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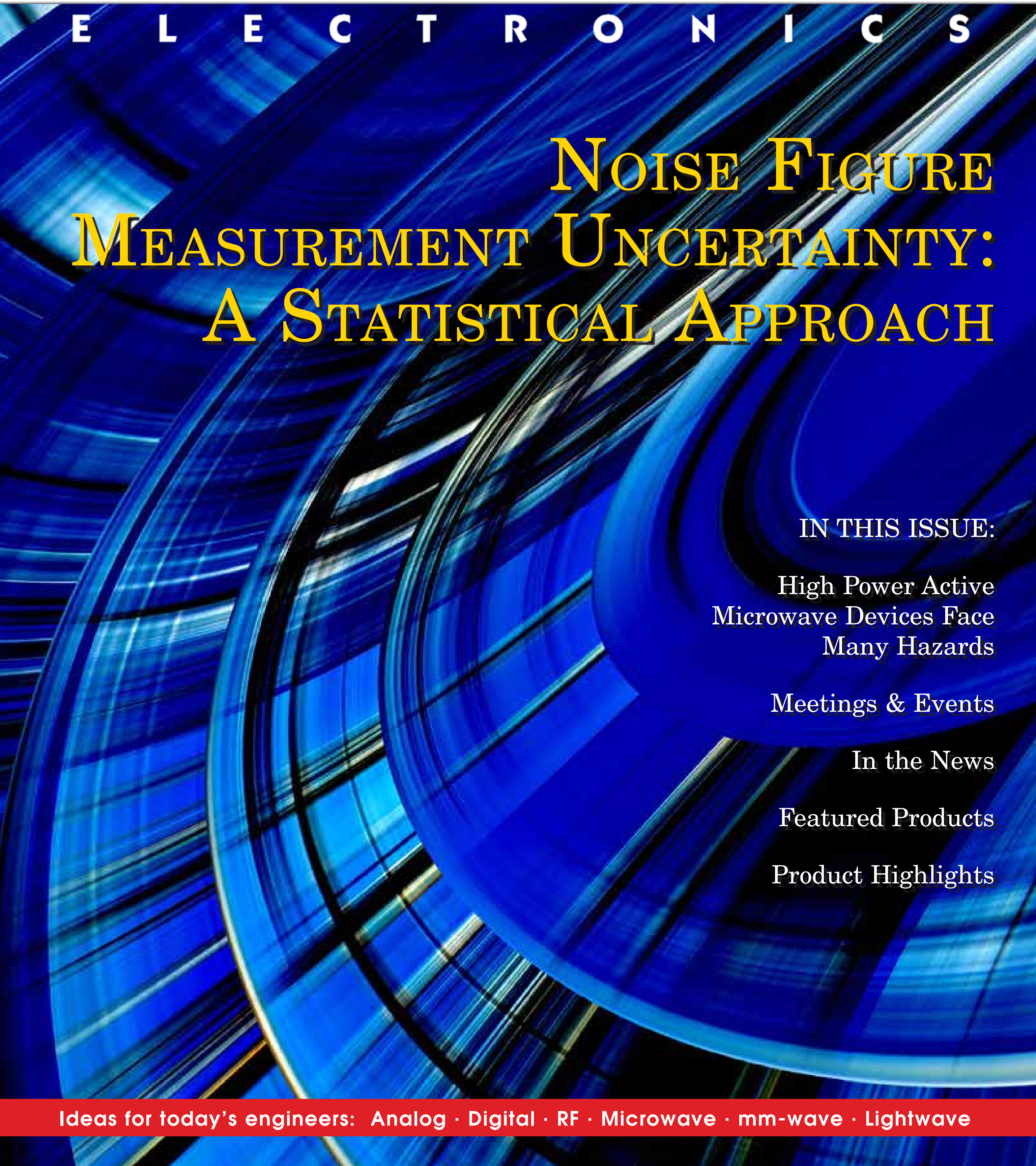
NOVEMBER 2015

HIGH FREQUENCY ELECTRONICS



Noise Figure Measurement Uncertainty: A Statistical Approach

IN THIS ISSUE:

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


powerfilm™
20

TINY

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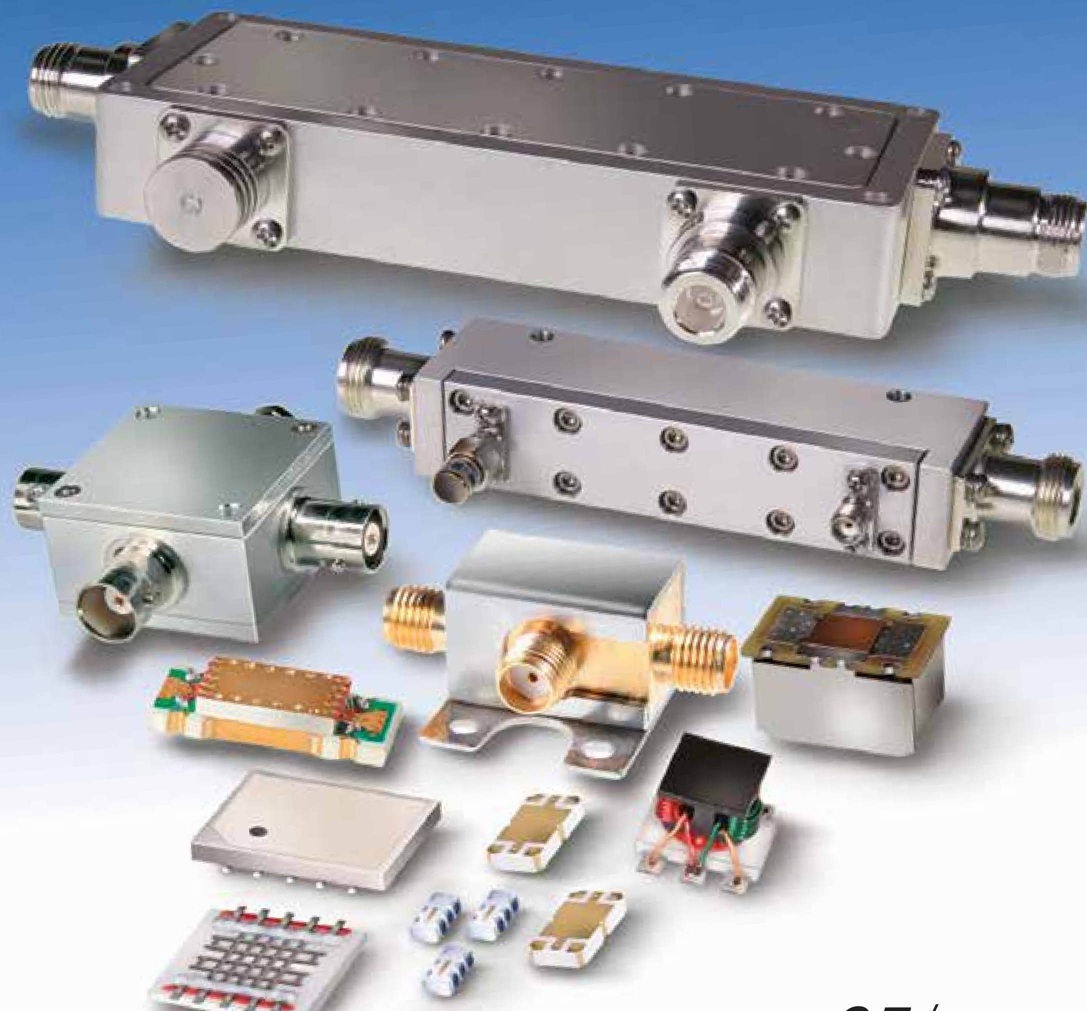
528 rev A

Directional / Bi-Directional

COUPLERS



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SUMMIT Technical Media LLC

Editorial

Inspiring Women

Scott L. Spencer
Publisher

In the mid-1970s I worked for a subsidiary of a major defense contractor. There were approximately 1,300 employees at the facility, about 400 of which were classified as engineers. As you would expect there were many engineering disciplines represented. There were electrical, mechanical, aeronautical, chemical, reliability, quality, manufacturing, materials, process, computer, thermal, optical, and more, all with engineering titles. As I look back it occurs to me that of the 400 or so engineers at this particular installation not a single one was female. What prompted this recollection was an email I received pertaining to IEEE Women in Engineering (WIE) and the outstanding work they are doing by encouraging, mentoring, and promoting women engineers and scientists across the globe. IEEE WIE has put together a network of some 500 affinity groups and has 15,000 members worldwide. Their work has had a positive and lasting impact on thousands of women and is reflected in their mission statement: "The mission of IEEE WIE is to facilitate the recruitment and retention of women in technical disciplines globally."

Marie Curie

When I think back it seems inconceivable that there existed a workplace so completely dominated by men. It is ironic because if it were not for the influence of women I might have chosen a different career path. Let me explain. I can't remember the exact year but I was in middle school and needed a book to read for a book report. It had to be nonfiction. My father gave me two books, a biography of Madame Marie Curie and another titled *The Fabulous Isotopes, What They Are and What They Do.* The books were written by Robin McKown, also a female. Both books provided a cursory introduction to nuclear physics, which was incomprehensible to me at the time, but they piqued an interest and desire to better understand the physical world.

The biography, however, told a much more compelling story. Talented and curious from a young age, Madame Curie's scientific endeavors helped establish a new frontier in physics and chemistry for which she was awarded two Nobel Prizes. In spite of the numerous obstacles placed in front of her because of her gender and life circumstances, she remained committed to her work and became the first woman to teach at the Sorbonne. A quote attributed to Madame Curie said volumes about the wonder of science and discovery: "A scientist in his laboratory is not a mere technician: he is also a child confronting natural phenomena that impress him as though they were fairy tales."

Edith Clarke

Later in life another book authored by a woman would open up a whole new world to me. I came across Edith Clarke's two-volume *Circuit Analysis of AC Systems.* Armed with a very basic knowledge of the principles of AC circuits I found her work to be straightforward and easy to understand. The concepts were presented using algebra, plane geometry and trigonometry, with an occasional integral or differential equation. Edith Clarke was a remarkable individual. She was the first female to earn a degree in electrical engineering from MIT, and she was the first female in the U.S. to be employed as an electrical engineer when she went to work for General Electric. She was the first woman to present an American Institute of Electrical Engineers paper (AIEE became the IEEE in 1963). Edith Clarke had an untold and profound influence on a generation of aspiring electrical engineers needing to understand AC circuit behavior.

Mary Ross

Mary Ross, the first Native American female engineer, went to work for Lockheed in 1942 as a mathematician. In 1952, she joined Lockheed's Advanced Development Program as one of the 40 founding engineers of the Skunk Works. There she worked on preliminary design concepts for interplanetary space travel, manned and unmanned earth-orbiting flights. She was at the forefront in the early days of U.S. space flight. She offered some sound advice that is as pertinent today as it was when she said it: "To function efficiently in today's world, you need math. The world is so technical, if you plan to work in it, a math background will let you go farther and faster."

Today, partly because of inspirational figures like Curie, Clarke, and Ross and the committed work of IEEE WIE, virtually every area of technology has women who are engaged at the highest levels and making important contributions to the advancement of science.

I encourage readers to go to the IEEE WIE website. Check out the work they are doing and consider making a donation. It will certainly be a sound investment in the future of science.

Meetings and Events

Conferences & Meetings

2015 IEEE International Conference on Microwaves, Communications, Antennas and Electronic Systems (COMCAS)
2 - 4 November 2015
Tel Aviv, Israel
http://www.comcas.org
Paper Submission Deadline: 30 May 2015

2015 IEEE MTT-S International Microwave and RF Conference (IMaRC 2015)
10 - 12 December 2015
Hyderabad, India
http://www.imarc-ieee.org
Paper Submission Deadline: 7 August 2015

2016 IEEE MTT-S Radio Wireless Week (RWW 2016)
24 - 27 January 2016
Austin, Texas
http://www.radiowirelessweek.org/
Paper Submission Deadline: 27 July 2015

2016 IEEE MTT-S International Wireless Symposium (IWS)
14 - 16 March 2016
Shanghai, China
Full Paper Submission Deadline: 16 Oct 2015
Final Submission Deadline: 16 Jan 2016

2016 IEEE MTT-S International Conference on Microwaves for Intelligent Mobility (ICMIM)
19 - 20 May 2016
San Diego, CA
Abstract Submission Deadline: 18 Dec 2015
Full Paper Submission Deadline: 26 Feb 2016
Final submission Deadline: 26 Feb 2016

2016 IEEE/MTT-S International Microwave Symposium - MTT 2016
22 - 27 May 2016
San Francisco, CA

2016 IEEE MTT-S Radio Frequency Circuits Symposium (RFIC 2016)
22-24 May 2016
San Francisco, California, USA
http://rfic-ieee.org/

87th ARFTG Microwave Measurement Symposium Topic
27 May 2016
San Francisco, California, USA
http://www.arftg.org/

Company-Sponsored Training & Tools

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

NI AWR
On-site and online training, and open training courses on design software.
http://www.awrcorp.com/news/trainings

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/

GaAs RF Device Revenue Reaches Record Levels in 2014

Driven by increasing GaAs content in cellular terminals, the GaAs device market experienced another year of record revenues. A recently released Strategy Analytics report forecasts that **GaAs device revenue will break the $7 billion barrier this year and surpass $8 billion before the end of the forecast period. The report states that GaAs device revenue will grow, even though price erosion and competitive technologies will slow the growth rates.**

The report concludes:

• Wireless applications remain the dominant segment of GaAs device market, accounting for just slightly less than 80 percent of all revenue.

• The cellular terminal portion of the wireless segment accounts for slightly more than 50 percent of all GaAs device revenue. New architectures will increase the GaAs content in cellular terminals and even though CMOS PAs will continue capturing market share, the cellular terminal share of the market will grow to slightly more than 55 percent by the end of the forecast period.

• In response to price erosion and losing market share to competitive technologies, **GaAs device revenue will peak in 2018 at just over $8 billion, before declining by less than 1 percent in 2019.**

—Strategy Analytics
strategyanalytics.com

Europe: Greater Interest in Renting T&M Equipment

Over the past couple of years, the share of Europe in the electronic test equipment market has reduced, as key markets in the region continued to face significant economic challenges. However, these challenges have turned out to be a growth driver for the rental and leasing services market, as customers' awareness about the availability and benefits of such services has increased.

