | 1395 | 1320 |
| • ZHL-20W-13SW+ | 20-1000 | 50 | 13 | 20 | 1445 | 1370 |
| LZY-2+ | 500-1000 | 46 | 32 | 38 | 1995 | 1895 |
| NEW ZHL-100W-13+ | 800-1000 | 50 | 79 | 100 | 2195 | 2095 |
| ZHL-5W-2G+ | 800-2000 | 45 | 5 | 6 | 995 | 945 |
| ZHL-10W-2G | 800-2000 | 43 | 10 | 13 | 1295 | 1220 |
| ZHL-30W-252+ | 700-2500 | 50 | 25 | 40 | 2995 | 2920 |
| ZHL-30W-262+ | 2300-2550 | 50 | 20 | 32 | 1995 | 1920 |
| ZHL-16W-43+ | 1800-4000 | 45 | 13 | 16 | 1595 | 1545 |
| ZVE-3W-83+ | 2000-8000 | 36 | 2 | 3 | 1295 | 1220 |
| ZVE-3W-183+ | 5900-18000 | 35 | 2 | 3 | 1295 | 1220 |

*Listed performance data typical, see minicircuits.com for more details.*

** To order **without** heat sink, add **X** suffix to model number (example: LZY-22X+).*

*• Protected under U.S. Patent 7,348,854*

**Mini-Circuits®**

**www.minicircuits.com** P.O. Box 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

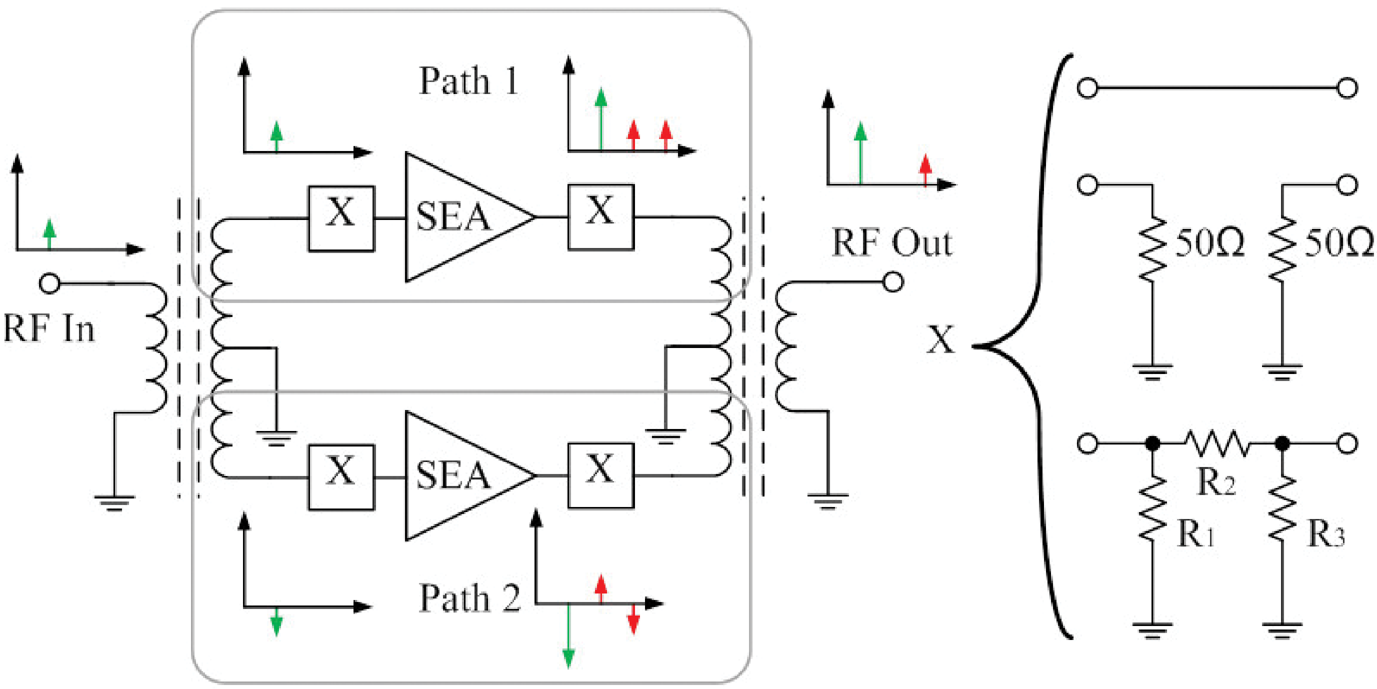



**Figure 1 •Push-pull amplifier where block X can be either a short, two 50Ω loads, or a Pi type attenuator.**

### Second Harmonic Suppressions in Push-Pull Amplifiers

Second harmonic distortion (2HD) in transformer coupled push-pull amplifiers has previously been examined [5] [6], but no mechanisms given for enhancing its suppression. 2HD is generated by non-linear processes, but its suppression is linear. A high degree of suppression requires a very small gain and phase imbalance [7]:

$$S_{dB} = 10\log_{10}((\cos\delta\theta - \delta A\cos\delta\theta)^2 + (\sin\delta\theta + \delta A\sin\delta\theta)^2) \tag{4}$$

where δθ is the phase imbalance between the two signals, and δA the amplitude imbalance. A phase and gain imbalance of 1° and 1 dB results in -18.8 dB suppression [8] as shown in Fig. 2.

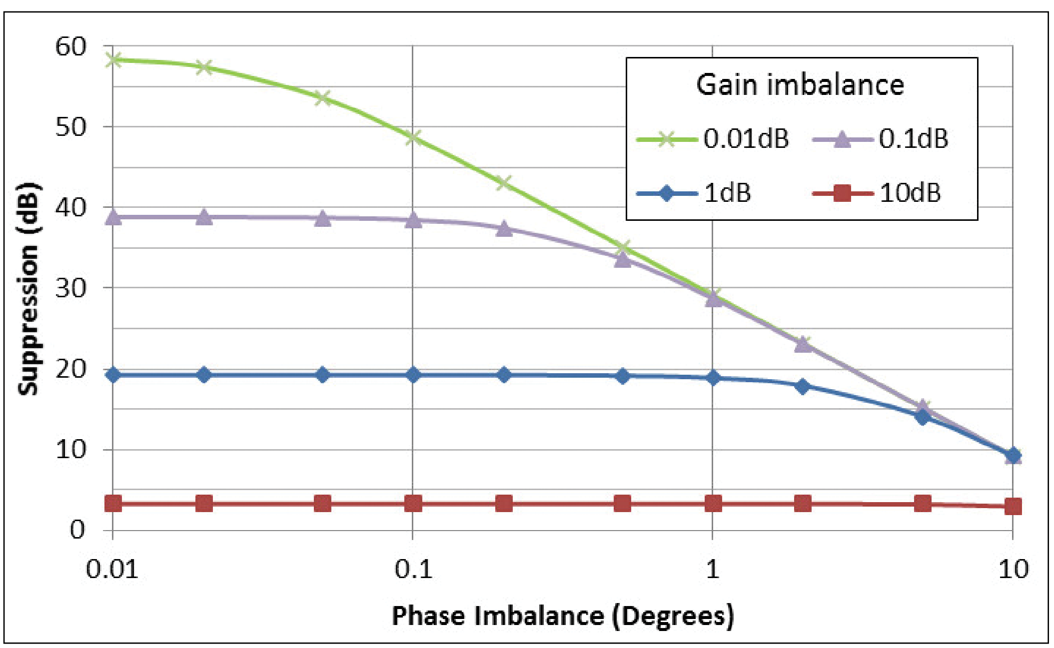



**Figure 2 • Dependence of signal suppression on gain and phase imbalance.**

Amphenol SV MICROWAVE®

# ATTENUATORS & TERMINATIONS...

SV Microwave offers the most comprehensive line of standard and QPL (Mil-Approved) Coaxial Attenuators and terminations in the industry today. Microwave Components Inc. has been delivering SV Microwave precision components from stock for more than a decade !!!

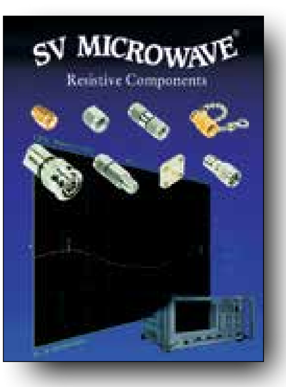
***Call us today and put our experience to work for you...***

## Attenuators

- SMA, TNC, N, 2.4 mm, 2.9 mm
- Nominal Impedance: 50 ohms
- Frequency Range: DC-50 GHz
- Interfaces IAW MIL-PRF-39012
- Meet requirements of MIL-A-3933
- Environmental Standards per MIL-STD-202

## Terminations

- SMA, TNC, N, 2.4 mm, 2.9 mm, ZMA
- Nominal Impedance: 50 ohms
- Frequency Range: DC-50 GHz
- Interfaces IAW MIL-PRF-39012
- Meet requirements of MIL-DTL-39030
- Environmental Standards per MIL-STD-202




## Mil Approved Products in Stock:

- M39012 – Connectors
- M3933 – Attenuators
- M39030 – Terminations
- M55339 – Adapters
- M83571 – Receptacles

***Contact us today for a Resistive Components Brochure***

VISA MasterCard AMERICAN EXPRESS

MICROWAVE COMPONENTS

Phone: (888) 591-4455 or (772) 286-4455 Fax: (772) 286-4496
E-mail: admin@microwavecomponentsinc.com
Web Site: www.microwavecomponentsinc.com

AS 9120
ISO 9001:2000
CERTIFIED

Fig. 2 is applicable for 2HD imbalance incurred at the output of the SEAs. Phase imbalance to the FUN at the input of the SEAs will result in a doubling of the 2HD phase imbalance at their outputs because if:

$$x = \cos \delta\theta \quad (5)$$

then:

$$x^2 = (\cos \delta\theta)^2 = \frac{\cos 2\delta\theta + 1}{2} \quad (6)$$

The impact of FUN input gain mismatch on the 2HD will be similarly affected by the $x^2$ term.

### Practical Amplifier Measurements

A test amplifier using two Analog Devices ADL5536s [9] was developed based on Fig. 1 (b). A photograph of it is shown in Fig. 3.