According to the recent Frost & Sullivan Market Insight, Test & Measurement Market in Europe: Trends in Rental and Leasing Services, **market participants in general have shown a greater interest in rental services to reduce acquisition and ownership costs associated with test and measurement equipment. Frost & Sullivan believes that the share of rental and leasing services in the test and measurement industry could represent close to a third of the total market revenues in the future.**

"Still, there is significant room for growth for the rental and leasing services market in the test and measurement industry in Europe with penetration currently fairly low in most countries", notes Frost & Sullivan Test & Measurement Industry Director **Jessy Cavazos**. "Rentals are a good fit for customers who have short requirements, cannot afford buying the test instruments, or are in an industry evolving at a fast pace from a technological standpoint accelerating instrument obsolescence".

The largest test and measurement equipment markets in Europe currently are Germany, Russia and Commonwealth of Independent States (CIS) countries, the United Kingdom, France, Scandinavia, Italy, and Spain. From a rental penetration standpoint, some of these markets have showcased a higher propensity to rent than others. The United Kingdom, for example, displays the highest rental penetration across the region. The French market also exhibits a higher penetration of rental and leasing services for test equipment in comparison to other countries in the region. However, it is dominated by a couple of large companies. Spain and Italy have been high-growth markets for participants in recent times due to the economic conditions in these countries, which are driving demand for rental services.

From these two perspectives, the ultimate target for market participants is Germany, which stands as the largest market for test and measurement equipment in Europe but features extremely low rental penetration.

—Frost & Sullivan
frost.com

Backdoor Entry of Gallium Nitride into Handsets?

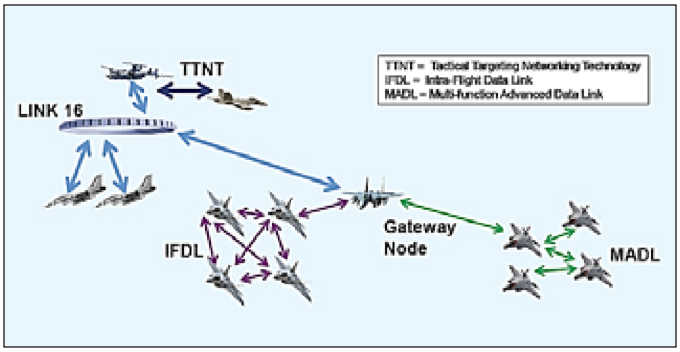
Akoustis has in development a new technology to meet the expected demand for radio frequency filters in LTE phones. A new Strategy Analytics report profiles the company and its technology, predicting changes in the market regardless of the ultimate success of the company.

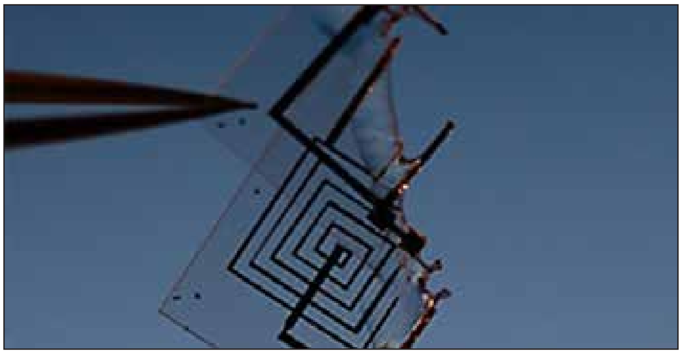
According to Strategy Analytics' **Christopher Taylor**, "We expect RF filter unit shipments for cellular devices to more than double by 2020, with high-performance bulk acoustic wave (BAW) filters soon making up more than half of shipments. The technology in development by Akoustis is just one sign of the growing demand for high-performance filters, a technology that could have big ramifications for RF front-end suppliers **Qorvo, Avago Tech, Murata, TDK-Epcos, Skyworks, Taiyo Yuden, and handset OEMs."**

SA's **Eric Higham** added that, "We often get asked whether gallium nitride (GaN) will make it into mobile phones, replacing gallium arsenide for power amplifiers. We don't think GaN in handset PAs could compete with GaAs in terms of cost, but perhaps BAW filters fabricated in GaN by Akoustis will replace aluminum nitride BAW filters now used in many phones."

—Strategy Analytics
strategyanalytics.com

In the News





Modern airborne warfare is becoming increasingly complex, with manned and unmanned systems having to rapidly share information in a volatile environment where adversaries use advanced, commercially available electronic systems to disrupt U.S. and allied communications. Complicating the communications challenge for allied warfighters, **many current airborne radio networks are incompatible with each other, the result of security and radio frequency (RF) format differences between aircraft types.** Specialized data-link gateways facilitate communication across network divides, but these gateways have limited capability and don't allow high-data-rate information to flow freely and seamlessly among multiple types of manned and unmanned aircraft.

With an eye toward overcoming this increasingly critical challenge, DARPA today published the Broad Agency Announcement solicitation for its Dynamic Network Adaptation for Mission Optimization (DyNAMO) program. **DyNAMO seeks novel technologies that would enable independently designed networks to share information and adapt to sporadic jamming and mission-critical dynamic network bursts in contested RF environments. The program seeks technology that can interconnect existing static networks and be able to connect future adaptive networks as well.**

"Current airborne networks are not designed to handle the complexities of modern distributed and dynamic combat missions, and the challenge is only going to increase in the years ahead," said **Wayne Phoel**, DARPA program manager. "DyNAMO's goal is to enable pilots in one type of aircraft with a specific suite of sensors to easily share information with different types of manned and unmanned systems and also receive sensor information from those various platforms for a comprehensive view of the battlespace. We aim to develop technology that dynamically adapts networks to enable instantaneous free-flow of information among all airborne systems, at the appropriate security level and in the face of active jamming by an adversary."

The network technology developed through the DyNAMO program is to be demonstrated on radio hardware being developed by DARPA's Communications in Contested Environments (C2E) program. C2E is designing flexible new development architectures so aircraft won't be limited to communicating with aircraft using the same radio and waveform. C2E also aims to leverage the proven commercial smart-phone architectural model in which the application processing, real-time processing, and hardware functions of a software-defined radio are separately managed, validated, and updated to ensure rapid deployment of capabilities. DyNAMO is designed to pick up where C2E leaves off, ensuring that raw RF data successfully communicated between previously incompatible airborne systems is not only conveyed but also translated into information that all the systems can understand and process, whether that information relates to time-sensitive collaborative targeting, imagery or networked weapons.

* * *

It sounds like an engineering fantasy, or maybe an episode from Mission Impossible: **A flock of small, single-use, unpowered delivery vehicles dropped from an aircraft, each of which literally vanishes after landing and delivering food or medical supplies to an isolated village during an epidemic or disaster**. And it would be nothing more than a fantasy, were it not that the principle behind disappearing materials has already been proven.

Building on recent innovations in its two-year-old **Vanishing Programmable Resources (VAPR) program, which has developed self-destructing electronic components, DARPA today launched ICARUS, a program driven by a vision of vanishing air vehicles that can make precise deliveries of critical supplies and then vaporize into thin air.**

"Our partners in the VAPR program are developing a lot of structurally sound transient materials whose mechanical properties have exceeded our expectations," said VAPR and ICARUS program manager **Troy Olsson**. Among the most eye-widening of these ephemeral materials so

In the News

far have been small polymer panels that sublimate directly from a solid phase to a gas phase, and electronics-bearing glass strips with high-stress inner anatomies that can be readily triggered to shatter into ultra-fine particles after use. A goal of the VAPR program is electronics made of materials that can be made to vanish if they get left behind after battle, to prevent their retrieval by adversaries.

"With the progress made in VAPR, it became plausible to imagine building larger, more robust structures using these materials for an even wider array of applications. And that led to the question, 'What sorts of things would be even more useful if they disappeared right after we used them?'" Olsson said. "In discussions with colleagues, we were able to identify a capability gap that we decided was worth trying to close."

From those deliberations emerged ICARUS, the mythology-alluding acronym for Inbound, Controlled, Air-Releasable, Unrecoverable Systems. Described in a Broad Agency Announcement, the two-phase program is slated to last 26 months with total funding of about $8 million.

The millennia-old Icarus story ends badly when the protagonist, soaring with youthful abandon on wings of feather and wax, flies too close to the sun and then falls and drowns in the ocean as his wings disintegrate. DARPA's new ICARUS program aims to mimic the material transience that led to Icarus' demise, but leverages that capacity in scenarios with more uplifting endings.

* * *

NuWaves Engineering, a veteran-owned small business delivering advanced radio frequency (RF) and microwave solutions, announced today that the company has been awarded a Phase II Small Business Innovation Research (SBIR) contract from the **U.S. Air Force Research Laboratory (AFRL) to develop and test an advanced triplexer in support of AFRL's Global Positioning System (GPS) technology development program.**

Under the AFRL-sponsored technology development effort, NuWaves Engineering and Exelis Inc., a wholly owned subsidiary of Harris Corp., will investigate, design, fabricate and test an innovative broadband, high-power-handling, low-insertion-loss triplexer designed to work on the GPS navigation payload. During Phase I the team designed and prototyped a GPS L1 band cavity filter and subjected the unit to multipaction testing in order to gain important insight to apply to the Phase II development plan. In Phase II the team will incorporate advanced filtering and cross-coupling techniques to minimize loss and maximize bandwidth, while also maintaining high isolation between channels.

"The combination of NuWaves' advanced filter and multiplexer design capabilities with Harris' system expertise and in-house qualification testing capabilities is expected to pay dividends," said **Jeff Wells**, President and CEO of NuWaves Engineering. "The team looks forward to delivering an affordable solution that the Air Force can count on to meet their GPS performance requirements today and into the foreseeable future."

* * *

W. L. Gore & Associates (Gore) announced that **WireMasters** has been named the North American distributor for Gore's bulk wire and cable products. Serving the military, aerospace, and defense markets, WireMasters will now be a stocking distributor of Gore's high-performance bulk wire and cable products, offering same day shipping to all customers across the globe.

NI AWR Design Environment

Now Playing on a Screen Near You

Microwave Office | Visual System Simulator | Analog Office | AXIEM | Analyst

V12 NI AWR Design Environment redefines the term "user productivity" for designers of MMICs, RF PCBs, modules, and more. With the addition of new amplifier, radar, and antenna specific features, expanded third-party flows for EM, stability analysis, and DRC/LVS, as well as additional speed and ease-of-use enhancements, it's never been easier to streamline your design process, improve your end-product performance, and accelerate your time to market. Display NI AWR Design Environment on your desktop today. Get started at awrcorp.com/v12.

>> Learn more at ni.com/awr

NATIONAL INSTRUMENTS™

Featured Products

Mobile Website

Pasternack launched its new mobile website, marrying powerful parametric search capabilities with a user-friendly interface intended for smart phones and tablets. Most noticeable to a mobile device user is the streamlined look and feel of the new homepage. The site provides engineers in the field the most intuitive process for searching and finding any of the company's +40,000 RF components and cable assemblies.

Pasternack
pasternack.com

Source Module: Electronic Attenuation

Expanding your millimeter wave solutions with the option of Electronic Attenuation. Now you can master your power with OML's Source Module. By controlling the attenuation through a DC voltage, this module gives you the power. Power leveling and power flatness can be achieved through computer control.

OML
omlinc.com

Microwave Laminates

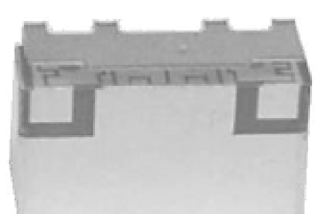
The unique properties of NorCLAD make it perfectly suited for use with patch antennas, and it has been used worldwide in land, sea, and airborne applications. NorCLAD has an ideal dielectric constant of 2.55, and as its thickness is proportional to bandwidth, NorCLAD provides designers with a wide range of flexibility for antenna arrays up 0.5 in. thick.

Polyflon
polyflon.com

Capacitor Kits

Passive Plus (PPI) has expanded its offering of custom capacitor kits to include its broadband capacitor line. PPI will now build custom sample kits for engineers who need the entire range of broadband capacitor offerings - from 01005 to 0402. PPI will also continue to offer the full range of values of MLC High Q capacitors.

Passive Plus
passiveplus.com



Filter

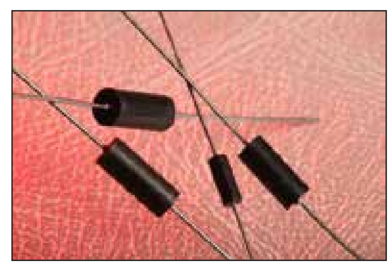
CTS Electronic Components introduced the latest surface-mount RF Bandpass Filter for use in LTE-U (unlicensed) and LTE-LAA (licensed assisted access). The CTS UPB550A has 0.7dB typical and <1.0dB worst case insertion loss, while providing >= 50dB rejection across all the major FDD bands. This would enable it to meet the receive sensitivity requirements when co-located with any base station power class.

CTS
ctscorp.com

High Power Amp

Empower RF's new RF amplifier system complements the frequency coverage and power level "footprint" of its next generation, high power PA product family. Model 2180 covers 1 to 2.5 GHz and delivers 2 kW CW of broadband output power in a 8U, air cooled chassis. It provides excellent performance for applications that include test and measurement, electronic warfare, and communications.

Empower RF
empowerrf.com



Inductors

Gowanda Electronics announced achievement of failure rate Level R on two more of its MIL-PRF-39010 RF Inductor Series – ER15M and ER18M – adding to the company's series already approved to Level R – ER10M and ER17S. These four thru-hole series meet the military's Qualified Product List (QPL) requirements for Established Reliability (ER) and address ten different MIL-PRF-39010 slash numbers (/01 through /10).

Gowanda Electronics
gowanda.com

Amplifiers

Pasternack released new, affordable coaxial-packaged RF amplifiers. Both low noise and gain block amplifiers are offered and display excellent performance covering wide octave frequency bands from 9 KHz to 3 GHz. These provide an out-

Featured Products

standing value and are all priced less than $500 USD for a single unit. These provide engineers a convenient, economical source of in-stock and ready to ship coaxial RF amplifier solutions.

Pasternack
pasternack.com

Rack Mount Power Divider

MECA announced the latest addition to its broad band line of Power Dividers with the 32-way splitter. Available in Type N & SMA, 30W Wilkinson Power Dividers, optimized for excellent performance with industry leading specifications from 500 MHz – 6.00 GHz. Offering typical VSWR's ranging from of 1.30:1, Isolation of 18dB typical offering phase and amplitude balance typically only seen in narrower/octave band models.

MECA Electronics
e-MECA.com

Power Amp

NuWaves Engineering released an upgraded broadband RF power amplifier (PA) for L- and S-band transmitters and data radios. The NuPower™ 12B01A features improved power efficiency and operational temperature performance and a wider supply voltage range. It delivers a minimum of 10 Watts, and typically 13 Watts, of RF power from 1000 to 2500 MHz when sourced with a 0 dBm (1 milliwatt) RF input signal.

NuWaves Engineering
nuwaves.com

E-Band Transceiver

Model SSC-7737731200-1212-C1 is an E-Band transceiver with a minimum transmit output power of -30 dBm in the frequency range of 76 to 78 GHz with an IF input power of 0 dBm in the frequency range of 550 to 950 MHz. Typical receive conversion loss is -12 dB with a typical RF input power of -20 dBm in the frequency range of 76 to 78 GHz and an IF output frequency range of 550 to 950 MHz.

SAGE Millimeter
sagemillimeter.com

Cable

Mini-Circuits' VBL-2R1-K+ is an ultra-wideband precision instrumentation cable specially designed for use with VNA equipment in test environments. The cable provides excellent VSWR and very low insertion loss over the entire frequency range. Passivated stainless steel rugged 2.92mm (F) connector interfaces directly with the ports of the VNA, and a rugged crush and torque resistant outer sheath protects the cable from damage in demanding lab settings.

Mini-Circuits
minicircuits.com

isola RF/Microwave Materials & Resources

- **IS680** materials offer a complete laminate materials solution for single- and double-sided printed circuit designs and are a cost-effective alternative to PTFE and other commercial microwave materials. Dk available from 2.80 to 3.45.
- **I-Tera® MT RF** materials are available in 0.010", 0.020" and 0.030" in 3.38, 3.45 and 3.56 Dk.
- **I-Tera® MT** materials are suitable for both high-speed digital and RF/microwave designs. A full compliment of cores and prepregs allowing flexibility in design is available in core thicknesses from 0.002" to 0.018". I-Tera MT has been used in designs up to 24 GHz.
- **TerraGreen®** halogen-free, very low-loss, thermoset materials are available in a variety of laminate and prepreg offerings. This material is inexpensive to process – improving your company's bottom line, as well as the environment.
- The revolutionary **Astra® MT** ultra low-loss thermoset laminates are a replacement for PTFE. Astra MT is available in core and prepreg for double sided, multilayer and hybrid designs using isola 185HR, 370HR or IS415. Astra MT has been used in designs up to 77 GHz.

	RF/MICROWAVE MATERIALS				
	IS680	I-Tera® MT RF	I-Tera® MT	TerraGreen®	Astra® MT
Tg	200°C	200°C	200°C	200°C	200°C
Td	360°C	360°C	360°C	390°C	360°C
Dk @ 10 GHz	2.80 - 3.45	3.38, 3.45 & 3.56	3.45*	3.45*	3.00
Df @ 10 GHz	0.0028 - 0.0036	0.0028, 0.0031 & 0.0034	0.0031*	0.0030*	0.0017
CTE Z-axis (50 to 260°C)	2.90%	2.80%	2.80%	2.90%	2.90%
T-260 & T-288	>60	>60	>60	>60	>60
Halogen free	No	No	No	Yes	No
VLP-2 (2 micron Rz copper)	Available	Available	Available	Standard	Standard
Stable Dk & Df over the temperature range	-55°C to +125°C	-55°C to +125°C	-55°C to +125°C	-55°C to +125°C	-40°C to +140°C
Optimized global constructions for Pb-free assembly	Yes	Yes	Yes	Yes	Yes
Compatible with other Isola products for hybrid designs	For use in double-sided applications	Yes	Yes	Yes	Yes
Low PIM < -155 dBc	Yes	Yes	Yes	Yes	Yes

* Dk & Df are dependent on resin content NOTE: Dk/Df is at one resin %. Please refer to the Isola website for a complete list of Dk/Df values. The data, while believed to be accurate & based on analytical methods considered to be reliable, is for information purposes only. Any sales of these products will be governed by the terms & conditions of the agreement under which they are sold.

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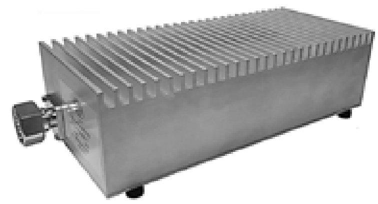

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Noise Figure Measurement Uncertainty: A Statistical Approach

By Brian Avenell

The derivation of noise figure measurement uncertainty is not a simple undertaking.

Introduction

The Y-factor technique is a popular and mature noise figure measurement method. A significant body of literature exists on the mechanics of making the Y-factor measurement. Not as well covered is the calculation of measurement uncertainty. In some of the literature, simplifications are made that may not necessarily apply to all measurement situations. At the other extreme, other literature discusses measurement uncertainty in a highly theoretical sense - covering a narrow portion of the overall uncertainty calculation that can leave the user unsure how to apply to the measurement under consideration.

Like any measurement, the accuracy of the noise figure result is essential. Noise figure measurement is especially prone to uncertainty due to its dependence on DUT gain, DUT noise figure value and the care taken in how the measurement is made. The derivation of noise figure measurement uncertainty is not a simple undertaking and for this reason, it is often a misunderstood topic.

One approach for the calculation of noise figure measurement uncertainty stems from Yield analysis or Monte Carlo analysis techniques that are used in RF circuit simulation software. In Yield analysis, all the parameters that comprise the final outcome are given a statistical probability distribution. A number of simulations are computed using a random selection of the parameter values. The final outcome of these simulations is itself randomly distributed. Based on these simulations, the mean of the final outcome's distribution function gives the error and the resulting standard deviation is the measurement the uncertainty.

The Y-Factor Technique in Brief

Average noise power is given according to

$$N = kTB \quad \text{[Watts]} \qquad (1)$$

where k is Boltzmann's constant, T is noise temperature, and B is the measurement bandwidth. Expressed in logarithmic units, this is the familiar -174 dBm/Hz. Equation (1) forms the basis of the Y-factor noise figure measurement whose setup is shown in Figure 1.

The Y-factor measurement procedure uses a calibrated noise source which outputs two noise levels, N_{icold} and N_{ihot}, corresponding to the noise generation diode being in its off (cold) and on (hot) states respectively. These two noise power levels are represented by the T_C and T_H cold and hot noise temperatures inside the noise source depicted in Figure 1. The noise source manufacturer specifies an excess noise ratio (ENR) from which the cold and hot noise temperatures can be derived[1]. From equation (1), noise power is directly proportional to the noise temperature. The hot and cold noise temperatures are unit dependent and frequency dependent.

Noise Figure

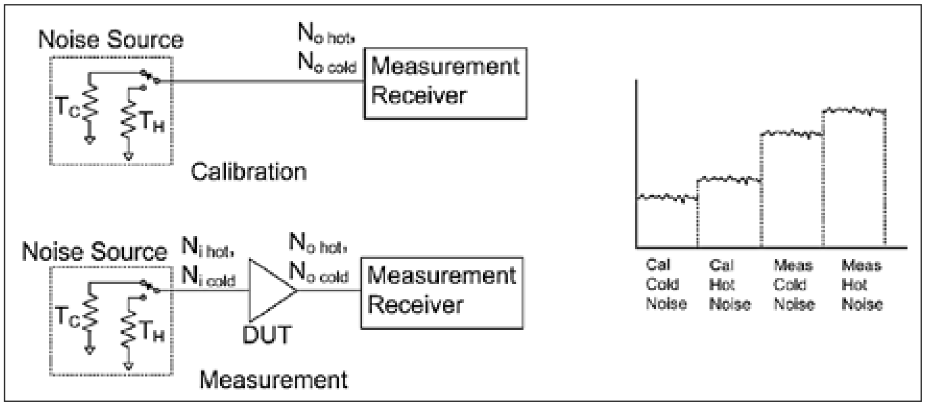


Figure 1 • Y-factor measurement setup.

Noise factor, F, is the ratio of input signal-to-noise to output signal-to-noise of the DUT. Noise figure is noise factor expressed in dB: Noise figure = 10*log(F). The more noise that the DUT adds, the higher the noise factor and noise figure values. The device added noise is given by[1]:

$$N_D = (F-1)kT_oB \tag{2}$$

where T_o is a standard temperature of 290 kelvin and F is the noise factor. Expanding equation (1), the noise power at the output of a DUT is given by:

$$N_O = GN_i + GN_D = kBG[T + T_O(F-1)] \tag{3}$$

where N_i is the noise power at the input of the DUT and G is the gain of the DUT.

The Y-factor measurement consists of four noise power measurements. In the first two measurements, the noise source is connected directly to the measurement receiver. The first measurement is made with the noise source cold and the second measurement is made with the noise source hot. This is considered the 'Calibration' phase – and it effectively characterizes the noise figure of the measurement receiver. For the next set of measurements, the DUT is connected between the noise source and measurement receiver. Subsequently, cold and hot noise measurements are made by the measurement receiver. This is considered the 'Measurement' phase.

The factor, Y, is expressed as the ratio of the measured hot noise power to the measured cold noise power. Y is given by[1]:

$$Y = \frac{N_{O\ hot}}{N_{O\ cold}} = \frac{T_H + T_O(F-1)}{T_C + T_O(F-1)} \tag{4}$$

The noise factor can then be extracted:

$$F = \frac{\frac{T_H - T_O}{T_O} - Y\frac{T_C - T_O}{T_O}}{Y-1} \tag{5}$$

Equation (5) is applied for both the 'Calibration' and 'Measurement' steps. Manipulating Friis' cascade noise figure equation results in the DUT's noise factor, F_{DUT}:

$$F_{DUT} = F_{meas} - \frac{F_{cal} - 1}{G_{DUT}} \tag{6}$$

The DUT Gain, G_{DUT}, can be extracted from the four noise power measurements used in the Y-factor measurement[1].

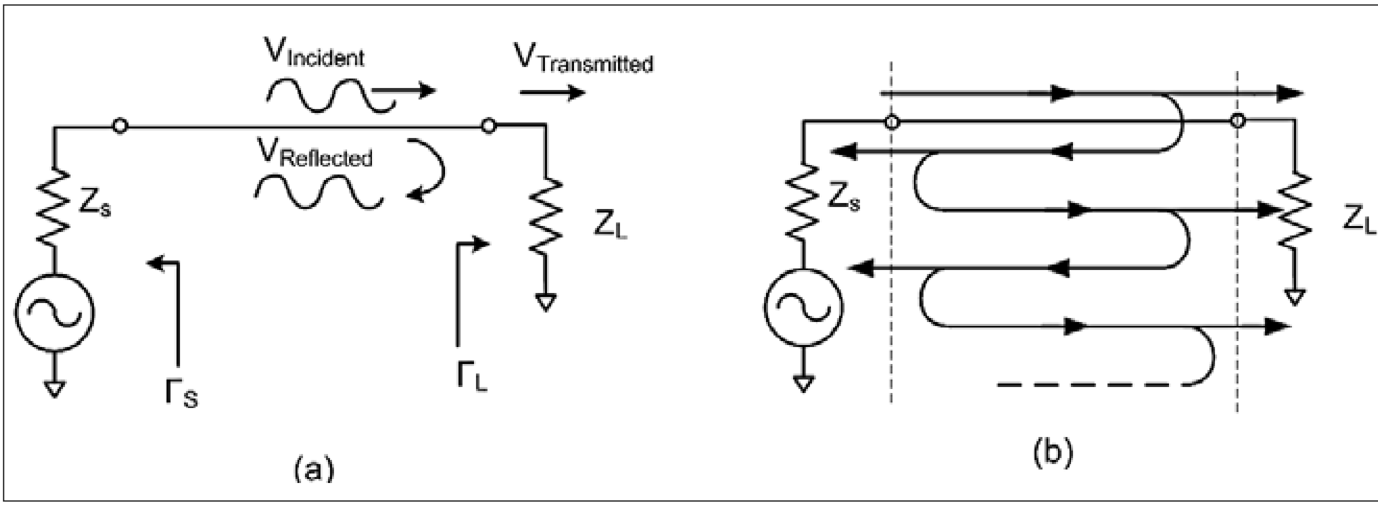


Figure 2 • Signal Reflections Due to Source/Load Impedance Mismatch.

Sources of Measurement Uncertainty

The mechanics of calculating DUT noise figure using the Y-factor technique does not give any indication of the accuracy of the measured result. Noise figure measurements are prone to many sources of measurement uncertainty. Some of the larger sources of measurement uncertainty follows.

Impedance Mismatch

Impedance mismatch itself leads to one of the larger sources of errors. However, when coupled with some of the other uncertainty sources listed below, impedance mismatch exacerbates those uncertainties as well. From transmission line theory, the voltage waveform consists of the combination of incident and reflected parts. For systems where the source and load impedances match, the reflected portion is zero and the entire incident signal is transmitted to the load. However, as depicted in Figure 2a, when there is a source and load impedance mismatch, the non-zero reflected portion of the returns back to the load.

The reflected signal then re-reflects back to the load at the source plane. The transmitted signal, as indicated in Figure 2b, is the vector combination of many of these re-reflected signals. When the impedances are characterized by their reflection coefficients, the resulting power transmitted to the load is:

$$P_L = \frac{1-|\Gamma_L|^2}{|1-\Gamma_S\Gamma_L|^2} \quad (7)$$

The numerator in equation (7) is a power loss term. The denominator, however, represents the uncertainty in the power delivered to the load. The source and load reflection coefficients are vector terms whose phases are unknown in most circumstances.