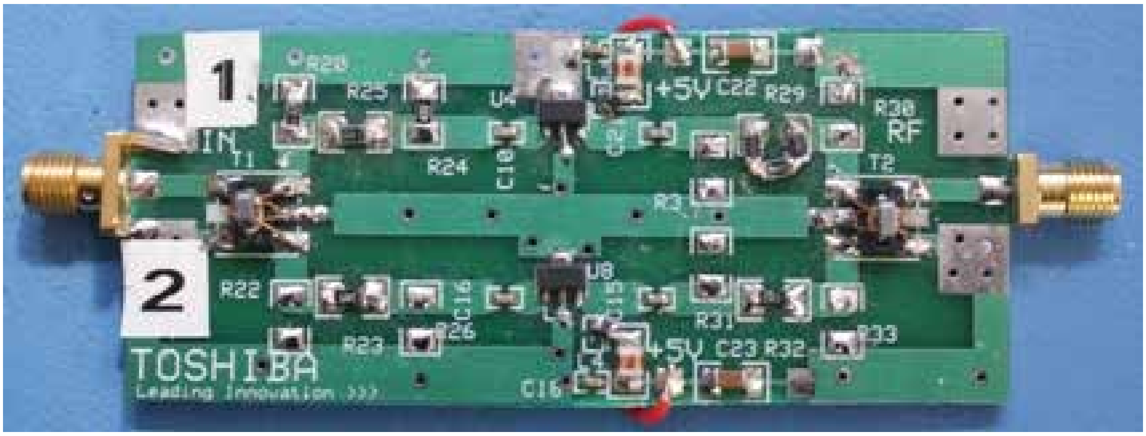



**Figure 3 • Photograph of test amplifier.**

The ADL5536 has a 1dB compression point ($P_{1dB}$) of 20 dBm and a second order intercept point (IP2) of 60 dBm. In a push-pull amplifier due to the signal power being amplified by two separate paths the combined $P_{1dB}$ will be 3 dB greater at 23 dBm. This assumes that the two paths are combined perfectly in phase. Any discrepancy in their phase will lead to a slight reduction in the combined amplitude [10].

The ADL5536 has a gain of 20 dB. With an IP2 of 60 dBm at the individual SEAs $P_{1dB}$ of 20 dBm, the 2HD will be -17 dBm, or -37 dBc relative to the FUN [7]. The 2HD at the output of the push-pull amplifier will be susceptible to the 3dB loss due to the combining transformer. Therefore it follows, that without any suppression the 2HD at the $P_{1dB}$ should be -40 dBc. This is a typical value for a broadband transformer coupled push-pull amplifier [2]. The measured $P_{1dB}$ and 2HD suppression of the test amplifier are shown in Fig. 4.

Although the two paths of the amplifier in Fig. 3 appear visually identical, Fig. 4 suggests otherwise. At 100 MHz the $P_{1dB}$ is 23 dBm as it should be, and the 2HD suppressed by an additional 17 dB to -54 dBc. However at 300 MHz the measured $P_{1dB}$ and 2HD suppression are equivalent to that of a single SEA.

This degradation is due to gain and phase imbalance between the paths. By splitting the push-pull amplifier into two paths each can be examined in isolation. Since the imbalance is due to both the SEAs and the transformer, it is necessary to include the transformers in these measurements. For example, to evaluate Path 1, the two X blocks of Path 2 in Fig. 1 are broken, both the transformers and SEA's input and output ports terminated with 50 Ω resistors. The ADL5536 has an $|S_{11}|$ of approximately -19 dB and an $|S_{22}|$ of -15 dB over the band of interest, which is close enough to 50 Ω.

By doing this the FUN and 2HD transfer responses of each path can be measured as shown in Fig. 5 and Fig. 6 respectively at both 150 MHz and 300 MHz, where performance is worse.

At 150 MHz, the gain imbalance between the generated 2HD is approximately 1.5 dB. Assuming zero phase imbalance, then (2) predicts an additional 2HD suppression of 16 dB. At 300 MHz the 2HD has a highly no-linear response, increasing by 6.4 dB/dB at worst. However, the gain imbalance at the $P_{1dB}$ is only 0.2 dB, equivalent to an additional 33dB of suppression, assuming zero phase imbalance.

It will be noted that the level of 2DH generated is considerably greater than that predicted by the IP2. This is likely due to the IP2 being a small signal measurement, not when the ADL5536 is at its $P_{1dB}$.

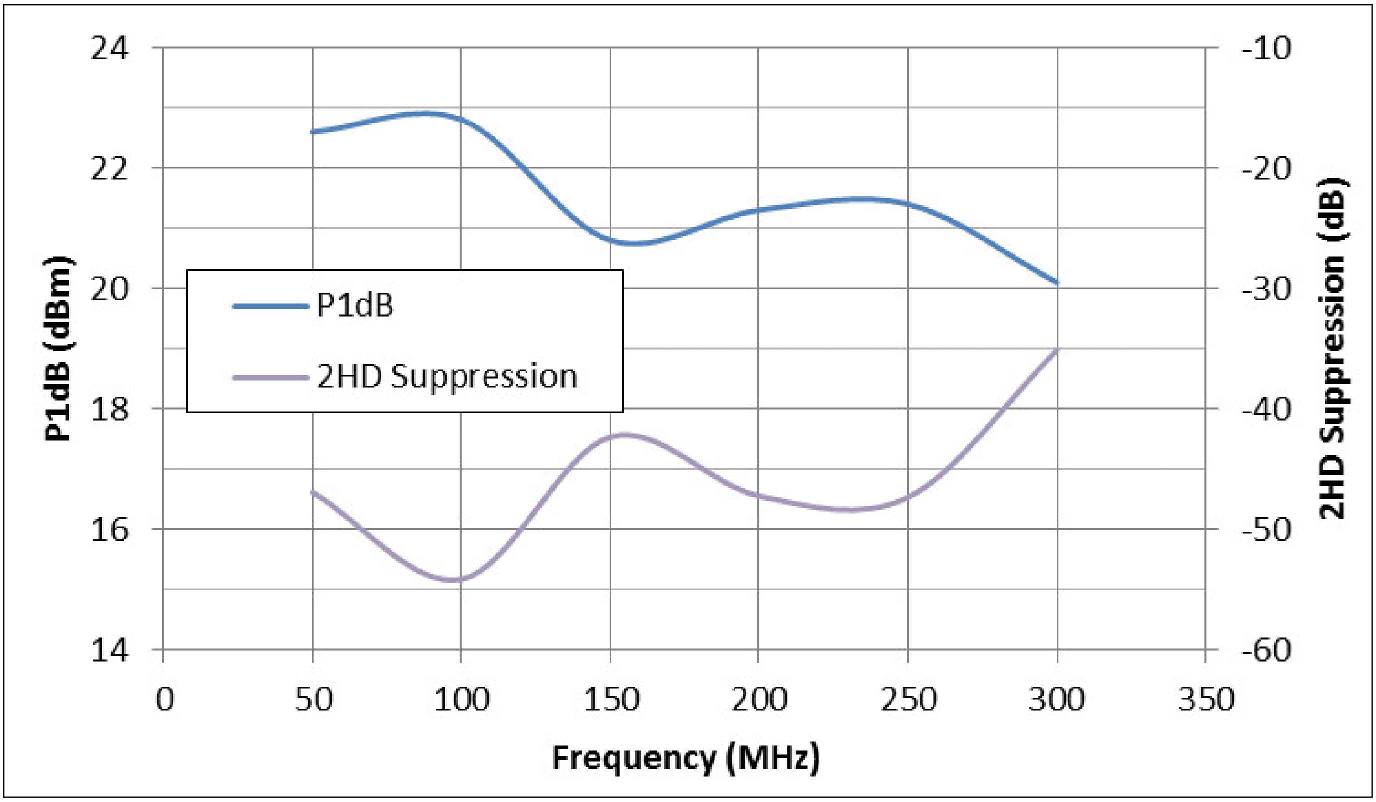



**Figure 4 • $P_{1dB}$ and 2HD suppression of test amplifier.**

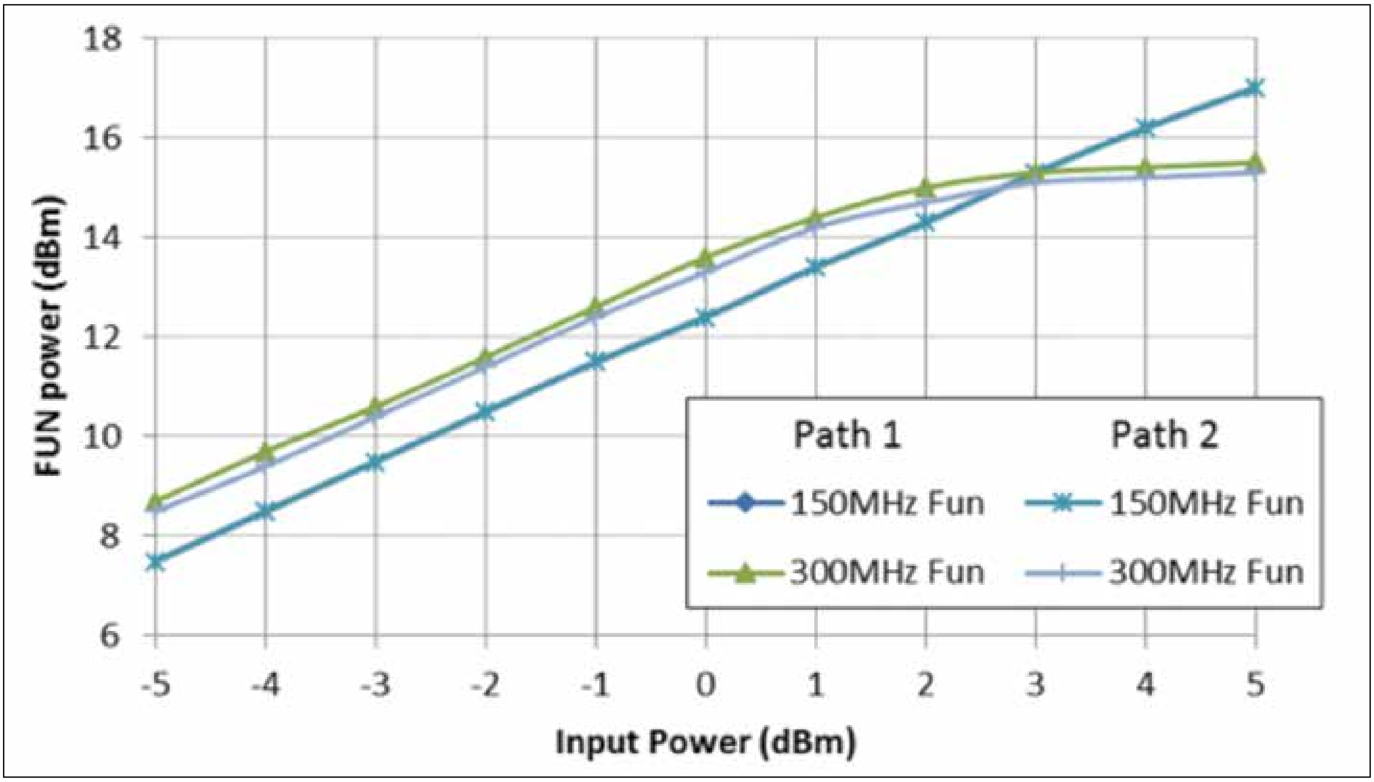



**Figure 5 • Power of the fundamental component at 150 MHz and 300 MHz up to the $P_{1dB}$.**

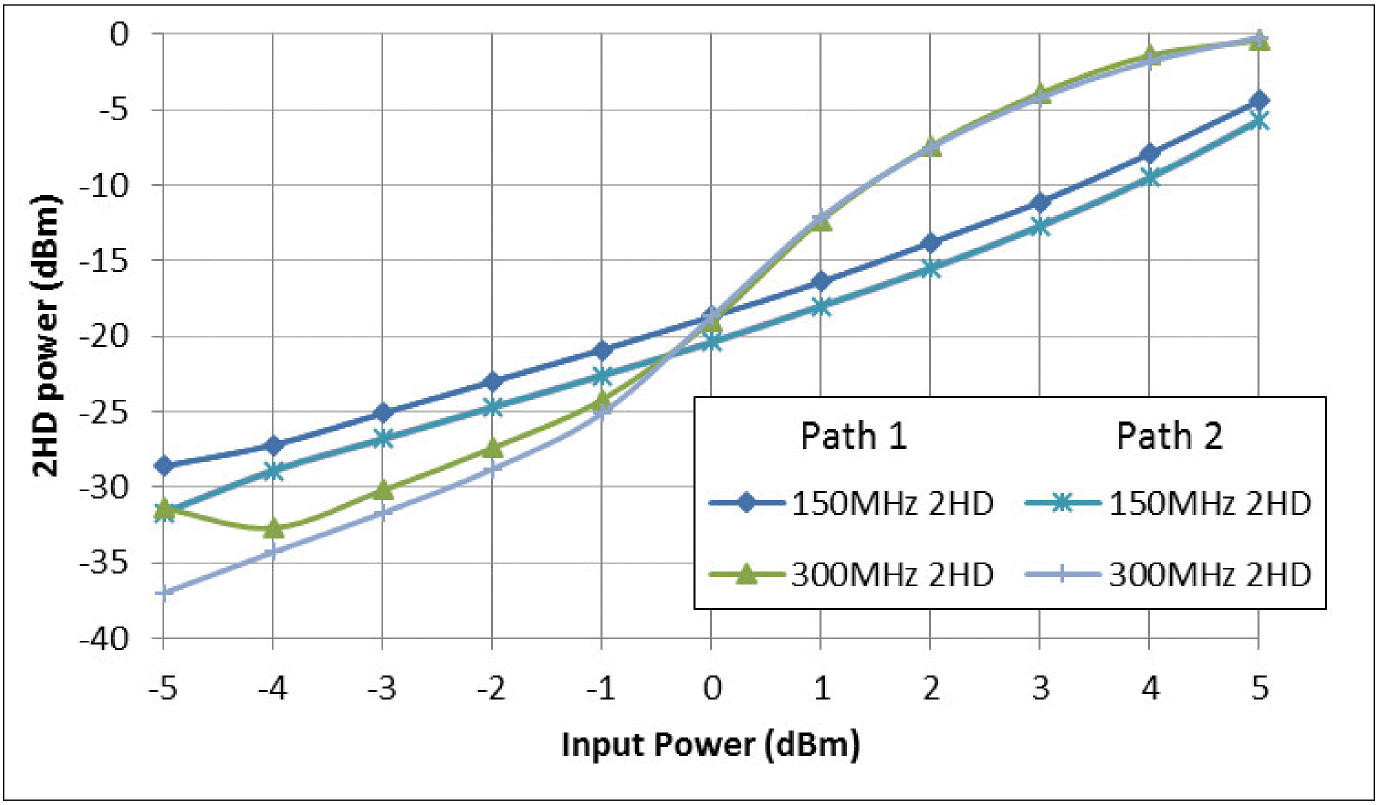



**Figure 6 • Power of the second harmonic component at 150 MHz and 300 MHz up to the $P_{1dB}$.**

### Modelling the 2HD Suppression

The degree to which gain imbalance in the individual paths affects the generated 2HD distortion can be analyzed by subtracting the individual powers of each path:

$$2HD_{pp} = 20\log_{10}\left(\left|10^{\left(\frac{2HD1}{20}\right)} - 10^{\left(\frac{2HD2}{20}\right)}\right|\right) \tag{4}$$

$2HD_{pp}$ is the 2HD of the push-pull amplifier, $2HD_1$ path 1 and $2HD_2$ path 2. Base on (7) and the results presented in Fig. 4, and Fig. 6 are compared in Table 1 at the $P_{1dB}$.

| 2HD | 150 MHz | 300 MHz |
|---|---|---|
| Measured push-pull amplifier | -21.7 dBm | -15.0 dBm |
| Measured Suppression | -42.4 dBc | -35.1 dBc |
| Measured Path 1 | -4.4 dBm | -0.4 dBm |
| Measured Path 2 | -5.7 dBm | -0.2 dBm |
| Modelled (7) | -21.5 dBm | -33.1 dBm |
| Modelled Suppression | -44.4 dBc | -54.5 dBc |

**Table 1 • Measured versus modelled 2HD.**

It is noted that at 150 MHz the model fits the measurements, suggesting that limited 2HD suppression is due to a gain imbalance between the paths. However, at 300 MHz, there exists a 19.4 dB difference between the measured and modelled results, suggesting a phase imbalance is the cause.

If zero gain imbalance is assumed, then the phase imbalance at 300 MHz is 5.2º. Since the phase shift through a delay line is proportional to frequency that at 150 MHz would be 2.6 º. This assumes a first order phase response, i.e.

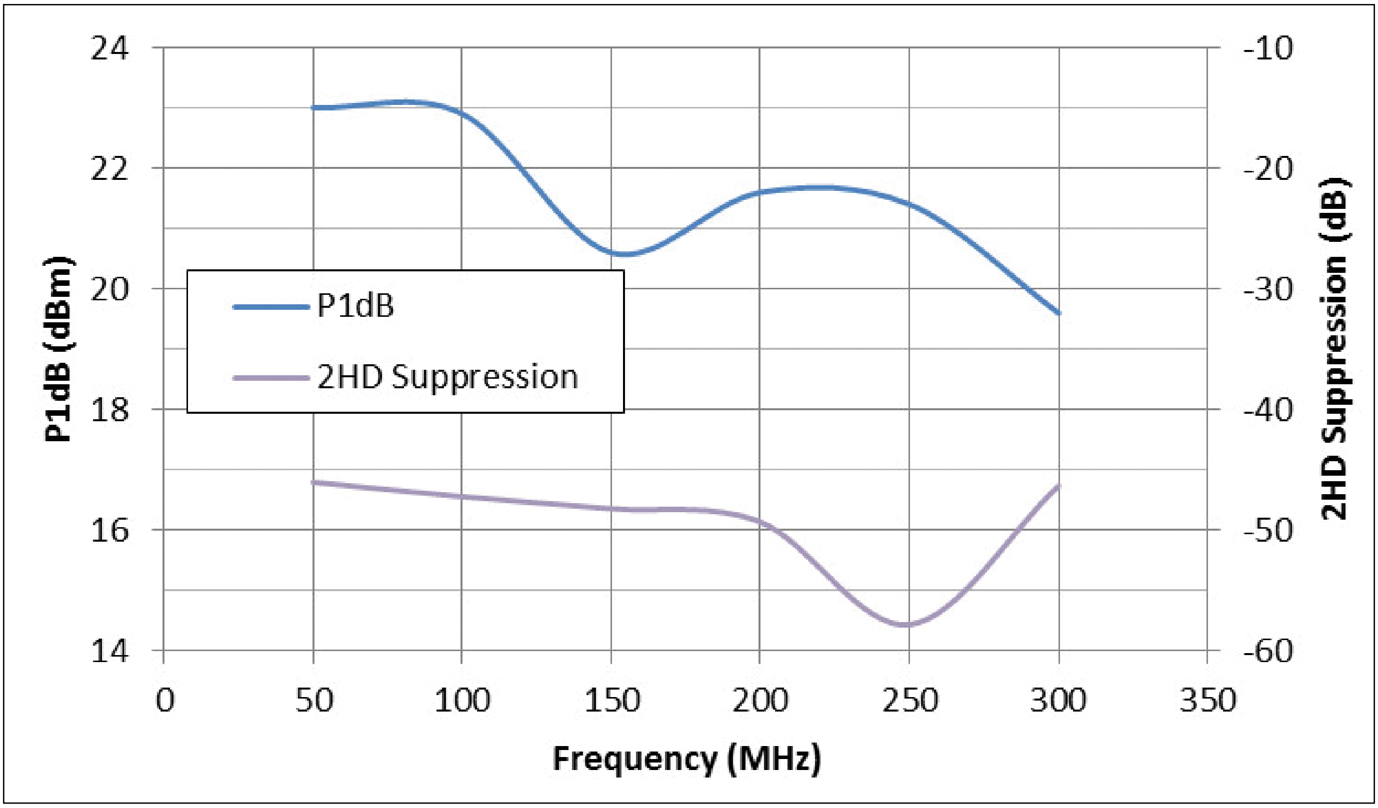



**Figure 7 • Broadband compensated second harmonic.**

increasing linearly with frequency. However, if the phase imbalance originates from the input of the SEAs it will be second order (6), i.e. phase shift is proportional to frequency$^2$.

### Compensation of Phase and Gain Imbalance

The 2HD of the SEAs at 150MHz increases at a rate of 2.8dB/dB as they approach the $P_{1dB}$. Therefore $x(t)^2$ in (1) becomes $x(t)^{2.8}$. The 2HD generated in Path 1 is reduced to the level of that of Path 2 with an attenuator at the input. As a compromise a 0.2dB Pi attenuator composed of 1 Ω and 4.3 kΩ resistors was found to work best. The 2HD suppression at 300MHz was improved with a small delay line also in Path 1. The optimum place for this was after the SEA, the phase shift it introduces will therefore be first order. The enhanced 2HD suppression is shown in Fig. 7.

Comparing Fig. 7 to Fig. 4, it is observed, that the 2HD is now suppressed by at least 45dB over all of the band, an improvement of 11.2dB at 300MHz.

Over narrow bandwidths suppression could be enhanced further, but the aim of this work is broadband compensation of 2HD over the whole 50 MHz to 300 MHz band. The measured 2HD with compensation at 150 MHz at the $P_{1dB}$ was -22.2 dBm, resulting in -42.7 dBc suppression and -26.7 dBm at 300 MHz resulting in -46.3 dBc. The 2HD is kept below -45 dBc apart from at 150 MHz due to a dip in FUN power. The reason for this is currently unknown, but likely due to resonances in the board layout. Applying these techniques to other push-pull amplifier like [2] would improve its 2HD suppression.