In the Y-factor measurement technique, there are three impedance mismatch planes as shown in Figure 3.

Figure 3a shows noise source/measurement receiver mismatch during the calibration process and Figure 3B shows noise source/DUT input and DUT output/measurement receiver mismatch. For discrete transistor characterization, the mismatch problem is especially acute. In these cases, adding impedance transformer networks at the DUT ports is an important consideration

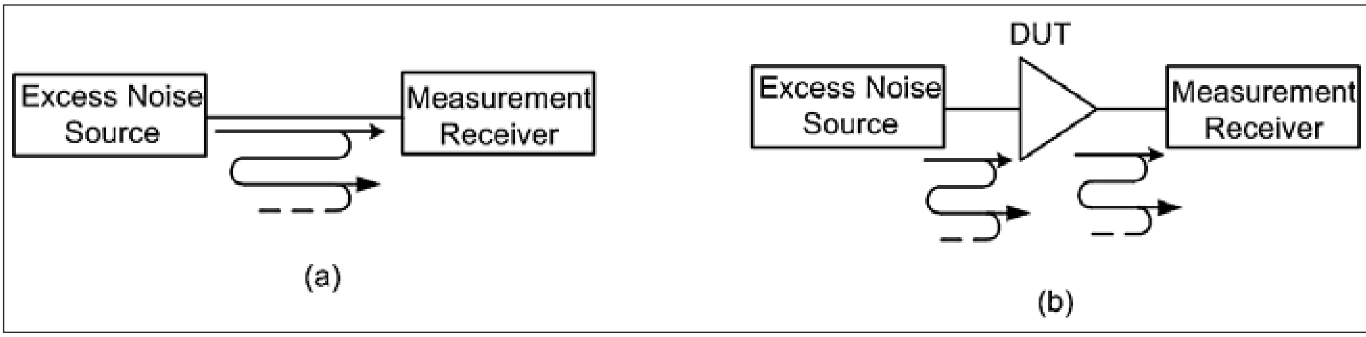


Figure 3 • Impedance Mismatch Effects in the Y-Factor Measurement.

Adding fixed attenuators at the DUT ports is another method of improving mismatch uncertainty. However, an input attenuator effectively degrades DUT noise figure and an output attenuator effectively degrades the receiver noise figure. As demonstrated below, both of these can adversely affect measurement uncertainty.

Receiver Noise Figure

Receiver noise figure as shown in Figure 4 can have a dramatic effect on measurement uncertainty.

In Figure 4a, the noise figure uncertainty is plotted versus DUT gain. Each trace represents a DUT noise figure value. In Figure 4b, each trace represents a measurement receiver noise figure value. In both cases, uncertainty increases for lower DUT gain and for higher DUT and measurement receiver noise figure.

Receiver Noise Measurement Variation

The measurement of noise requires averaging to reduce the measurement variance. Figure 5 demonstrates the measurement receiver's measured noise with two levels of trace averaging.

The downside of trace averaging is that it results in longer measurement time. However, given that there are four noise measurements associated with the Y-factor technique, reducing noise variance by means of trace averaging is highly recommended in order to reduce overall noise figure measurement uncertainty.

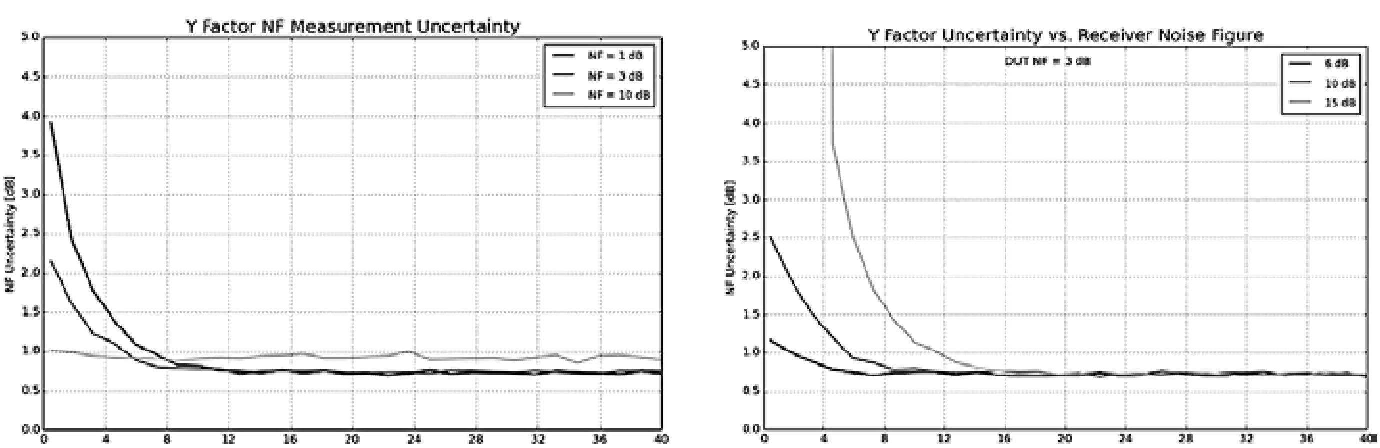
Choosing the right combination of trace averaging and measurement time is a delicate art. The benefit of noise figure measurement utilities from instrument manufacturers is that this tradeoff has been optimized for the particular instrument.

DUT Optimum Noise Match

In some cases, gain block amplifiers and especially discrete transistor devices have noise figure values that depend on the impedance match presented to the input of the device. However, the calibrated noise source most often has a nominal impedance of 50 Ohms. A lossless impedance tuner, either with discrete components or a commercially available adjustable version, placed between the noise source and the DUT input port allows for optimum DUT noise match.

Other Considerations

Finally, the noise source ENR value will have its own measurement uncertainty. The noise source manufactur-



(a) (b)

Figure 4 • Noise Figure Uncertainty vs. DUT Noise Figure and vs. Receiver Noise Figure.

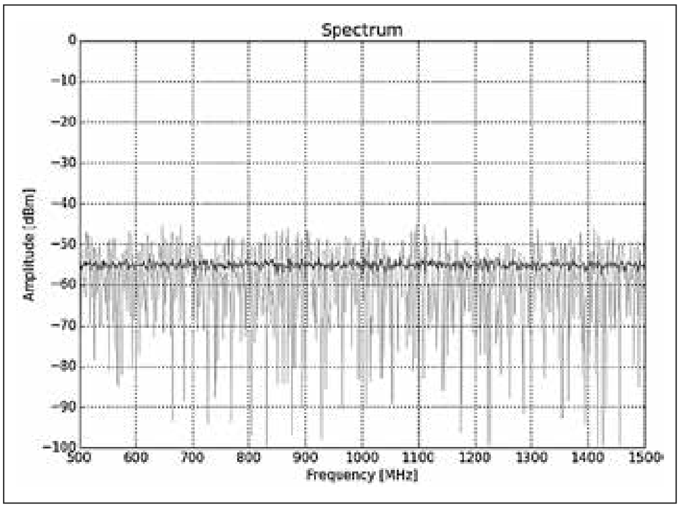


Figure 5 • Noise Measurement Variation vs. Trace Averaging.

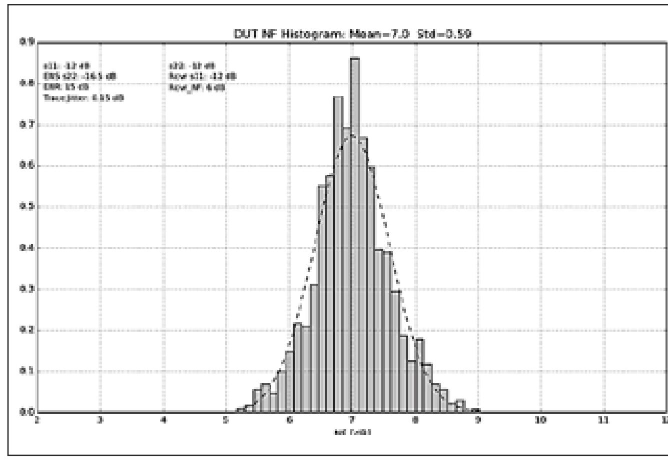


Figure 6 • Noise Figure Measurement Histogram.

er or the calibration lab used to determine the ENR values will need to specify the ENR uncertainty. ENR temperature dependence should be accounted for. ENR values are defined for a temperature of 290 K (16.85 deg C). When the physical temperature is not 290 K, an adjustment must be made.

Spurious responses either generated from the DUT, the measurement receiver, or coupled in from the environment must also be considered. If the noise measurement is being made at a frequency where a spurious response resides, misleading results in the noise figure measurement will occur. First identifying whether a spurious response is at the measurement frequency should take place. A slight offset in the measurement frequency to move away from the spurious response is then needed. Shielding the DUT with a metal enclosure can further reduce the spurious signals from the environment coupling into the measurement setup.

Measurement Uncertainty Calculation Procedure

The measurement uncertainty calculation procedure used to generate the graphs in Figure 4 is based on a Monte Carlo analysis. In Monte Carlo, parameters used to compute an outcome are randomly distributed according to each parameter's probability distribution function. The results of many simulations are in turn randomly distributed. From this result mean and standard deviation will yield the measurement error and measurement uncertainty.

For the noise figure measurement uncertainty, the Y-factor equations outlined above are used in the computation. Factors including DUT gain, DUT input and output reflection coefficients, DUT noise figure, measurement receiver noise figure, measurement receiver input reflection coefficient, noise measurement trace variation, noise source reflection coefficient, ENR uncertainty, and so on, are all given a probability distribution. Phases are given a uniform distribution and all other parameters are given a normal distribution.

The result for one simulation at a fixed DUT gain and DUT noise figure value is shown in Figure 6.

The resulting histogram from 1000 Monte Carlo simulations shows an approximately normal probability distribution. From this the mean and standard deviation can be computed. Measurement uncertainty for the graphs in Figure 4 is computed as the mean error plus two standard deviations – which is equivalent to a 95% confidence level that the measured noise figure value is correct.

NI has a utility to compute the noise figure measurement uncertainty based on the Monte Carlo technique. Figure 7 shows the front panel of this measurement utility.

Observe in Figure 7 that the user enters DUT and measurement system parameters. Under the Advanced Settings tab, the user can select which parameters are used in the Monte Carlo simulation. This feature allows the user to gauge the sensitivity of the individual parameters on the overall noise figure measurement uncertainty.

Summary

Any measurement is prone to a certain level of uncertainty in the resulting value. Noise figure uncertainty is especially complicated in that the individual parameters have inter-dependencies and the DUT gain and noise figure is a strong function of the end result. NI has provided a tool to ease the burden of the noise figure measurement uncertainty calculation.

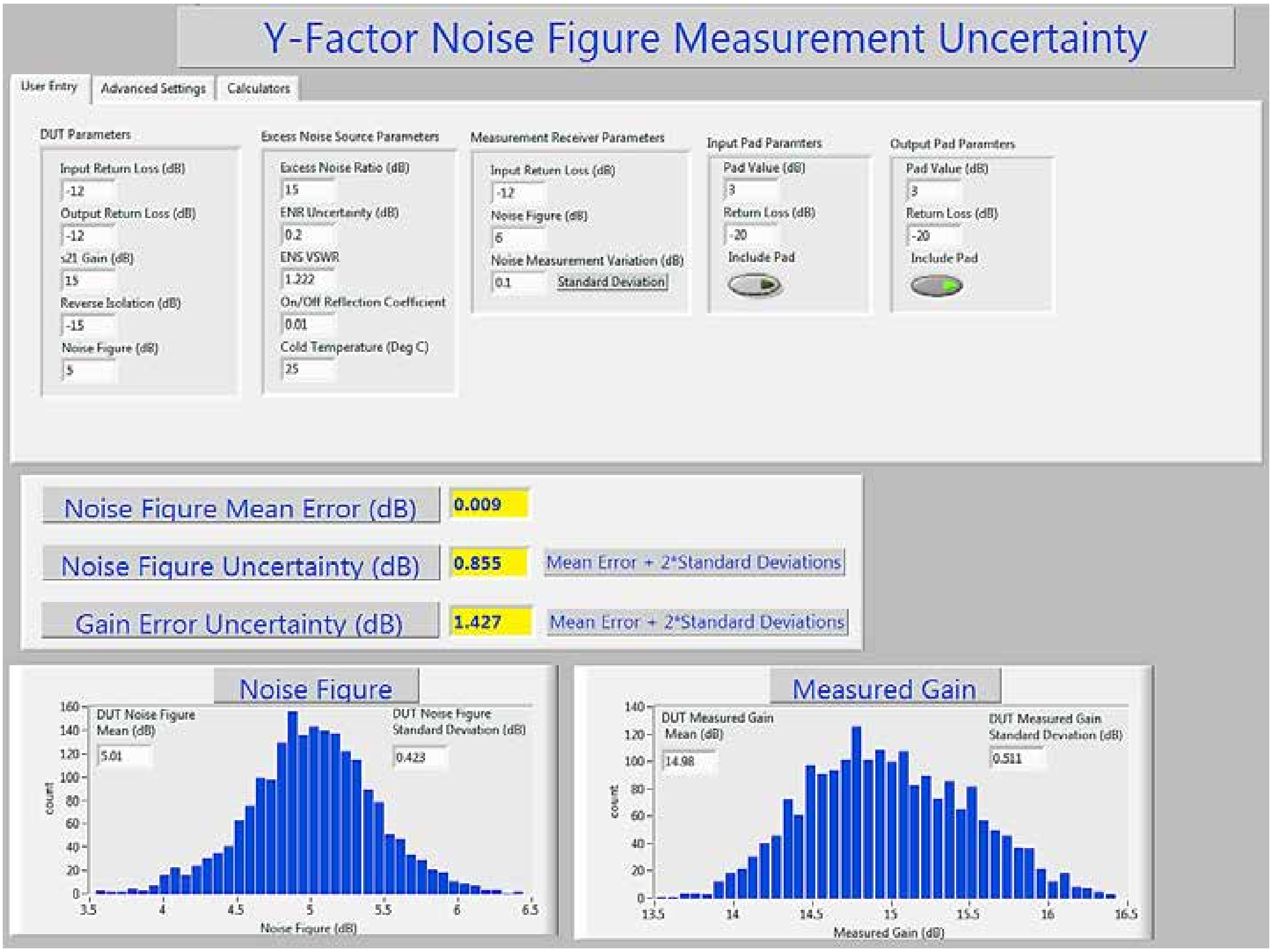


Figure 7 • NI Noise Figure Uncertainty Calculator.