Other factors not modelled in this paper are the distortion products generated at the input of the SEAs and reflected back into the input transformer [11]. The input generated distortion of one SEA will be amplified by the other. This highly non-linear effect, is hard to model, due to its phasing and combining in the transformer, but could possibly be exploited to improve 2HD suppression in the future.

### Conclusion

The second harmonic suppression of a broadband push-pull amplifier is examined here and mechanisms devised to improve it. Although the generation of the distortion is non-linear its suppression is linear. For a test amplifier phase imbalance was compensated for by introducing a small electrical delay into one of paths and gain imbalance with an attenuator. Using these techniques, the suppression was enhanced by up to 11.2 dB over an operating bandwidth of 50 MHz to 300 MHz.

### About the Author:

Gavin T. Watkins, MIET, MEuMA, serves as Principal Research Engineer at Toshiba Research Europe Limited, 32 Queen Square, Bristol BS1 4ND, United Kingdom, gavin.watkins@toshiba-trel.com.

### References

1. R. G. Meyer, R. Eschenback, R. Chin, "A wide-band ultralinear amplifier from 3 to 300 MHz", IEEE Journal of Solid-State Circuits, Vol. SC-9, No. 4, Aug. 1974, pp. 167-175.

2. M. Seo, K. Kim, M. Kim, H. Kim, J. Jeon, J. Sim, M. Park, Y. Yang, "Design of a 40Watt ultra broadband linear power amplifier using LDMOSFETs", Proceedings of Asia-Pacific Microwave Conference 2010, 2010, pp. 414-417.

3. J. Zhou, K. Morris, G. Watkins, K. Yamaguchi, "Three-band high-efficiency modulator for envelope tracking power amplifier using class-B push-pull amplifiers", 2012 42nd European Microwave Conference (EuMC), 2012, pp. 124-127.

4. Mini-Circuits Application Note AN-60-009, "HELA-10: High IP3, wideband linear power amplifier", available from www.minicircuits.com, viewed 08/04/13.

5. W. H. Lambert, "Second-order distortion in CATV push-pull amplifiers", Proceedings of The IEEE, Vol. 58, No. 7, 1970, pp. 1057-1065.

6. K. W. Gurnett, R. A. Hilbourne, "Distortion due to the mismatch of transistors in push-pull audio frequency amplifiers", Proceedings of the IEE – Part C: Monographs, Vol. 104, No. 6, 1957, pp. 411-422.

7. P. B. Kenninvton, "High-linearity RF amplifier design", Artech House, 2000, ISBN: 1-58053-143-1.

8. G. T. Watkins, P. A. Warr, "Flexible linearity profile low noise feedforward amplifiers for improving channel capacity", The 57th IEEE Seminanual Vehicular Technology Conference, 2003, Vol. 3, 22-25 Apr. 2003, pp. 1567-1570.

9. ADL5536 datasheet, available from www.analog.com, viewed 08/04/13.

10. R. Smith, S. Cripps, "Broadband Push-Pull Power Amplifier Design at Microwave Frequencies" 2013 Spring ARMMs Conference, Apr. 22nd and 23rd.

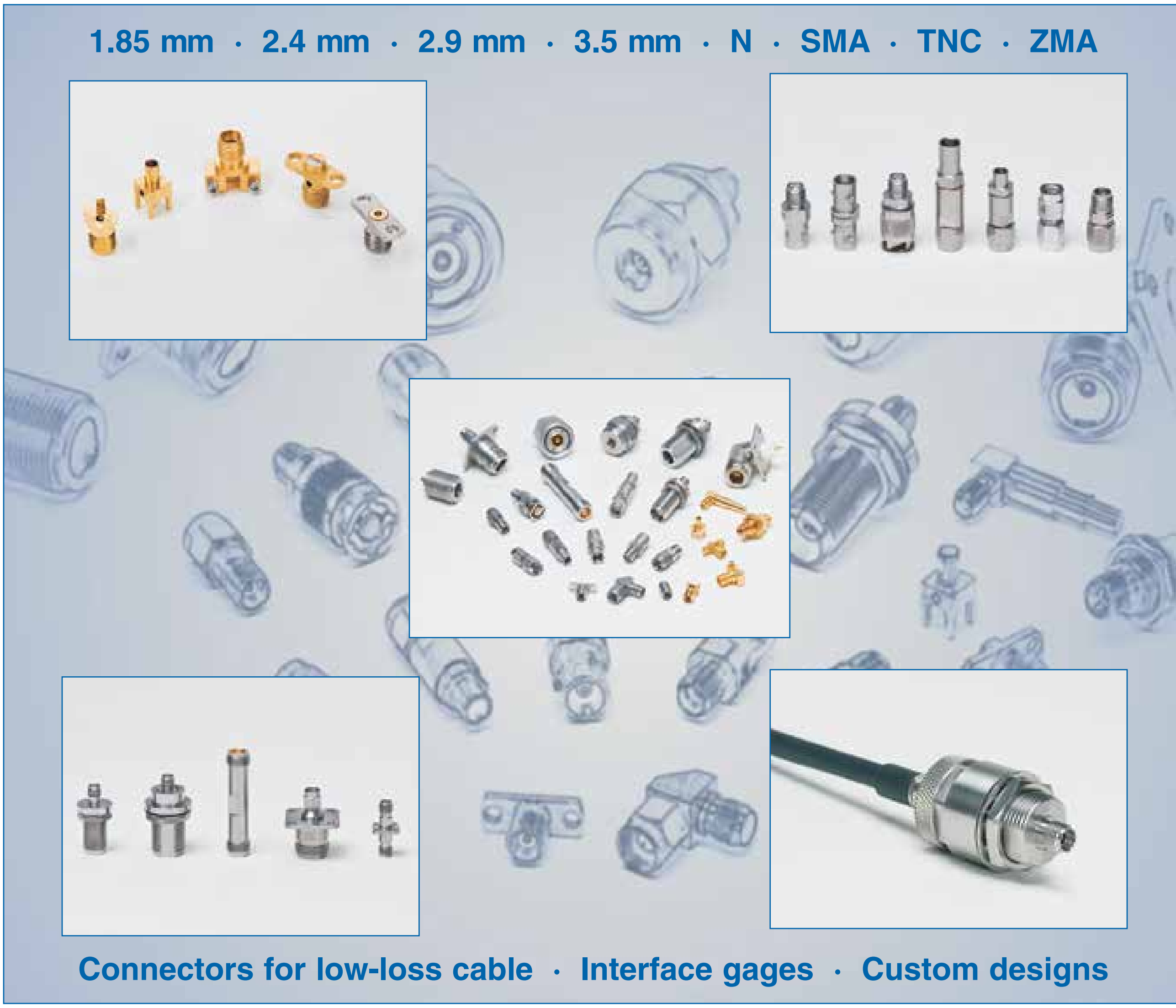
11. P. A. Warr, M. A. Beach, J. P. McGeehan, "Amplifier linearization by exploitation of backwards-travelling signals", Electronics Letters, Vol. 38, No. 6, pp. 260-261.

*DISTRIBUTOR AND MANUFACTURER'S REPRESENTATIVES*

# C. W. SWIFT & Associates, Inc.

SRI CONNECTOR GAGE COMPANY

*Featuring Coaxial Connectors, Adapters, and Interface Gages from SRI Connector Gage*




*We stock RF, microwave and millimeter wave connectors, adapters, and interface gages from SRI Connector Gage and other fine manufacturers. Call today for a quote.*

## C. W. SWIFT & Associates, Inc.

15216 Burbank Blvd.
Van Nuys, CA 91411
Tel: 800-642-7692 or 818-989-1133
Fax: 818-989-4784
sales@cwswift.com
www.cwswift.com

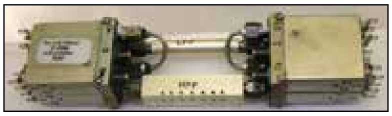
*CLOSED EVERY ST. PATRICK'S DAY !*

## Multiplier

Model SFA-903983418-10KF-N1 is a W band X4 active multiplier with center frequency at 94 GHz with minimum ± 4 GHz operational bandwidth. The active multiplier converts 22.5 to 24.5 GHz/+5 dBm input signal to +18 dBm output power in the frequency range of 90 to 98 GHz. The active multiplier has better than -25 dBc harmonic suppression.

**SAGE Millimeter**
**sagemillimeter.com**

## Filter Assembly



RLC provides Switched Filter Bank assemblies designed and built to customers' exact electrical, mechanical, and environmental specifications. Through integration, RLC is able to help the design engineer minimize mass and overall circuit footprint while optimizing the transitions between circuit elements. By optimizing internal interfaces, RLC is able to provide improved loss and VSWR performance in a small package.

**RLC Electronics**
**rlcelectronics.com**

## Couplers

VidaRF offers a wide selection of Directional Couplers, Dual Directional Couplers and Hybrid Couplers, designed to cover 0.1 GHz to 20 GHz. Average power from 50W to 1kW. Standard coupling values 3, 6, 10, 15, 20, 25 and 30 dB. Standard Connector type: SMA female, other connectors available upon request.


VidaRF is a North Carolina based company that is focused on being a solutions provider.

**VidaRF**
**vidarf.com**


## Controller

Micrel introduced the MIC21000, true-digital PWM controller for high-current, non-isolated DC-DC power supplies in computing and telecom applications. Designed to work with an external industry standard DrMOS as well as Micrel's proprietary IntelliMOS® solution, the MIC21000 can be used as a flexible building block for +12V or +5V step-down, high current point-of-load power supplies.

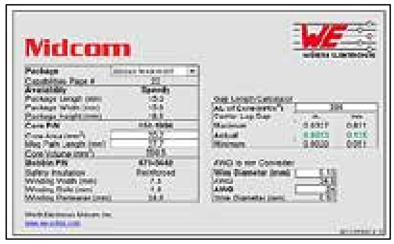
**Micrel**
**micrel.com**


## LNAs

The TQL9042 and TQL9043 low-noise amps both feature bypass switches and shut-down pins offering receivers the highest level of sensitivity performance. The TQL9042 offers 19 dB gain over 0.5 to 2GHz with a market leading 0.42 dB noise figure. The TQL9043 provides frequency coverage from

1.5 to 2.7GHz with >18dB gain and 0.5dB noise figure.

**RFMW**
**rfmw.com**



### Online Calculator

Wurth Electronics Midcom announced the new, online Gap Calculator, which provides a quick calculation of the gap length of a transformer's core once the desired AL value and the package are known. To use the Gap Calculator, a user must first choose the desired package from the drop-list. Then, insert the AL value in the correct field. From here, the calculated gap can be extracted from the "Actual" field.

**Wurth Electronics Midcom**
**we-online.com**

### Recording System

The Talon RTS 2707 is a turnkey, multiband recording and playback system for recording and reproducing high-bandwidth signals. The RTS 2707 uses 12-bit, 500 MHz A/D converters and provides sustained recording rates up to 1.6 GB/sec in two-channel configuration.

**Pentek**
**pentek.com**

### Prototyping System

The Quick Circuit model QC12000 is equipped with an oversized 13" x 24" work area. The QC12000 provides everything you need to produce circuit board prototypes within hours. Its generous work area will

allow you to address truly unique prototyping applications. Available in Standard Series 8,000 - 24,000 rpm, and High Speed 5,000 - 60,000 rpm spindle speeds.

**T-Tech**
**t-techtools.com**

### MLCCs

AVX Corp. expanded its range of high reliability C0G (NP0) dielectric multilayer ceramic capacitors (MLCCs). Available in case sizes spanning 01005 to 2225, voltages up to 500V, and capacitance tolerances as low as ±0.1pF, AVX's C0G (NP0) MLCCs provide one of the most stable capacitor dielectrics available in today's market, making them ideal for matching circuits, handheld devices, and GPS, among others.

**AVX Corp.**
**avx.com**

### VCO

Crystek's CVCO55CC-2380-2380 VCO operates at 2380 MHz with a control voltage range of 0.3V~4.7 V. This VCO features a typical phase noise of -119 dBc/Hz @ 10 KHz offset and has excellent linearity. Output power is typically +2.5 dBm. It

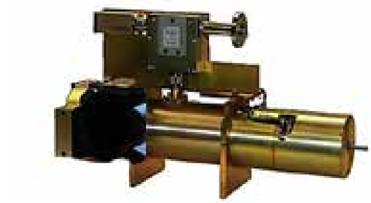
is packaged in the industry-standard 0.5-in. x 0.5-in. SMD package.

**Crystek**
**crystek.com**


## Coupler

Mini-Circuits' ZGBDC20-33HP+ broadband high power bi-directional coupler offers excellent performance across a wide range of popular frequency bands. Built using low loss suspended substrate construction, it can pass up to 3A of DC current from input to output and handle up to 250W CW. Rugged sealed construction makes this coupler ideal for field applications or remote monitoring sites; however, it is also ideal for high power lab testing.

**Mini-Circuits**
**minicircuits.com**



## Oscillator

The PC-0453-5-10 Series is designed as a 50 kilowatt oscillator spanning the 705-850 MHz bandwidth. It is ferrite isolator protected at its output, has built-in forced-air cooling, and the capability of either manual tuning, or motorized remote tuning. 50 kW nominal output power, low rise time, high reliability. This unit can be customized to suit your specific requirement.

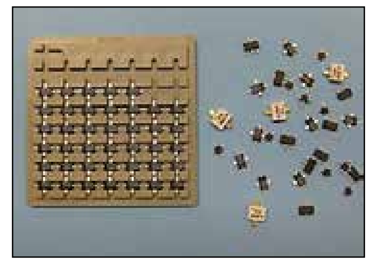
**Pro-Comm Inc.**
**procomm222.com**

## Components

ARRA, Inc. manufactures Attenuators - Phase Shifters – Terminations - Dividers - Filters - Couplers – Switches. Manufacturing micro-

wave and RF components since 1957.

**ARRA, Inc.**
**arra.com**

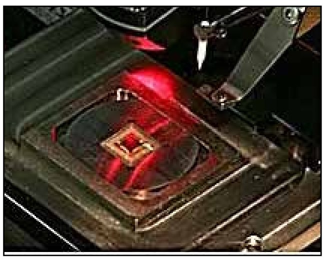


## MMICs

AMCOM has the expertise, manpower, space, and equipment for manufacturing state-of-the-art products. Capabilities include active device design, MMIC design,

and power amplifier module design. We are experts in device/MMIC packaging, module assembly and RF/DC testing. For active devices, we either procure parts such as silicon LDMOS, or GaN HEMT, or we use a semiconductor foundry to fabricate our own proprietary device/ MMIC.

**AMCOM**
**amcomusa.com**



## IC Packaging

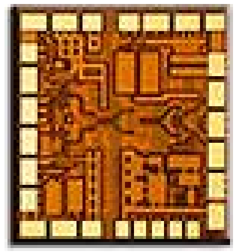
Quik-Pak, a division of Delphon, provides IC Packaging and Assembly services. The company specializes in a variety of services that together provide a full turn-key solution including wafer preparation, die attach, wire bonding, remolding and marking/branding. Custom assembly services are also offered for Flip Chip, Ceramic Packages, Chip-on-Board, Stacked Die and MEMS.

**Quick-Pak**
**icproto.com**

## Synthesizer

MLBS-Series Bench test synthesizers are ideal for production test sets, laboratory tests and test equipment racks where generation of microwave signals is essential. Frequency coverage is 2 to 20 GHz. Each bench top synthesizer consists of a frequency synthesizer, heat sink, power supply, cooling fans, keyboard, display, USB interface, Ethernet interface and a manual tuning knob.

**Micro Lambda Wireless**
**microlambdawireless.com**



## TIA

The HMC7590 is a high-speed, high-gain, low-power limiting transimpedance amplifier (TIA) used in optical receivers with data rates up to 43 Gbps. It features low input referred noise, 36 GHz bandwidth, 4 kΩ differential small signal transimpedance and output cross point adjustment. HMC7590 exhibits an optical input dynamic range between -10 dBm and +5 dBm while maintaining 10e-12 BER at 43 Gbps operation.

**Hittite Microwave**
**hittite.com**


## Slope Equalizer

ZEQ-8-222S+ is a 50W coaxial slope equalizer. This model offers excellent performance in the “L band” frequency range of 950-2150 MHz with minimal deviation in the attenuation slope. Features: good matching; minimal deviation in the attenuation slope ± 0.4 dB; connectorized package.

**Mini-Circuits**
**minicircuits.com**

## Legacy ICs

Lansdale Semiconductor Inc. is licensed to manufacture over 3,000 military, commercial wireless, telecommunications, and aerospace integrated circuits with the original tooling and packages, exactly as they were produced by Motorola, Freescale, Philips, Signetics, Intel, National, Fairchaild, Raytheon and AMD. Our life-cycle management

program assures a dependable, quality source of obsolete ICs, forever.

**Lansdale Semiconductor**
**lansdale.com**

## Detector

The HMC7447 power detector provides a linear output voltage over a -0.5 to +23.5 dBm input power range with low insertion loss of 0.45 dB and typical input return loss of only 19.5 dB. Ideal for monitoring transmitter operation or enabling closed loop transmitter output power, the detector exhibits excellent sensitivity and a frequency response of ±0.2 dB over the 71 to 86 GHz frequency band.

**Hittite Microwave**
**hittite.com**


## Downcoverter

Holzworth downconversion products have been specifically designed as frequency extensions for phase noise analyzers. These downconverters exhibit very low additive phase noise characteristics so as to maintain the signal integrity of high performance DUTs.

**Holzworth Instrumentation**
**holzworth.com**

- Amplifiers
- Attenuators - Variable
- DLVA & ERDLVA & SDLVA's
- DTO's & Frequency Synthesizers
- Filters
- Form, Fit & Function Products
- IFM's & Frequency Discriminators
- Integrated MIC/MMIC Modules
- I/Q Vector Modulators
- Limiters & Detectors
- Log Amplifiers
- Pulse & Bi-Phase Modulators
- Phase Shifters
- Rack & Chassis Mount Products
- Receiver Front Ends & Transceivers
- Single Sideband Modulators
- SMT & QFN Products
- Solid-State Switches
- Switch Matrices
- Switch Filter Banks
- Threshold Detectors
- USB Products

# Planar Monolithics Industries, Inc.

***Offering State-Of-The-Art RF and Microwave Components & Integrated Assemblies From DC to 40GHz***

# FREQUENCY SYNTHESIZERS

## *Model No. PFS-618-CD-1*


- 6.0 to 18.0GHz
- 100kHz Frequency Step Size
- +/-1MHz Frequency Accuracy
- 1uS Settling Time to 1MHz
- 1uS Tuning Speed
- +10dBm Output Power
- Phase Noise:
  - -78dBc/Hz @ 1kHz Offset
  - -96dBc/Hz @ 100kHz Offset
  - -100dBc/Hz @ 10MHz Offset
- DC to 10MHz Modulation BW

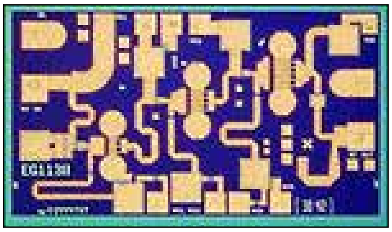
| | |
|---|---|
| Frequency Range | 6.0 to 18.0GHz |
| Frequency Step Size, Nominal (LSB) | 100kHz |
| Power Output Level | +10dBm Min. |
| Power Variation | 5dB P-P (±2.5dB) Max. |
| Frequency Accuracy | ±1MHz Max. |
| Frequency Aging | ±2 PPM / Year |
| Settling Time to 1MHz | 1usec |
| Tuning Control | Binary, TTL 17 Bits (Parallel) |
| Tuning Speed | 1usec |
| SSB Noise | 6.0 to 18.0GHz Max. |
| @ 1kHz Offset | -78dBc / Hz |
| @ 100kHz Offset | -96dBc / Hz |
| @ 10MHz Offset | -100dBc / Hz |
| Spurious Output | -55dBc Max. |
| Harmonics | -30dBc Max. |
| Sub-Harmonics | -55dBc Max. |
| Reference | Internal Reference |
| Frequency Modulation | |
| Modulation Bandwidth | DC to 10MHz |
| Frequency Deviation | ±400MHz Min., 100MHz / Volt |
| Control | Analog |
| Sensitivity | 1.1 : 1 |
| Power Supply | +12V @ 2.5A Max. (1.4A measured)<br>-12V @ 0.6A Max. (0.1A measured)<br>+5V @ 4A Max (1.6A measured)<br>-5V @ 2A Max. (0.1A measured) |
| Connectors | |
| Control | 37 Pin Sub-D Male |
| Power | 9 Pin Sub-D Male |
| RF Output | SMA Female |
| Modulation Input | SMA Female |
| Size | 6.48" x 6.23" x 1.6" |


***West Coast Operation:***
4921 Robert J. Mathews Pkwy, Suite 1
El Dorado Hills, CA 95762 USA
Tel: 916-542-1401 Fax: 916-265-2597
Email: sales@pmi-rf.com

***East Coast Operation:***
7311-F Grove Road
Frederick, MD 21704 USA
Tel: 301-662-5019 Fax: 301-662-1731
Website: www.pmi-rf.com


Hermetic Sealing, High Reliability to Mil-Std-883, Small Quantity Requirements accepted.
We offer Custom Designs

**ISO9001/2008 REGISTERED**



## Medium Power Amp

The TriQuint TGA1073A-SCC is a three stage MPA MMIC design using TriQuint's proven 0.25 micrometer mmW pHEMT 2MI process. It is designed to support a variety of millimeter wave applications including point-to-point digital radio and LMDS / LMCS. The three stage design consists of a 200 um input device driving a 480 um interstage device followed by an 800 um output device.