References

[1] "Noise Figure Measurements: Theory and Application," , National Instruments Application Note, http://www.ni.com/rf-academy//

About the Author

Brian Avenell is a RF/Microwave design engineer at NI. Brian holds a MSEE from the University of California, Santa Barbara. System and circuit level design work associated with test and measurement receivers and sources comprise Brian's experience.

High Power Active Microwave Devices Face Many Hazards

By Tim Galla

Solid state RF and microwave amplifiers are increasing in power and power density. This greater threshold of power in a smaller area is raising the bar for other active components power handling capability. A challenge to maintain at high RF and microwave power levels is to handle higher powers as fast switching speed, good linearity, and wide bandwidth performance. Engineers working with high power systems in the telecommunications or aerospace/defense are accustomed to accounting for the many design constraints of high power at high frequencies. Test and measurement and research engineers are more often encountering high power levels to best handle developing materials and modeling high power technologies.

There are many design constraints and specialized technologies suited to high power systems.

For any application calling for high levels of RF and microwave power, there are many design constraints and specialized technologies suited to high power systems. The design constraints associated with high power regime technologies are mostly based on preventing material damage, heating, and potential component failure. Knowledge of the limitations of each active device category is necessary during system and device design to avoid overpower and stress damage leading to failure and early aging.

Greater Complexity

Unlike passive devices, active devices have an additional level of complexity and high power challenges. One of these challenges is that active devices have many more states and operation modes than passive devices. Generally, this leads to active devices being much more, if not impossible, to fully characterize. Often, datasheets will only offer rough details on a preferred mode of operation, though it is implied that the device will operate similarly in other modes. The modulation method, either continuous wave (CW), pulsed, or complex modulation schemes must also be taken into account and the time dependent power and voltage

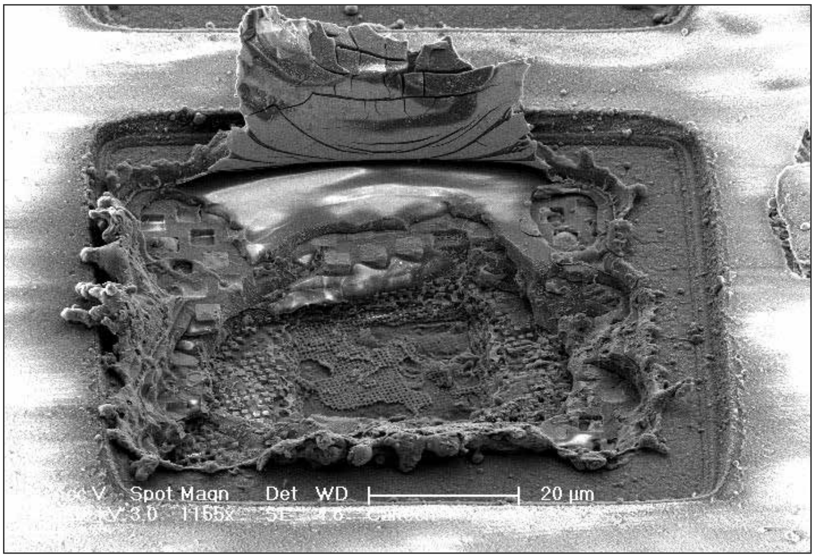


Figure 1 • A research laboratory from Caltech emulated power amplifier device failure by using a high powered laser to test self-healing technologies.
Source: http://phys.org/news/2013-03-caltech-self-healing-electronic-chips.html

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characteristics of the signals will also impact device performance. A designer will have to be much more prudent in active device selection and prototype testing to ensure that the device truly does meet system requirements, especially under extreme power, temperature, and environmental parameters.

Active devices also have power/bias, control, and often, sensors as a necessary part of device operation. With the addition of any components, the increase chance for high power devices to suffer from failures associated with the accessory electronics. Also, active device performance specifications, such as linearity, noise, and accuracy, are dependent upon these accessory electronics. In an high power environment, small degrees of nonoptimal compliance can dramatically impact downstream performance and induce failures. A savvy engineer will have thoroughly scrutinized the complete active device system during prototype and testing phase to uncover any common or specific device anomalies or failure modes.

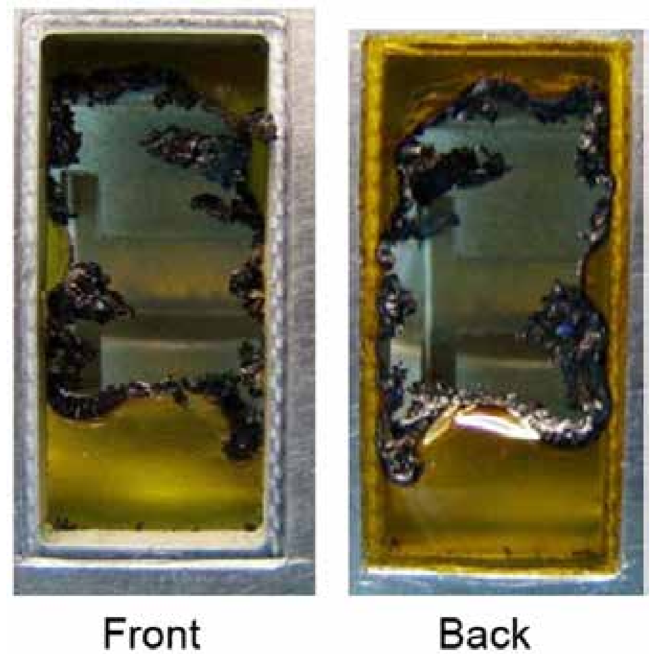
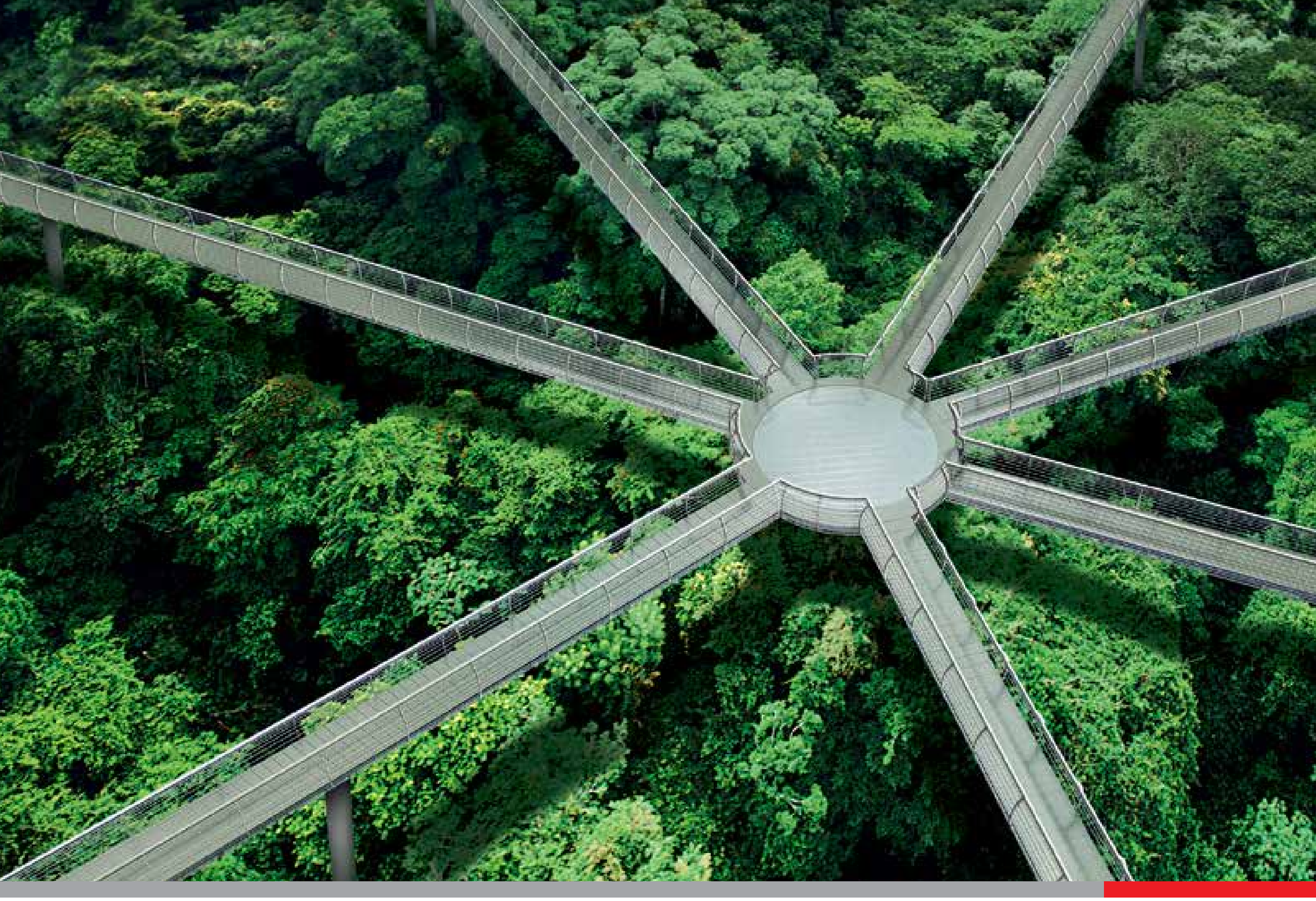


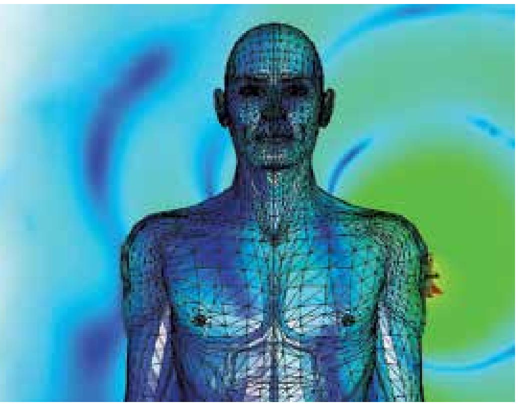
Figure 2 • As the various materials used in the construction of RF and microwave devices each have different power and temperature handling capability, the "weakest" material or component is the limiting factor in a design. Source: http://llis.nasa.gov/lesson/1796

High Power Amplifiers

Often considered the primary component of a high power RF and microwave system, the high power amplifier (HPA) essentially converts DC or AC power into a higher powered version of a stimulus signal. This means that a small stimulating signal on the range of microwatts or milliwatts can have the effect of kilowatts at the output of an HPA. Additionally, these signals are generally used to transfer information or as a radar/imaging technique were detailed knowledge of the output response is critical for accurate performance. Another important feature is that HPAs are commonly driven into the nonlinear region of operation, making predictions of performance challenging.

These factors bring up the challenge of properly modeling, simulating, and measuring an HPA's performance. As the power levels are so intense, there are very few instruments that can directly measure an HPA's true performance. Also, tiny inaccuracies in measurement can lead to enormous impacts in high power systems. However, devices such as network analyzers, can contribute uncertainty, which could be large compared to the magnitude





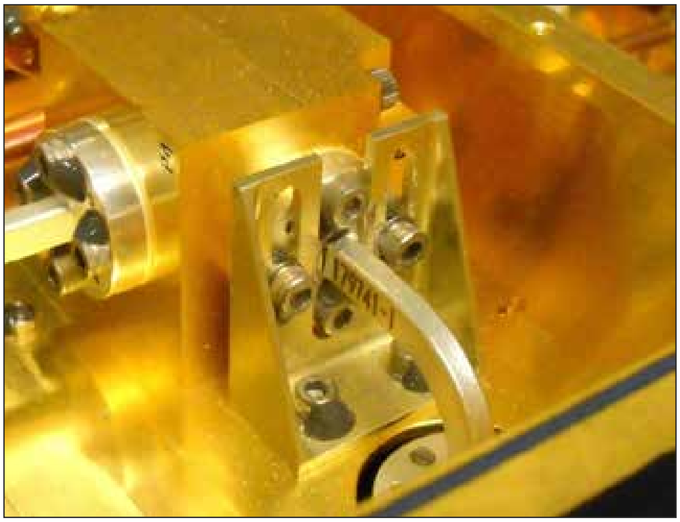


Figure 3 •The degradation or failure of an interconnect component can lead to undesired device performance, as the impedance may have an effect on the tuning or configuration of the active device. Source: http://www.microwaves101.com/mortuary/992-microwave-mortuary-2010

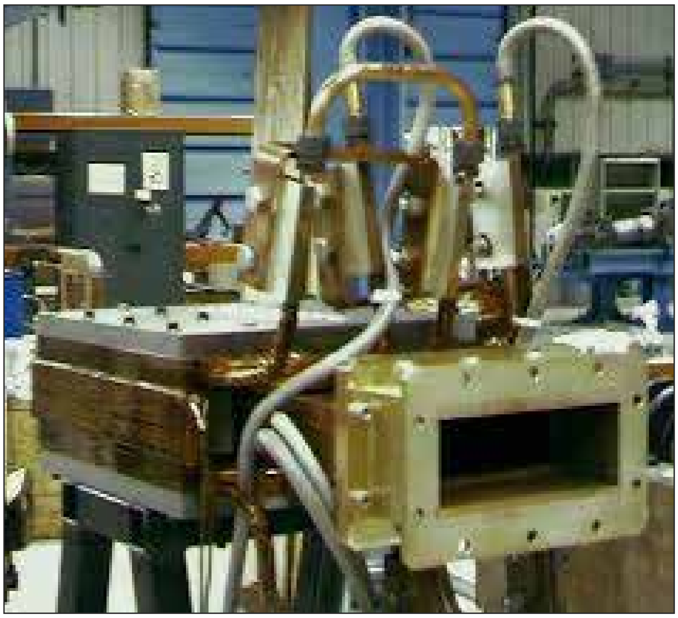


Figure 4 • Often, high power microwave electronics are housed in larger metal structures to aid in heat dissipation and thermal capacity. Source: http://lss.fnal.gov/archive/2005/conf/fermilab-conf-05-107-td.pdf

of the reflection coefficient. This is especially and issue with HPAs, as the real part of the input/output impedance can be below 1Ω. With a network analyzer with error on the order of 1Ω, this could lead to substantially different expectations and reality of device operation.

For example, an HPA's input and output impedance is determined by many factors. The primary contributing factors that can be controlled with an HPA are the frequency and operating conditions. Of which, the temperature, mode of operation, bias conditions, age, and modulation content of the signal all contribute. All of these conditions and the various states these conditions have, create an extremely complex web of the complete system states. This makes HPAs largely impossible to fully characterize.

Moreover, there are certain device parameters, such as input and output impedance, that depend upon these characteristics. Commonly, HPAs are tuned during operation to ensure optimal impedance match. This optimal match will only be in place for a certain set of conditions, and will be nonoptimal as the conditions change. Understandably, this leads to a wide range of potential impedance, reflection, and VSWR behavior.

There are a few modern solutions to this challenge. Automated tuners can be used to measure HPA states much more rapidly, producing a more detailed understanding of the devices behavior under many modes/conditions. Enhanced nonlinear simulators are also increasing in their ability to accurate describe HPA device performance. With more accurate and detailed measurements alongside heightened nonlinear simulator performance, an HPA can be more accurately predicted and better tuned to be optimal under a wide range of conditions. Obviously, these methods still hinge on an engineer's detailed knowledge of the environment in which the HPA will be operating and the desired performance constraints.

Switches and Switch Matrices

Switches are often employed in high power applications to avoid the need for having many HPAs. With modern radar, and even telecommunications, antenna arrays require a high density of switches, or switch matrices, to operate efficiently. In a high power scenario, the factors of greatest concern, are the amount of power the switch can pass or block, and the amount of signal degradation the switch will contribute. These factors are significant concerns in switch matrices, where a signal may pass through many switches before routing through the switch matrix output.

Generally used as the figure of merit for linear switch operation, the 1dB compression point, details the switches power limit before significant nonlinear performance begins. Most engineers will spec a switch with a 1dB compression point 10% to 10% beyond their predicted operational requirements to ensure linear modes

Figure 5 • Under high stress electrical conditions, certain effects, such as electrically welding metals and metallic sputtering, can arise.
Source: https://www.bicsi.org/uploadedfiles/bicsi_conferences/fall/2012/presentations/CONCSES_4C.pdf

of operation. If complex modulation schemes are being implemented, the signal integrity constraints may force the need for greater linearity headroom.

Considerations should also be made for switch aging. Switch aging can be affected by time, power levels used, heat, shock/vibration, and environmental exposure. Aging may reduce the linear operation capability, power handling, insertion loss, and switching speed. This is the case for both mechanical and solid state switches.

In cases that the switch may be operated when RF power is at the input, the hot switching capability of the device needs to be evaluated. Under hotswitching conditions, the internal stresses on the transistors or mechanical contacts are dramatically increased. Voltage and current transients under hot switching can lead to carrier migration in solid states switches and arcing that causes debris build up on mechanical contacts. Thus, lifetime of switches can be reduced significantly this way. Also, the voltage and current transients during hot switching could exceed the power handling parameters and permanently damage the device if care isn't applied.

Specifically for mechanical switches, environmental conditions could lead to moisture or particulate ingress into the switch body. Any interference with the switch contacts can enhance the aging effect and lead to premature failure. There are many types of sealing technology, though not all may be ideal for a specific application. Additionally, mechanical switches may build up heat when performing a high number of switch operations and carrying significant RF power. Often under these extreme conditions, a switches datasheet nominal performance may not be realizable. Ensuring proper environmental protections and thermal management could extend the switch's life and maintain the best switch performance.

High Power Phase Shifters

Phase shifters are often used to aid in the combining of multiple HPA outputs or in coordinating phased array antenna inputs. As phase shifters operate at the output of HPAs, both solid state and mechanical phase shifters may need to deal with substantial power outputs under a wide range of signal modes. In over power conditions, the insertion loss and VSWR of a phase shifter may increase substantially. Amplitude balance and minimal reflections are also desired parameters of phase shifters, and having a phase shifter specified for the power operation thresholds of the design is especially critical in concern to these parameters.

The power handling of an electronic phase shifter is a function of the diodes reverse bias and the size of the diodes. Greater power levels often reduce the phase shifting range of solid state phase shifters. For mechanical phase shifters, the devices are limited by the resonant behavior of the L-C network. If the Q of the network is extremely high, the power handling capability of the mechanical phase shifter will be higher. Though, the resistive components of the network will result in insertion loss and heat dissipation primarily within the inductors of the phase shifter. Even with high Q inductors, depending upon the power levels, thermal management technologies, such as heatsinks, may be necessary to keep the inductors operating within nominal temperatures. As phase shifters tend to be sensitive to temperature and environmental factors, proper protections and thermal management may be necessary to maintain nominal phase shifter operation.

Surge Suppressors

Especially with high power telecommunications and fixed radar applications, voltage and current transients due to adverse weather are unavoidable concerns. Lightning strikes often hit telecommunications towers at a rate of tens of times a year. This necessitates protections from electronic equipment from the extreme power and temperatures associated with lightning strikes. This is evident as the average peak power of a lighting strike is approximately one trillion watts.

Fortunately, the tower and enclosure designs are often designed to dissipate the majority of the electrical surge from a lightning strike. However, a significant amount of electrical energy may travel along the ground shielding of coaxial cables or the outer body of a waveguide. Unfortunately, these high performance RF transmission lines and waveguides may conduct surge currents directly into the sensitive RF electronics. On the other hand, the majority of energy of a lightning surge current is below 1 MHz. This means that surging electronics may be used to shunt the surge power without damaging the sensitive RF circuitry.

Surge suppressors are conveniently designed to do just that, without conflicting with the normal RF operation. Often found between base station enclosures and the coaxial cabling traveling to a communications tower, RF surge suppressors use surge activated breakdown devices. Types of these devices include, thyristor diodes, metal-oxide varistors (MOVs), or gas discharge tubes (GDTs), to shunt the surge energy under a high current event to a grounded plug. These devices aren't the perfect defenders, as they do have a lifetime and can be overwhelmed by an extremely high surge event, possibly leading to cascade failures. Several surge suppressors are often used in series in different parts of the signal path to ensure redundant protection to sensitive electronics and prevent system downtime.

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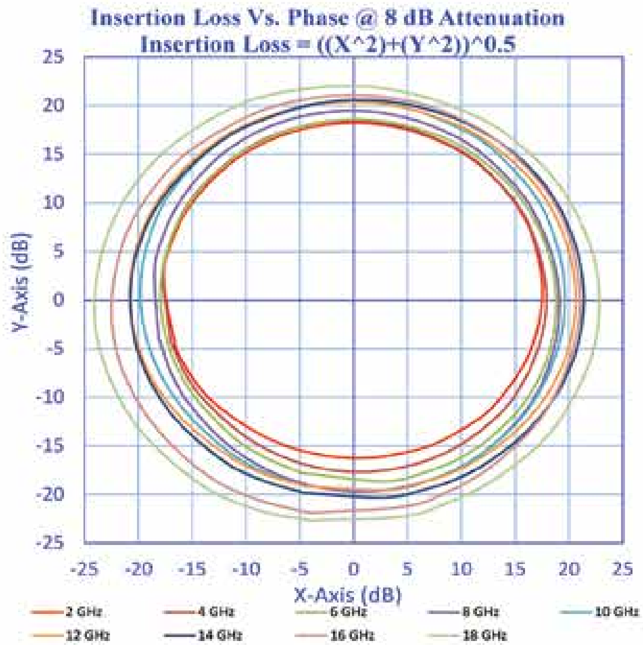
- Receiver Front Ends & Transceivers
- Single Sideband Modulators
- SMT & QFN Products
- Solid-State Switches
- Switch Matrices
- Switch Filter Banks
- Threshold Detectors
- USB Products

BROADBAND IQ VECTOR MODULATOR

PMI MODEL No: PIQ-2G18G-360-16-CD-1

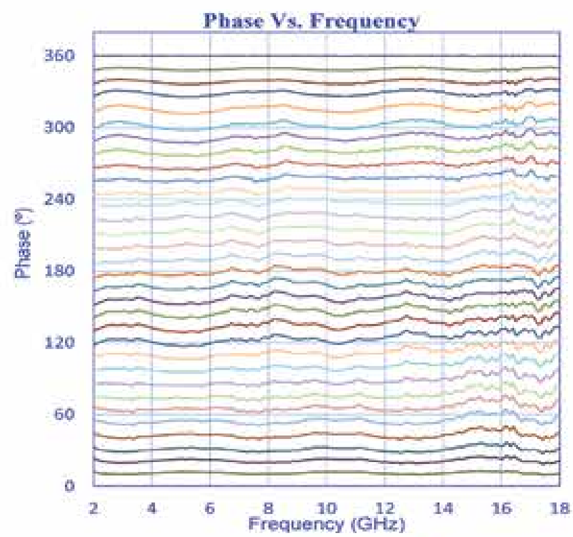
- 16 dB & 360° Dynamic Range
- RF Input Power 1 Watt max.
- 16.0 dB max. Insertion Loss
- 2.2:1 max. VSWR
- Attenuation vs. Frequency
  ±1.17 dB @ 0 dB Attenuation
  ±2.72 dB @ 16 dB Attenuation
- Phase vs. Frequency
  ±8.28° @ 0 dB Attenuation
  ±19.92° @ 16 dB Attenuation
- ±12V to ±15V @ +95 mA, -78 mA
- 2 X 12 Bit (I & Q) TTL Control
- Linear Control Slopes
- 500 nsec max. Switching Speed
- Size: 4.25" X 3.50" X 1.00"



BROADBAND PHASE SHIFTER

PMI MODEL No: PS-2G18G-360-8D

- 360° Phase Range
- RF Input Power 1 Watt max.
- 16.0 dB max. Insertion Loss
- 2.2:1 max. VSWR
- Amplitude vs. Phase (PM/AM) ±1.17 dB
- Phase vs. Frequency ±8.28°
- ±12V to ±15V @ +95 mA, -78 mA
- 8-Bit TTL Compatible
- 500 nsec max. Switching Speed
- Size: 4.25" X 3.50" X 1.00"



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Conclusion

In addition to the design challenges associated with predicted high power RF and microwave active device performance, environmental factors heap greater constraints and considerations on top of an already complex task. Thus, detailed knowledge of the environmental factors where the high power system will be deployed make a significant impact on the success or failure of a system. When designing for high power applications, failure modes and device damage often drive system constraints, even before meeting necessary operational parameters. Also, each high power RF device must be carefully selected and proven to perform before being included in a high power system.

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About the Author

Tim Galla is Pasternack's Product Manager for Active RF Components. Mr. Galla brings 25+ years of product development, applications engineering and business development expertise to his position. Prior to joining Pasternack, he held the position of Business Development Manager and Program Manager of RF/microwave components at Mercury Systems. Mr. Galla has also worked for several other industry leaders including Watkins-Johnson, Stellex Microwave Systems, Teledyne Microwave, Tyco Electronics and M/A-COM. He holds a degree in Electrical Engineering from a leading California University with an emphasis in advanced mathematics.


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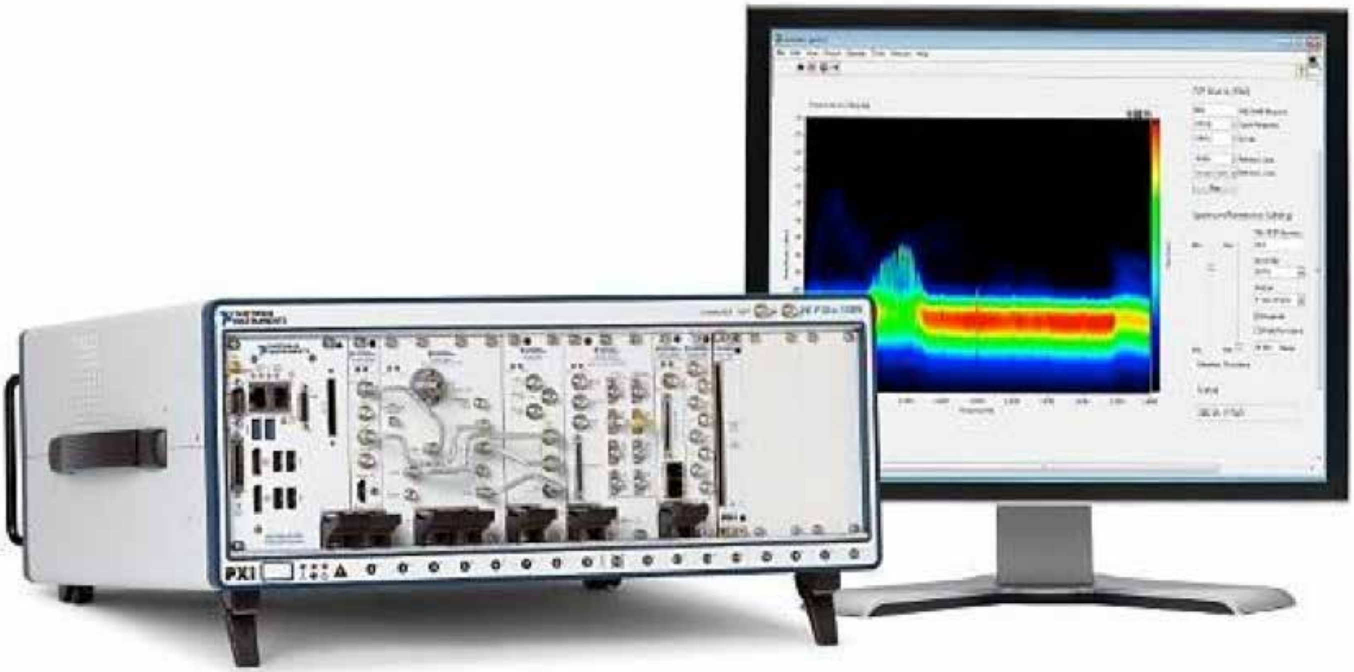
www.svmicrowave.com



Vector Signal Analyzer Features Wide Bandwidth, Dynamic Range

NI's PXIe-5668R vector signal analyzer (VSA) is a 26.5 GHz PXI RF signal analyzer that offers industry leading measurement bandwidth and best-in-class measurement performance. The PXIe-5668R serves a wide range of spectrum and vector signal analysis applications, ranging from real-time spectrum analysis to modulation accuracy measurements to radar pulse measurements. In addition, this instrument also features a LabVIEW-programmable FPGA. By programming the FPGA, engineers can customize the instrument's behavior by adding custom triggering or signal processing routines.