**TriQuint Semiconductor**
**triquint.com**


## Controller

TI introduced an analog DC/DC step-down controller with remote bipolar junction transistor (BJT) temperature-compensated inductor current sensing that minimizes total solution footprint in high-power POL conversion. The 20-V LM27403 DC/DC synchronous buck controller provides greater than 95-percent efficiency from a 12-V input at 25 A of output current.

**Texas Instruments**
**ti.com**

## TWTA

The Model 200T26z5G40A is a self-contained, forced air cooled, broadband traveling wave tube (TWT) microwave amplifier designed for applications where wide instantaneous bandwidth, high gain and moderate power output are required. A reliable TWT subsystem provides a conservative 200 watts

minimum at the amplifier output connector.

**AR RF/Microwave Instrumentation**
**arworld.us**


## Connectors

Looking for a subminiature push on connector with excellent performance? Visit SV Microwave's website for a newly released Application Note for the SMP, SMPM & SMPS connector series. SMP series connectors are recommended for applications up to 40 GHz; SMPM series connectors are recommended for applications up to 65 GHz; SMPS series connectors are recommended for applications up to 100 GHz.

**SV Microwave**
**svmicrowave.com**

## Dividers/Combiners

JFW Industries is pleased to showcase its line of resistive power dividers/combiners. Available in 2-Way, 4-Way, 5-Way, 7-Way, 8-Way, 9-Way and 11-Way configurations; they operate from DC - 6 GHz. This family of divider/combiners is specifically designed for laboratory testing of radio transceivers in mesh networks, allowing for signal connectivity over a wide bandwidth with minimal isolation.

**JFW Industries**
**jfwindustries.com**

## Signal Generators

The S-Series is uniquely scalable with multiple instruments Aerolocked together within a standard 19" format. Build your measurements from our S-Series range of signal generators, signal analyzers and function modules. The SGA analog signal generator sets the standard for switching speed and noise. The SGD digital vector signal generator leads the way with the bandwidth required for the latest wireless standards including 802.11ac, LTE-A and beyond.

**Aeroflex**
**aeroflex.com**

## Relays

RelComm's SMA Connectorized Relays are available in 1P2T, Transfer, 2P2T, Multi-Throw, and Redundant configurations, with 50 Ohm terminated options available.

**RelComm Technologies**
**relcommtech.com**

## Broadband Amp

The R&S®BBA150 is a family of broadband amplifiers for the microwave range. The instruments, which are optimized for high frequencies, offer high power, yet are compact and lightweight. Features: Two frequency ranges from 0.8 GHz to 3.0

# Rosenberger® Rmor™ Cables Assembly

# PHASE STABLE THROUGH 70GHz

Rosenberger Rmor™ cables are designed for rugged environments for indoor and outdoor applications. Each shielded coaxial cable is protected with flexible, SPIRAL-wound 304 Stainless Steel armor coated with extruded Polyurethane. The connector ends are sealed and encapsulated with a pressure injection-molded polymer strain relief.

This combination of materials and technology provides superior ruggedization, environmental resistance, RF shielding effectiveness and stability under flexure and vibration.

Additional connector interfaces and armor/cable diameters are available on request.

## DESCRIPTION

Rosenberger connectors, cable assembly, standard length 915mm or 36 inches

## GENERAL ELECTRICAL SPECIFICATIONS

| | |
|---|---|
| Impedance: | 50 +/- 1 Ohms |
| Operating frequency: | DC to 70 GHz |
| Return loss: | 14 dB minimum up to 70 GHz |
| Cable insertion loss: | .67 dB/ft @ 10.0 GHz |
| Velocity of propagation (%): | 78 % nominal |
| Capacitance: | 24.7 pf/ft. nominal |
| Shielding effectiveness: | < -90 dB |
| Dielectric withstand voltage: | 1000 Vrms |
| Amplitude & phase stable: | +/- .03dB & +/- 1° @10GHz |

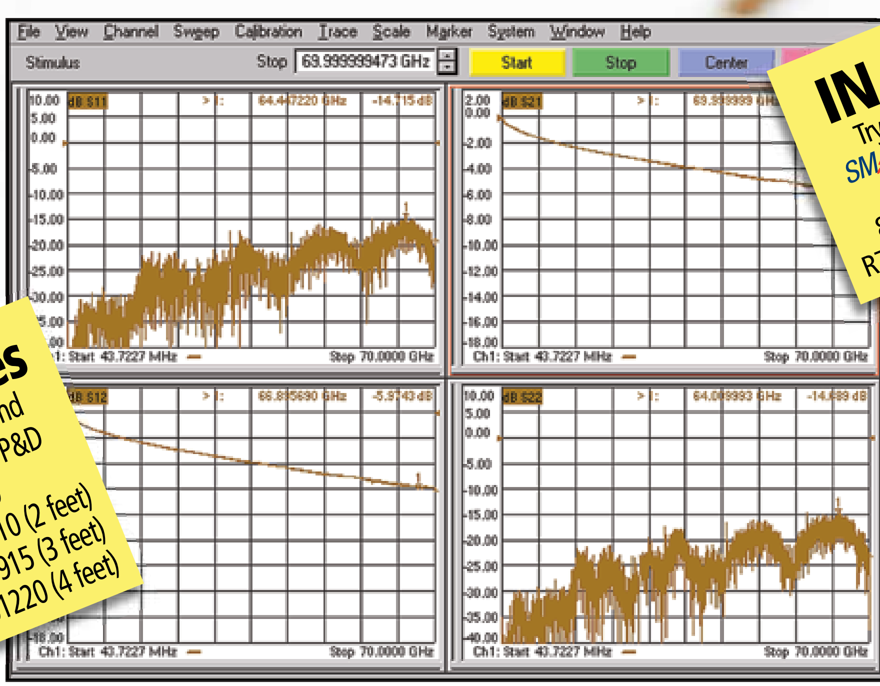
## MECHANICAL SPECIFICATION

| | |
|---|---|
| Cable jacket & armor outer diameter: | 092 inches nominal & .250 inches nominal |
| Minimum bend radius: | .5 inches |
| Armor crush strength: | 450 lbs/in (min) |
| Connector retention: | ≥25 lbs. |
| Mating torque: | 7-10 inch pounds |

## MATERIALS AND FINISHES

| | |
|---|---|
| Armor type: | SPIRAL-wound 304 SS & Polyurethane blue jacket |
| Connector environmental testing: | Per MIL-STD-202, Meth 101,106,107,204 & 213 |
| Connector interface dimension: | IEC 60169-17 Per MIL-PRF-39012 DINEN122200 |

Note: Cable assemblies also available with interfaces such as 1.85mm, 2.4mm, 2.92mm, SMA +, SMA, N.




Example of typical 36 inches assembly up to 70 GHz




RFMW is the exclusive stocking distributor for **Rosenberger**® Connectors and Cable Assemblies
RFMW, 188 Martinvale Lane, San Jose, CA 95119
PH: 408.414.1450 or 877.367.7369 Email: sales@rfmw.com
Website: www.rfmw.com/Rosenberger

GHz and 2.5 GHz to 6.0 GHz; Output power from 15 W to 400 W; Ideal for system configuration together with the R&S®BBA100 broadband amplifier family.

**Rohde & Schwarz**
**rohde-schwarz.com**

## Power Divider

Pulsar Model PS2-56-450/15S covers the frequency range of 8-60 GHz with 3.0 dB typ. insertion loss, 10 dB typ. isolation, and VSWR 2.00:1 typ. Amplitude and phase balance are 1.0 dB and +/- 15 degrees respectively. Maximum input power is

10 watts. 1.85 female connectors are utilized in a housing with dimensions 1.04 x 0.6 x 0.38 inches.

**Pulsar Microwave**
**pulsarmicrowave.com**



## Base Station Antenna

Stacked collinear broadband dipoles are provided on a common mast. The dipoles are shown installed for vertical polarization; however the installation kit allows for horizontal polarization as well. This type of collinear dipole array is available for many frequency bands, for instance, the SA V425 designed for the US Navy, tuned for 400-450 mHz with +4 dBi and 1.5 kw cw power handling.

**Signal Antenna Systems**
**signalantenna.com**

## Antenna

Model SAF-2733331624-315-S1 is a Ka-band scalar feed horn antenna with center frequency at 30 GHz and ± 3 GHz operation bandwidth. The antenna has 24 degree half power beamwidth with a typical of 16 dBi gain. The antenna offers lower than -25 dB sidelobe levels and supports both linear and circular polarization waveforms. The RF connector of the antenna is 0.315" diameter circular waveguide with UG599/U Flange.

**SAGE Millimeter**
**sagemillimeter.com**

**Capacitor**

AVX Corp. doubled the capacitance of its 0603 Multilayer Organic Capacitor (MLOC) Series, extending the highest-rated capacitance value from 2.5pF to 5.1pF. Ideal for applications including RF power amplifiers, low noise amplifiers, filter networks, and instrumentation.

**AVX Corp.**
**avx.com**

**Oscillator**

Model SOM-67314308-15-M1 is a free running V band mechanically tuned Gunn oscillator with +8 dBm output power from 60.0 GHz to 74.0 GHz. It is composed of a Ka band broadband mechanically tuned Gunn oscillator which can produce +20 dBm output power with +/-3.5 GHz bandwidth and a V band passive X2 multiplier which converts 30.0 to 37.0 GHz/+20 dBm input signal to deliver + 8 dBm typical output power in the frequency range of 60 to 74 GHz.

**SAGE Millimeter**
**sagemillimeter.com**

## HOW TO SUBMIT

**Product Releases to HFE**

To be considered for publication, please submit text in Word along with a 300 dpi min. color JPG image of your product. *Submit to:*

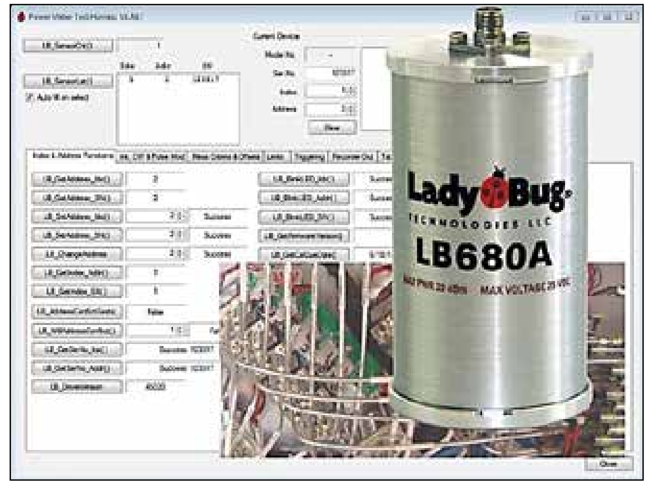
tim@highfrequencyelectronics.com

# Product Showcase

## Signal Generators

Two new signal generator models provide unmatched performance in phase noise, output power and frequency-switching speed. The N5183B MXG and N5173B EXG microwave analog signal generators provide important alternatives in size, speed and cost. The N5183B MXG analog is an alternative to the high-performance PSG. The MXG offers accuracy, efficiency and near-PSG performance in just two rack units. The N5173B EXG analog is a cost-effective choice when system creators need to balance budget and performance.