One of the most impressive features of the PXIe-5668R is its combination of wide measurement bandwidth and dynamic range. With up to 765 MHz of bandwidth, the NI VSA is actually the widest bandwidth fully-integrated high-performance signal analyzer. Although wide measurement bandwidth is valuable in a range of applications – it is perhaps most critical in applications such as radar pulse measurements and spectrum monitoring. In fact, the wide bandwidth of this instrument allows engineers to measure pulse rise times as low as 5 ns – which is among the best performance in the industry.

For spectrum monitoring applications, the combination of the PXIe-5668R's wide bandwidth and LabVIEW-programmable FPGA presents engineers with a unique product offering. Not only can engineers capture extremely wide contiguous blocks of bandwidth in real-time, but the onboard FPGA can process this data in real time. For example, the real-time-spectrum analysis LabVIEW example provides the functionality of a high-performance real-time spectrum analyzer that features an industry-leading 100% probability of intercept of 1.5 µS. In addition, this example is written using modifiable LabVIEW code, allowing engineers to customize the FPGA with their own signal processing routines.

The PXIe-5668R is a high-performance 26.5 GHz VSA that is ideal for a wide range of applications. The combination of excellent analog performance, extremely wide bandwidth, and ultimate flexibility empower engineers to solve challenging measurement applications ranging from basic spectrum measurements to some of the most advanced RF measurement applications.

National Instruments
ni.com/microwave

Product Highlights

Handheld Spectrum Analyzer: Lightweight, Long Battery Life

Rohde & Schwarz announced an entirely new handheld spectrum analyzer with impressively low weight and long battery life – the R&S Spectrum Rider. It offers solid RF performance and high accuracy for measurements in the field and in the lab. Its large buttons and touchscreen make it very easy to operate. The instrument has a frequency range from 5 kHz to 2 GHz, which can be extended up to 4 GHz with a key code.

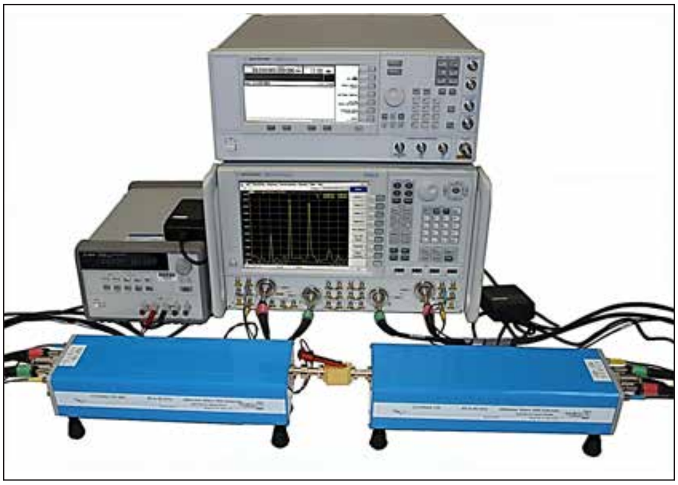
The frequency range of the R&S Spectrum Rider can be extended via software upgrades – a feature unrivaled in this instrument class. The base model covers the frequency range from 5 kHz to 2 GHz, which can be expanded to 3 GHz or 4 GHz to support applications that require higher frequencies such as measuring radio signals above 2 GHz or signals above 3 GHz in TD LTE bands.

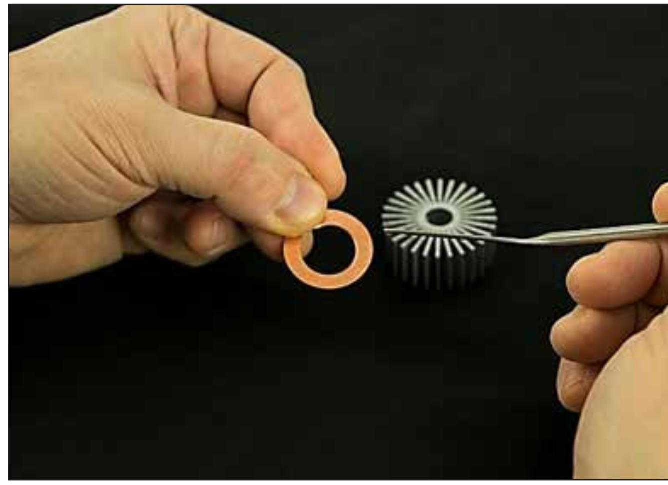
Rohde & Schwarz has optimized the R&S Spectrum Rider for mobile use. The battery of the lightweight unit (2.5 kg) lasts up to eight hours, making it the only instrument of its kind capable of working a full day without recharging. The backlit keypad allows users to work in the dark, and the non-reflective display supports a daylight mode for good readability in direct sunlight. The R&S Spectrum Rider has been field-tested in line with MIL PRF 28800F Class 2 and comes with protected interfaces and ports.

The instrument is the industry's first handheld spectrum analyzer to offer a large format capacitive touchscreen that enables lab users to easily and intuitively adjust settings such as frequency, span and reference level and to set markers. Its large buttons and practical multifunction wheel also make it easy to operate with gloves in outdoor environments.

Rohde & Schwarz
rohde-schwarz.com

Product Highlights





IMD Module

OML provides the first direct connect solution for mm-wave Intermodulation Distortion (IMD) measurements. This module is fitted to characterize mm-wave devices not only for IMD but also for S-parameters and gain compression. Compatible with modern network analyzers, OML offers mechanical compatibility with existing probe stations, including the flexibility to upgrade existing VNA modules with IMD capabilities.

OML
omlinc.com

Epoxy System

Master Bond EP21NDCL is a unique two component epoxy system that cures optically clear in thin sections, even though Part A is translucent and Part B is light amber. This non-drip compound is formulated for a variety of bonding, sealing and coating applications in the optical, opto-electronic, electrical, aerospace, and specialty OEM industries. EP21NDCL offers convenient handling with a one to one mix ratio by weight or volume.

Master Bond
masterbond.com

SMA Connectors

SGMC Microwave's SMA series (Sub-Miniature-A) are precision grade connectors for microwave applications requiring excellent performance up to 18 GHz and beyond to 26.5 GHz. The SMA series is mechanically compatible with 3.5mm and 2.92mm connector series. SGMC offers an extensive line of SMA precision adapters, receptacles, and cable connectors for various semi-rigid and flexible coaxial cables. Special designs available upon request.

SGMC Microwave
sgmcmicrowave.com

Product Highlights

Power Dividers

VidaRF offers power dividers from 2-16 way Model: VPD-2080A** frequency range from 2.0 - 8.0 GHz, 20 watts power handling with SMA S/Steel connectors, operating temp -55 to +85 C. If required sealed and painted to meet IP65 standards.

VidaRF
vidarf.com

Bias Tee

The Z3BT-2R15G+ is a low loss bias tee designed for use with L-Band systems, cabable of injecting up to 2A, this Bias tee is ideal for satellite communications applications. Built in a rugged shielded case, the Z3BT-2R15G+ is equipped with SMA Female connectors for all ports. The Z3BT-2R15G+ is ideally suited for powering Satellite up converters and LNBs where RF and DC are injected on a single coax cable.

Mini-Circuits
minicircuits.com

Right Angle Attenuators

MECA announced the addition to its 662 series, 2 watt SMA attenuators operating now up to 4 GHz. The 662-dB-1RA series attenuators cover all wireless applications from Hz – 4.0 GHz and available in standard values of 3, 6, 10, 20 & 30dB. And as always made is USA carrying MECA's 36 month warranty.

MECA Electronics
e-meca.com

V-Band Transmitter

Model SSK-ST573673-15-ITS1 is a V-Band transmitter (upconverter) that emits two orthogonally polarized signals from 57 - 67 GHz. It takes a 14.250 to 15.875 GHz/+0 dBm signal through a X4 active multiplier to generate a mmW signal as its local oscillator and DC to 3.5 GHz/0 dBm as its IF input signal to generate 57 to 67 GHz RF signals. The generated RF signal is fed into two power amps to produce the horizontal and vertical polarized signals, which is combined into circular polarized waveform through a V-Band orthomode transducer and transmitted via a 14 dBi gain conical antenna. The EIRP of both horizontal vertical polarized signals is +36 dBm typically. The assembly requires a typical +6 VDC/ 670 mA bias power. The assembly uses SMA (F) connectors for both LO and IF ports.

SAGE Millimeter
sagemillimeter.com

Power Sensor Demo Kit

LadyBug Technologies' LB5900 series of patented no-zero no-cal before use RF Power Sensors offer coverage from 9 kHz to 40 GHz. The product's broad frequency range combined with exceptional sensitivity make it ideal for satellite, radar, EMC testing along with defense applications and general testing. The line offers an optional SPI / I2C connectivity system, allowing the sensors to be used in compact instruments and ATE systems that do not include a PC. LadyBug now offers its LB9040A Demonstration Kit for use with LB5900 sensors with the I2C/SPI Option. The demo system is complete with a pre-programmed micro-processor board with example firmware installed, along with all required hardware and adaptors. Just add a LB5900 Sensor with Option SPI.

LadyBug Technologies
ladybug-tech.com

Product Highlights

Driver Amp

Richardson RFPD announced availability and design support for a new 2W GaN driver amplifier from Qorvo. The TGA2958-SM is a packaged Ku-band amplifier fabricated on Qorvo's 0.15um GaN on SiC production process. Operating over a 13-18 GHz bandwidth, it delivers 2W of saturated output power with 20 dB large signal gain and > 25% power added efficiency. This allows it to support a variety of low power Ku-band systems or as a linear, high-voltage driver for Qorvo's line of high-power Ku-band amplifiers.

Richardson RFPD
richardsonrfpd.com

Phase Shifter

RFMW announced design and sales support for API Technologies phase shifters designed for applications in optical communication systems. The precision adjustments on the OPS-0002 phase shifter allow enhanced resolution and accuracy setting. To serve this market, the API OPS-0002 is offered with precision 2.4mm female connectors and operates up to 50GHz.

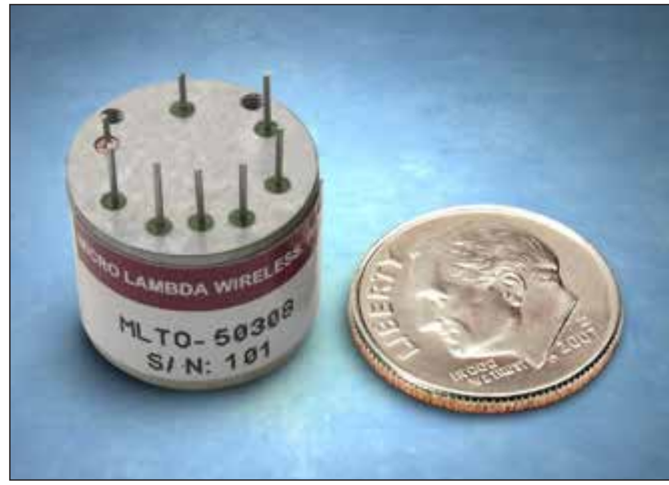
RFMW
rfmw.com

Wideband Amp

Mini-Circuits' GVA-92+ is an advanced wideband amplifier fabricated using GaAs HBT technology. It offers high gain and excellent output power with high Power Added Efficiency (PAE) in application bands.

Mini-Circuits
minicircuits.com

Product Highlights



SATCOM IC

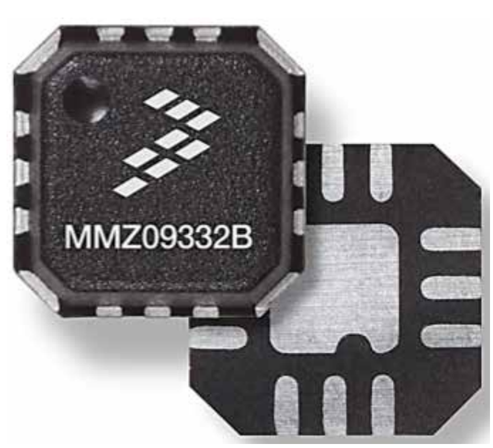
Richardson Electronics announced the availability of a new K-band silicon SATCOM Rx quad-core integrated circuit from Anokiwave. The highly-integrated AWS-0102 is intended for satellite communications applications. The device supports four dual-polarization radiating elements with full programmable polarization flexibility. It provides 22 dB gain with a noise figure of 3.4 dB. Additional features include gain compensation over temperature and temperature reporting.

Richardson Electronics
rellpower.com

YTOs Cover 8 to 16 GHz

Micro Lambda Wireless announced the production release of TO-8 YIG-Tuned oscillators covering the frequency range from 8 to 16 GHz. This new model is only .5" tall and perfect for next-generation products that use plug-in technology. The standard model operates over the 0 to +65 C temperature range, but military versions covering -40 to +85C are available on special order. Applications include Test Instruments, Wide Band Receivers, Telecom, Satcom and a variety of defense applications.