**Agilent Technologies**
**agilent.com**




## Test Harness

LadyBug Technologies' latest enhanced test harness helps programmatic users, such as ATE builders, to interrogate and control any of LadyBug's broad line of sensors. The full featured RF Power Sensor control system includes source code in C++ & C# and is available at no cost from the "downloads" section of LadyBug's website. The included source code helps to shorten system development time for custom test systems, built-in applications and other purposes.

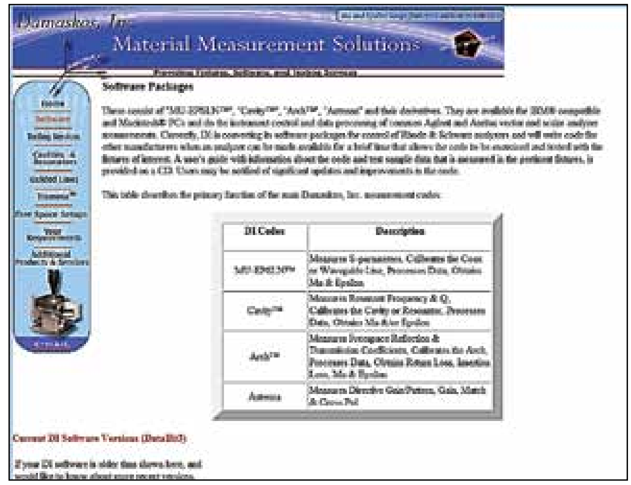
**LadyBug Technologies**
**ladybug-tech.com**

## Signal Analyzers

R&S FSV and R&S FSW signal and spectrum analyzers equipped with the new software options support developers of vehicular communications components, modules and systems. They can perform spectrum measurements in line with IEEE 802.11p and analyze the modulation quality of the signals. Predefined spectrum masks can be used to verify that the transmitted signal is ETSI/FCC compliant.

**Rohde & Schwarz**
**rohde-schwarz.com**

# Product Highlights: Test & Measurement


**Transceiver Module**

The NI 5782 intermediate frequency (IF) transceiver adapter module for NI FlexRIO is ideal for applications that require the acquisition and generation of IF or baseband signals with inline, real-time processing. You can analyze acquired signals in the NI FlexRIO FPGA module to perform measurements and generate response signals. Application areas include RF modulation and demodulation, channel emulation, bit error rate testing (BERT), signal intelligence, radio frequency identification (RFID) and near-field communication (NFC) test, real-time spectrum analysis, and software defined radio (SDR).

**National Instruments**
**ni.com**

**Vector Analyzer Software**

Damaskos Inc. software packages consist of "MU-EPSLN™", "Cavity™", "Arch™", "Antenna" and their derivatives. They are available for IBM® compatible and Macintosh® PCs and do the instrument control and data processing of common Agilent and Anritsu vector and scalar analyzer measurements. DI is converting its software packages for control of Rhode & Schwarz analyzers and will write code for other manufacturers.

**Damaskos, Inc.**
**damaskosinc.com**

---

**Radio Comms Test**

The 3550 is the first truly portable touch-screen radio communication test system. The 3550 takes radio and repeater site testing to the next level with a quantum leap in an easy to use, integrated test system for complete radio receiver and transmitter performance testing, cable fault and antenna system analysis. With its ultra-responsive capacitive touch screen, the 3550 brings a whole new experience to RF testing.

**Aeroflex**
**aeroflex.com**

# Product Highlights : Interconnects

**Adapters**

Both In-Series and Between-Series precision adapters from SGMC Microwave offer low VSWR, captivated center contact, and ruggedized construction for repeatability & reliability. In-Series adapters are phase matched. Frequency range includes DC-65 GHz. Straight, Bulkhead, and Right Angle configurations are readily available.

**SGMC Microwave**
**sgmcmicrowave.com**

**Attenuators**

Coaxicom's DC to 4 GHz attenuators utilize an innovative alternative to high-cost stainless-steel production, and provide a cost-effective solution for general applications and in-field use. The low-frequency attenuator line is available in Type N (5910) and SMA (3910) series with an average power rating of 2 watts. Available in reverse polarity, between series adapters, as well as 50 or 75 Ohm.

**Coaxicom**
**coaxicom.com**

---

**Connectors**

Molex SSMCX micro-miniature connectors are designed for electronic applications with size and weight limitations while maintaining good RF characteristics. SSMCX connectors are approximately 35% smaller than MMCX connectors are available in 50 and 75 Ohm versions. The extremely small size makes them an ideal solution to create multi-port, high-density RF applications.

**Molex**
**molex.com**

# Product Highlights : Interconnects

## Cable Assembly Tools

Seven Associates is the technology leader for coax cable assembly tools designed to fit a variety of applications. See how our tooling experience can help you with your semi-rigid cable assembly, or how our facility can produce cables to your specification.

**Seven Associates**
**sevenassociates.com**

## SMA Connectors

Southwest Microwave's "Standard SMA" is referred to as "Super SMA." The Super SMA is a higher performance field service SMA connector. Super SMA utilizes the basic PTFE dielectric interface (true SMA) and features low VSWR mode free through 27 GHz and less than -100 dB RF leakage. The thick outer conductor wall also provides great durability to assure reliability in repeat mating.

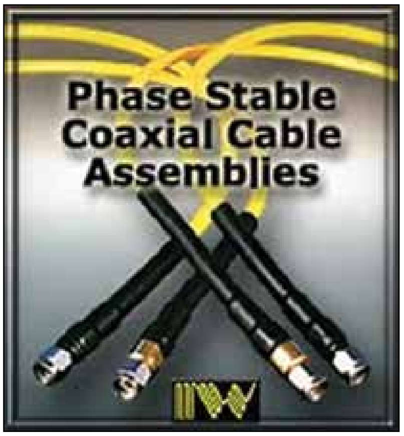
**Southwest Microwave**
**southwestmicrowave.com**

---


## Cable Assemblies

San-tron SRX™ low PIM cable assemblies and adapters are the perfect choice when passive intermodulation-distortion issues plague your critical signal transmissions. These assemblies are phase-and-attenuation-stable, provide excellent shielding, support UL/NEC Plenum-class CMP, are corrosion-resistant, are low in weight, and are highly flexible. They feature intermodulation performance as low as -181 dBc with an eSeries 7/16 connector terminated on flexible-141 cable.

**San-tron**
**santron.com**




## Cable Assemblies

This new line of low loss, phase stable cable and assemblies yields smaller diameters, lighter weights, lower insertion loss and enhanced electrical stability versus flexure and temperature. This all adds up to the "Best of all Worlds" for an engineer designing high performance systems. We believe it is imperative that our customer gets the maximum performance, from the widest possible range of products, delivered on time, for the lowest cost.

**IW Microwave**
**iw-microwave.com**

# Product Highlights: Defense Electronics

**High Power Amp**

Aethercomm Model Number SSPA 0.595-1.300-50 is a high power, Gallium Nitride (GaN) amplifier that operates from 600 MHz to 1300 MHz minimum and is packaged in a compact, rugged enclosure. This amplifier is designed for operation in harsh environments where communication systems are deployed. Typical output power is 70 watts across the band at PSat. These RF amplifier modules employ digital circuitry for command and control.

**Aethercomm**
**aethercomm.com**

**IFMs**

Proven on the battlefield and across a wide range of platforms, Anaren's line of IFMs, DFDs, DRFMs and other standard and custom EW subassemblies continue to meet the performance, reliability, and durability demands of OEMs and military customers worldwide. Because we have met the requirements of a variety of customers and EW systems, chances are that we have a design that is similar to your needs.

**Anaren**
**anaren.com**

---

**Amplifier**

The BBM2E3KLO (SKU 1163) is a 20 to 520 MHz amplifier guaranteed to deliver 125W output power (P3dB) and related RF performance under all specified temperature and environmental conditions. Typical power output is 150 W; suitable as a broadband PA building block in target markets and related end applications for electronic attack, digital communications, and test and measurement in the UHF/VHF frequency bands.

**Empower RF Systems**
**empowerrf.com**

# Product Highlights: Defense Electronics

## Log Periodic Array

The unit shown is our SA LPMA4, and operates over 4-16 MHz (useable 3.5-21 MHz) provides up to 12 dBi gain and handles 20 kw cw power levels. The unit was designed for OTHR (over-the-horizon radar) use, and is supplied with an extensive on-earth ground system. The antenna system is designed to be portable, and can be set up by a few people in a relatively short time. Weather protection is included, and 100 mph wind survival is standard.

**Signal Antenna Systems**
**signalantenna.com**

## Video Management System

The Video Management System (VMS) offers complete surveillance solutions for rotary and fixed wing aircraft. A VMS includes rugged displays, video distribution and recording equipment that are scalable, highly interoperable and easy to install and reconfigure. The Video Management System has been successfully fielded in a wide range of demanding applications, including SAR and border patrol operations.

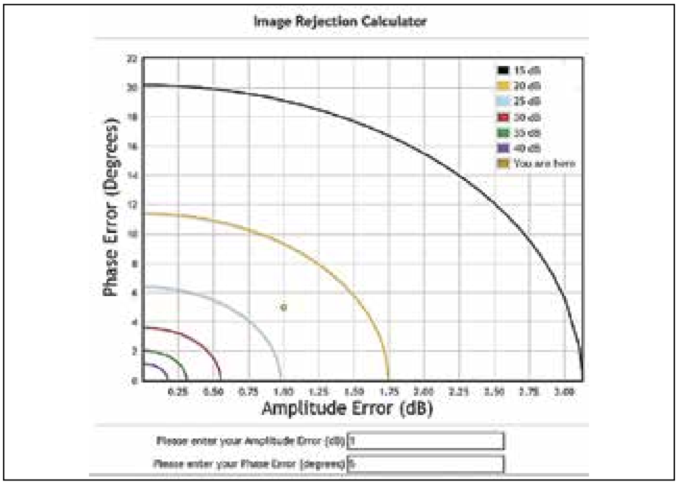
**Curtiss Wright Controls**
**cwcdefense.com**

## Wireless Radio

Available in 1.3 GHz, the Spartan Series of Wireless radios are designed to meet the rigorous demands of government and defense users worldwide. These radios use an embeddable high-performance security module to provide FIPS 140-2* level 2 encryption. The Spartan Series combines high performance with a small size making it ideal for applications where space is at a premium. Designed to meet more robust security requirements, the modular architecture of the Spartan Series saves on time and money.

**FreeWave Technologies**
**freewave.com**

# Product Highlights





**Calculator**

Custom MMIC introduced an easy-to-use Image Rejection Calculator to their suite of free online tools. This innovative new tool displays the contours of constant image rejection as a function of phase and amplitude error. After the user inputs a specific error condition, the program computes the image rejection and displays the result on the graph along with the contours.

**Custom MMIC**
**custommmic.com**

**Splitter/Combiner**

Mini-Circuits' SEPS-4-272+ 4-way 0° surface mount power splitter/combiner covers frequencies from 690 to 2700 MHz, providing an ideal solution for many applications including cellular, GPS, PCS, CATV, ISM, and wireless communication systems. This model provides maximum input power of 5W (as a splitter), good output matching with 1.1 VSWR, 1.25 dB insertion loss (above 6.0 dB), and 20 dB isolation.

**Mini-Circuits**
**minicircuits.com**


## Website Highlights

**dB Control**

Our TWT Amplifiers (TWTAs), microwave power modules (MPMs), transmitters, power supplies and modulators are reliable even under the harshest environmental conditions. Our modular products for ground-based, shipboard and high-altitude military manned and unmanned platforms can be quickly and easily configured to meet your custom specifications. With in-house repair depot services, specialized contract manufacturing and high-voltage testing, we've got everything you need under one roof.

**dbcontrol.com**

# 2014 IEEE Radio Frequency Integrated Circuits Symposium
Tampa, FL
IEEE
*1-3 June, 2014*

IMS2014 - Tampa Bay, Florida
POWERING THE WAVES

# NEW: RFIC 2014 Calls for 2-Page Industrial Submissions

The **2014 IEEE Radio Frequency Integrated Circuits Symposium (RFIC 2014)** will be held in Tampa, FL, on 1-3 June 2014. For the latest information, please visit: **rfic-ieee.org.**
**New for RFIC 2014: 2-page INDUSTRIAL papers are welcome for 10-minutes oral and special poster/demo session.**

**Electronic Paper Submission/Communication:** Technical papers must be submitted via the RFIC 2014 website at **rfic-ieee.org.** Hard copies will not be accepted. Complete information on how and when to submit a paper is posted on the RFIC website.

**Technical Areas:** The conference will solicit papers describing original work in RFIC design, system engineering, system simulation, design methodology, RFIC circuits, fabrication, testing, and packaging to support RF applications in areas such as, but not limited to:

- **Wireless Mobile ICs:** 3G/4G/LTE, WCDMA, TD-SCDMA, HSPA, WiMax, Mobile TV.
- **Wireless Connectivity:** WLAN, 802.11xx, Bluetooth, FM, GPS, UWB, Wireless HD.
- **Low Power Transceivers:** RFID, NFC, Zigbee, WPAN, WBAN, Biomedical, Sensor Nodes.
- **RF Front-End Circuits:** RF and mm-wave LNAs, Mixers, VGAs, phase shifters, RF switches, & Integrated FEM.
- **Mixed-Signal RF & Analog Baseband Circuits:** RF and BB Converters (ADC/DAC), Sub-sampling/Over-sampling Circuits, and all analog baseband circuits including filters and modulators.
- **Reconfigurable and Tunable Front-Ends:** SDR/Cognitive Radio, Wideband/Multi-band Front-Ends, Digital RF circuits/architectures, RF BIST, and reconfigurable data converters.
- **Large-Signal Circuits:** Power Amplifiers (RF & mm-Wave), Drivers, Advanced TX circuits, Linearization.
- **VCOs and Frequency Multipliers:** RF and mm-Wave VCOs, Frequency Multipliers.
- **Frequency Generation Circuits:** PLLs, Synthesizers, ADPLL, DDS, Frequency Dividers.
- **Modeling and CAD:** Active/Passive Devices, Packaging, EM Simulation, Co-Simulation.
- **Device Technologies:** CMOS, SOI, SiGe, GaAs, MEMS, Integrated Passives, Reliability, Characterization, Testing.
- **mm-Wave SOCs:** mm-wave SOC and SIP systems above 20GHz for data, video, and imaging apps, beam steering applications.
- **High-Speed Data Transceivers:** Wireline, Wireless, Optical Transceivers, CDRs for High-Speed Data links.

**RFIC Program:** The conference starts on Sunday, 1 June 2014 with workshops, followed by our plenary talks and reception. Monday, 2 June 2014 and Tuesday, 3 June 2014 will be comprised of presentations of contributed papers and special lunch-time panel sessions.

**New 2-page Industrial Session in 2014!** RFIC invites 2-page short-format ORIGINAL INDUSTRIAL paper submissions on all the areas listed above. While traditional 4-page industrial papers are encouraged for detailed discussions, the new 2-page industrial briefs are welcome to report the latest, state-of-the-art RF IC designs. The 2-page industrial short papers do not require the die photos and detailed schematics, however, will be reviewed upon the same technical criteria. The accepted industrial briefs will be presented in a 10-minutes short slot. In addition, these industrial papers will be invited for presentation at a special poster/demo session during the popular evening RFIC Reception on Sunday, June 1, 2014, which will offer a venue for the industry to showcase their newest RF IC designs to both the attendees and the press. The 4-page submissions would be reviewed and invited for special issues in IEEE Transactions on Microwave Theory and Techniques, and IEEE Journal of Solid State Circuits. 2-page industry briefs will not be reviewed for special issue invitations.

TINY

# Wideband Transformers


0.15-8000 MHz as low as 99¢ each (qty. 1000) RoHS compliant.

*Rugged, repeatable performance.*
At Mini-Circuits, we're passionate about transformers. We even make own transmission line wire under tight manufacturing control, and utilize all-welded connections to maximize performance, reliability, and repeatability. And for signals up to 8 GHz, our rugged LTCC ceramic models feature wrap-around terminations for your visual solder inspection, and they are even offered in packages as small as 0805!

*Continued innovation: Top Hat.*
A Mini-Circuits exclusive, this new feature is now available on every open-core transformer we sell. Top Hat speeds customer pick-and-place throughput in four distinct ways: (1) faster set-up times, (2) fewer missed components, (3) better placement accuracy and consistency, and (4) high-visibility markings for quicker visual identification and inspection.

*More models, to meet more needs*
Mini-Circuits has over 250 different SMT models in stock. So for RF or microwave baluns and transformers, with or without center taps or DC isolation, you can probably find what you need at minicircuits.com. Enter your requirements, and Yoni2, our patented search engine, can identify a match in seconds. And new custom designs are just a phone call away, with surprisingly quick turnaround times gained from over 40 years of manufacturing and design experience!

Mini-Circuits®

**www.minicircuits.com** P.O. Box 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

377 rev AA

# 90° SPLITTERS

## 5 MHz to 8 GHz  from $3.95 ea. qty. 20

**Two-way 90° power splitters (hybrids)** are critical building blocks in a wide array of RF design solutions. That's why Mini-Circuits offers extra-tight phase and amplitude balance, to ensure your expected high-performance design results. Plus, our robust, rugged units deliver repeatable performance and are available in over 70 different SMT models, in the widest range of frequencies in the industry (from 5 MHz to 8 GHz), and in package sizes as small as 0.08" x 0.05".

***RoHS compliant***

**LTCC models now available in small-quantity reels**, with standard counts of 20, 50, 100, 200, 500, 1000, or 2000 *at no extra cost!* For full performance details and product availability, visit our web site ***www.minicircuits.com***. You can order online and have units in-hand as soon as next-day.

**Mini-Circuits®**

**www.minicircuits.com** P.O. Box 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

# Advertiser Index



*The ad index is provided as an additional service by the publisher, who assumes no responsibility for errors or omissions.*

### Find Our Advertisers' Web Sites using *HFeLink*™

1. Go to our company information Web site: www.HFeLink.com, or
2. From www.highfrequencyelectronics.com, click on the *HFeLink* reminder on the home page
3. Companies in our current issue are listed, or you can choose one of our recent issues
4. Find the company you want ... and just click!
5. Or ... view our Online Edition and simply click on any ad!


## High Frequency Electronics

**PUBLISHER**
Scott Spencer
Tel: 603-472-8261
Fax: 603-471-0716
scott@highfrequencyelectronics.com

**ADVERTISING SALES — EAST**
Gary Rhodes
*Vice President, Sales*
Tel: 631-274-9530
Fax: 631-667-2871
grhodes@highfrequencyelectronics.com

**ADVERTISING SALES — WEST**
Tim Burkhard
*Associate Publisher*
Tel: 707-544-9977
Fax: 707-544-9375
tim@highfrequencyelectronics.com

**ADVERTISING SALES—WEST—NEW ACCOUNTS**
Jeff Victor
Tel: 224-436-8044
Fax: 509-472-1888
jeff@highfrequencyelectronics.com

**ADVERTISING SALES — CENTRAL**
Keith Neighbour
Tel: 773-275-4020
Fax: 773-275-3438
keith@highfrequencyelectronics.com

**PRODUCT SHOWCASE**
Joanne Frangides
Tel: 201-666-6698
Fax: 201-666-6698
joanne@highfrequencyelectronics.com

**U.K AND EUROPE**
Sam Baird
Tel: +44 1883 715 697
Fax: +44 1883 715 697
sam@highfrequencyelectronics.com

**U.K AND EUROPE**
Zena Coupé
Tel: +44 1923 852 537
Fax: +44 1923 852 261
zena@highfrequencyelectronics.com

*High Frequency Electronics* (USPS 024-316) is published monthly by Summit Technical Media, LLC, 3 Hawk Dr., Bedford, NH 03110.
Vol. 13 No. 1 January 2014. Periodicals Postage Paid at Manchester, NH and at additional mailing offices.
POSTMASTER: Send address corrections to *High Frequency Electronics*, PO Box 10621, Bedford, NH 03110-0621.
Subscriptions are free to qualified technical and management personnel involved in the design, manufacture and distribution of electronic equipment and systems at high frequencies.

# The choice is clear
for all your RF needs.

## Custom solutions and standard products from a single source.

With decades of experience in the interconnect industry, we know what's important to engineers. That's why Molex manufactures the world's broadest line of radio frequency connectors, cable assemblies and custom products. Our RF solutions can be optimized to minimize signal loss over a wide range of frequencies in a broad spectrum of sizes and styles of connectors. Plus, our service-oriented team can turn around drawings in 48 hours and deliver custom products in less than eight weeks — so you can get your products to market faster.

For the industry's largest array of product options backed by reliable service, turn to Molex — your clear choice for RF interconnect products and solutions.

molex®
one company › a world of innovation

www.molex.com/product/rf.html

*Get info at www.HFeLink.com*