Micro Lambda Wireless
microlambdawireless.com

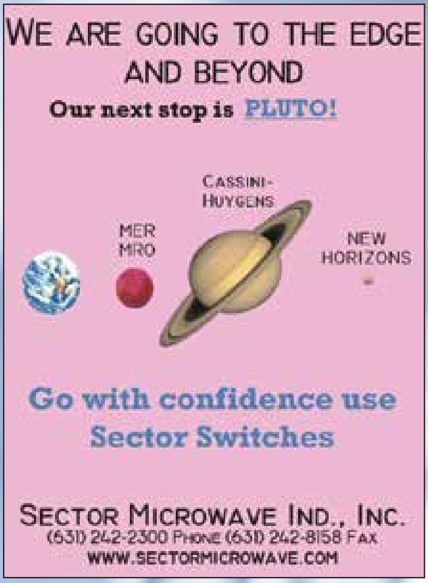


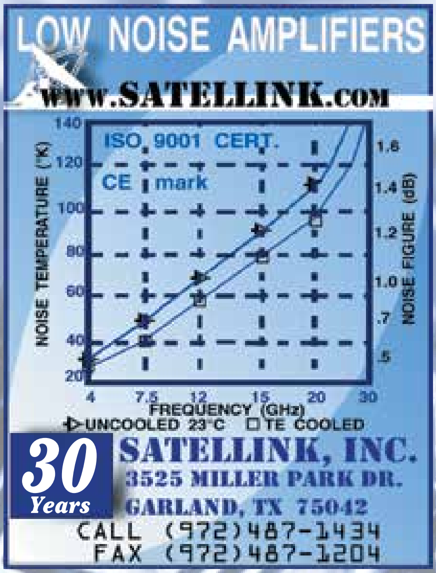
Linear Amp

Freescale Semiconductor released the MMZ09332B, a 2 W, two-stage, broadband InGaP HBT linear amplifier. It is ideal for use as a driver application in macro and small cell 3G and 4G base stations, smart grids and other wireless applications. The MMZ09332B is designed to cover frequencies from 130 to 1000 MHz and operates from a supply voltage of 3 to 5 volts.

Freescale Semiconductor
freescale.com

Product Showcase





Product Highlights

Attenuators

MECA's New Compact Low PIM 50 watt Attenuators (-160 to -165dBc typical) feature industry-leading thermally stabilized low PIM distortion performance (low thermal noise). In addition, all of the terminations cover 0.698 - 2.700 GHz frequency bands. Available in: Type N & 4.1/9.5, 4.3/10.0 and 7/16 DIN models both within connector series and mixed series configurations.

MECA Electronics
e-meca.com

Power Amp

Exodus Advanced Communications released a state of the art, ruggedized power amplifier. AMP1029 is a 2 to 6 GHz, 50 W Min/70 W typical broadband module, featuring Class AB linear GaN hybrid design in a small, lightweight form factor. Its compact size, 35% efficiency and full load protection makes it suitable for applications demanding small size and high efficiency: jamming, communications, EW, and more.

Exodus Advanced Communications
exoduscomm.com

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Product Highlights

Couplers

Werbel Microwave is developing a new series of high-directivity directional couplers for laboratory use. The series is designed to operate over the frequency band 1-18GHz but the devices are useable over 0.5-20GHz with some performance roll-off. Currently available in 10 and 20 dB units. Directivity is 15 dB minimum and VSWR is 1.5:1 maximum over the entire band. Coupling flatness is +/- 0.5dB nominal within a +/- 1.0 dB window. Made in Livingston, NJ, USA.

Werbel Microwave
werbelmicrowave.com

Type "N" Adapters

SGMC Microwave's Type N series are precision grade connectors designed for applications requiring excellent performance up to 18 GHz. SGMC offers an extensive line of N precision adapters, receptacles, and cable connectors for various semi-rigid and flexible coaxial cables. Frequency Range: DC to 18 GHz (Extended Performance); Ruggedized construction for repeatability and reliability; Captivated Center Contact; Low VSWR and insertion loss.

SGMC Microwave
sgmcmicrowave.com

Ka Band Transmitter

Model SST-2730253027-28-S1 is a Ka Band compact transmitter module operating at 26.8 GHz, designed and manufactured for small satellite applications. It incorporates a phase locked oscillator to convert 1.0 GHz signal to 26.8 GHz signal. With an integrated 23 dBi circular polarized lens corrected antenna, the module delivers +50 dBm EIRP. A robust filtering system greatly reduces the harmonic and spurious levels, making it a great choice for ground, ground to satellite and satellite to satellite communication applications. Two such modules are flying in orbit since July 2014.

SAGE Millimeter
sagemillimeter.com

Product Highlights

Attenuator

BroadWave Technologies added model series 351-319-XXX (insert desired attenuation value to complete the model number) to its portfolio of 50 Ohm fixed attenuators. Standard attenuation values are 3, 6, 10, 20, 30 and 50 dB. The average power rating is 50 watts @ 25°C with 1000 watts peak power. Maximum VSWR is 1.40:1. Other attenuation values and connector configurations are available upon request.

BroadWave Technologies
broadwavetechnologies.com

Transformer

Mini-Circuits' TC4-122-75X+ is a 75Ω, 40 to 1250 MHz, RF Transformer that features: wideband, 40-1250 MHz; balanced transmission line with secondary center tap; plastic base with leads; aqueous washable. Applications: PCS; cellular; CATV; DOCSIS 3.1.

Mini-Circuits
minicircuits.com

Coupler

A new hybrid coupler features reliable construction using multi-section design and provides power dividing/combining up to 1600 watts CW in a small coaxial package that has proven performance for power and reliability under extreme environmental conditions. Covering the 1-2 GHz band, the Hybrid has an amplitude balance of 0.55 dB with a 6 phase balance and low insertion loss of 0.2 dB while having a minimum of 18 dB of isolation. It is supplied with type "SC" Female connectors on all ports. Other connector configurations are available.

Preferred Power Products
preferredpowerproducts.com

Product Highlights

Socket Adapter

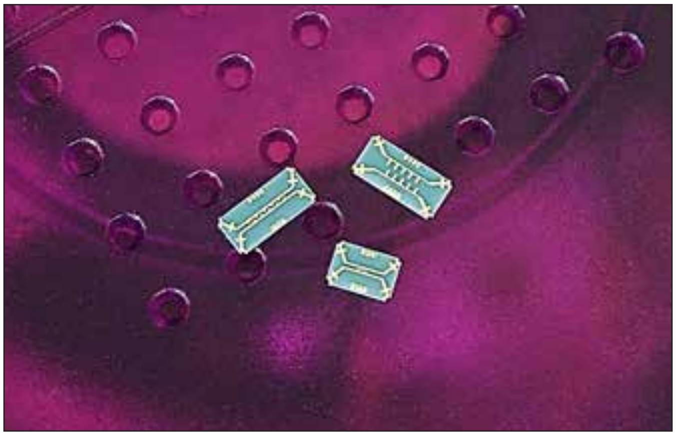
Ironwood Electronics' SMD Socket Adapter, LS-BGA84H-61, allows user to socket a BGA chip having only the SMT pads on the target PCB without any additional space for a socket. The companion SF-BGA84H-B-64 is attached directly to the target PCB using the same soldering methods as attaching a BGA IC. The target IC is soldered to the LS-BGA84H-61. The two parts are interconnected together with gold plated machined pins for highest reliability. The height of the socket not including IC is then 4.5 mm.

Ironwood Electronics
ironwoodelectronics.com

Connector Family

ERNI expanded its compact MaxiBridge(TM) wire-to-board connector family with a new dual row version. The 10-pin or 20-pin connectors offer a current carrying capacity of up to 12 A per contact on a 2.54mm grid for heavy-duty and space-saving connections. Available in vertical and right angle version, the dual row MaxiBridge connector system is offered with 2 x 5 and 2 x 10 positions.

ERNI
erni.us



Couplers

10 and 20 dB coupling values are available from DLI in common footprints for C, X and Ku Bands. Surface mount devices (chip and wire hybrid also available) using DLI's high permittivity dielectrics allows for a smaller size device with temperature stability. Using thin film technology, these devices are highly repeatable and a great solution for high frequency power monitoring.

Knowles Capacitors
knowlescapacitors.com

Product Highlights

Coupler

P1dB announced its newest octave band SMA Directional Coupler series operating from 2 to 4 GHz. The series P1CP-SAF-0204G are available in 10 dB, 20 dB and 30 dB coupling values and will handle up to 50 Watts. The SMA couplers have a minimum directivity of 22 dB and a VSWR specification of 1.15:1. A common coupling value for SMA Couplers is 10 dB and its part number is P1CP-SAF-0204G10W-10. All coupler values and frequency ranges can be found in the Coupler category page on the P1dB website.

P1dB
p1db.com

Attenuator

Link Microtek launched a new range of high-power attenuators that offer a flat response across their specified frequency band of 26.5 to 40GHz, making them ideal for use in the testing of military or commercial Ka-band satellite-communications systems. The AM28J-XXMP series devices are available with attenuation levels ranging from 10 to 30dB, while a microwave power handling capability of up to 100W CW enables measurements to be carried out on either TWT or solid-state high-power amplifiers.

Link Microtek
linkmicrotek.com

Power Doubler

RFMW announced sales support for two DOCSIS 3.1 compliant power doubler amplifiers from Qorvo. The RFPD3210 and RFPD3220 are hybrid GaAs/GaN devices offering excellent linearity and low distortion. Designed for 45 to 1218MHz CATV amplifier systems, the RFPD3210 and RFPD3220 also offer high gain of 22.5 and 24.5dB respectively. Low noise figure of 3 dB punctuates the performance of these Qorvo power doublers and GaN technology provides both reliability and power efficiency.

RFMW
rfmw.com

Product Highlights

Power Amp

NuWaves Engineering introduced the NuPower 05E05A, a compact and highly efficient solid-state power amplifier (PA) module for S-band transmitters and data links. Providing 30 Watts on average, and 20 Watts minimum, RF output power, the NuPower 05E05A operates from 2000 to 2600 MHz for continuous wave (CW) and near-constant-envelope waveforms.

The connectorized PA module accepts a nominal 0 dBm (1 milliwatt) input signal and provides 44 dB of RF gain while operating at 40% DC power efficiency with a +28 VDC supply voltage.

With a 4.50” x 3.50” x 0.61” aluminum chassis that weighs only 9 ounces, the NuPower 05E05A is small and lightweight, ideal for communications, telemetry and electronic warfare systems in air- and ground-based tactical, test and training platforms. An optional fan-cooled heat sink assembly is also available to provide cooling to the module.

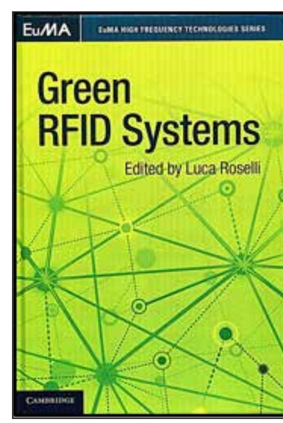
NuWaves Engineering
nuwaves.com

Book Review

Green RFID Systems

Edited By: Luca Roselli

ISBN 978-1-107-03040-4 (Hardback)



Ever heard of EAS, GNR, NFC, SECE, SSHI, SSPB, SWIM, and WISP? Interested in RFID protocols and regulations? Want to know more about differences between passive, active and battery-assisted passive (BAP) tags? Then this book is for your enlightenment.

RFID devices are now part of our everyday activity. In some forms called tags, they are constantly evolving. They will play a significant role in the internet of things (IoT) and wearable ID and medical devices. Energy scavenging from ambient sources, mechanical stress and motion, temperature gradients and electromagnetic radiation has become practical. Huge advances that have recently been made in efficient power conversion and storage are explained.

Organic conductor and semiconductors are explored. Biodegradable paper circuitry using inkjet-printed circuitry and antennas are discussed. Properties of graphene, which has widespread application possibilities for devices, circuits and systems, are examined. Textile antenna and antenna arrays designs are explored. Test techniques and set-ups are briefly discussed, also. This subject matter is both at the end-item level as well as the characterization of substrates using some proven techniques such as ring and T resonators. Networking of RFID devices is examined in fairly good detail.

With some 28 technical contributors, this text shares a wealth of knowledge from a worldwide perspective, which can apply beyond the boundaries of RFID technology. The illustrations, schematics, photographs, and data presentations are well done and unambiguous with good consideration that the use of color is not present. Some of the techniques described are finding their way into other areas of electromagnetics such as electronic countermeasures and radar. Generous mention of references is made in each chapter.

The subject matter may have wider appeal and scope than just the current “green” attraction. With the rapid pace of RFID technology advances, the book is likely to have a short “half-life.” However, as things stand now, it is a very valuable source of information. The technology described, if used judiciously, forms the basis for almost boundless possibilities for the future benefit of mankind.

—Tom Perkins
Senior Technical Editor

Product Highlights

Radio Path Alignment

HXI's AutoPoint System, designed exclusively for HXI Radios, provides mmWave radio path alignment from any remote location. It is the perfect solution to align and maintain high bandwidth directional antennas for many communication applications. AutoPoint is a complete hardware and software solution. It can be used to "fine tune" initial alignment, and more importantly, can be used to re-align your link as required. The Web based user access makes it easy to optimize link performance regardless of the time of day, season, or current weather conditions.

HXI
hxi.com

VNA Test Cables

Pasternack released a new line of ruggedized phase stable VNA test cables operating up to 40 GHz depending on the series. The VNA test cables are specially designed to withstand the rigors of test lab use and production testing for 50 ohm communications systems.

The new phase stable cables can be ordered with male or female versions of SMA or Type-N connectors for cables operating to 18 GHz, 2.92mm connectors for cables operating to 26.5 GHz or 2.4 mm connectors for test cables performing up to 40 GHz. Torsion resistant connector heads are directly attached to stainless steel conduit style armoring providing a rugged design for up to 5,000 mating cycles with proper care. The cable's armoring enhances amplitude and phase stability by preventing stress due to over bending while maintaining the flexibility required for testing in a lab environment.

The cables have a maximum phase change of +/- 2 degrees at 18 GHz, +/- 3 degrees at 26.5 GHz and +/- 5 degrees at 40 GHz with typical calibration procedures.

Pasternack
pasternack.com


MCL B 744
ADP-2-10
MCL B 744
ADP-2-10
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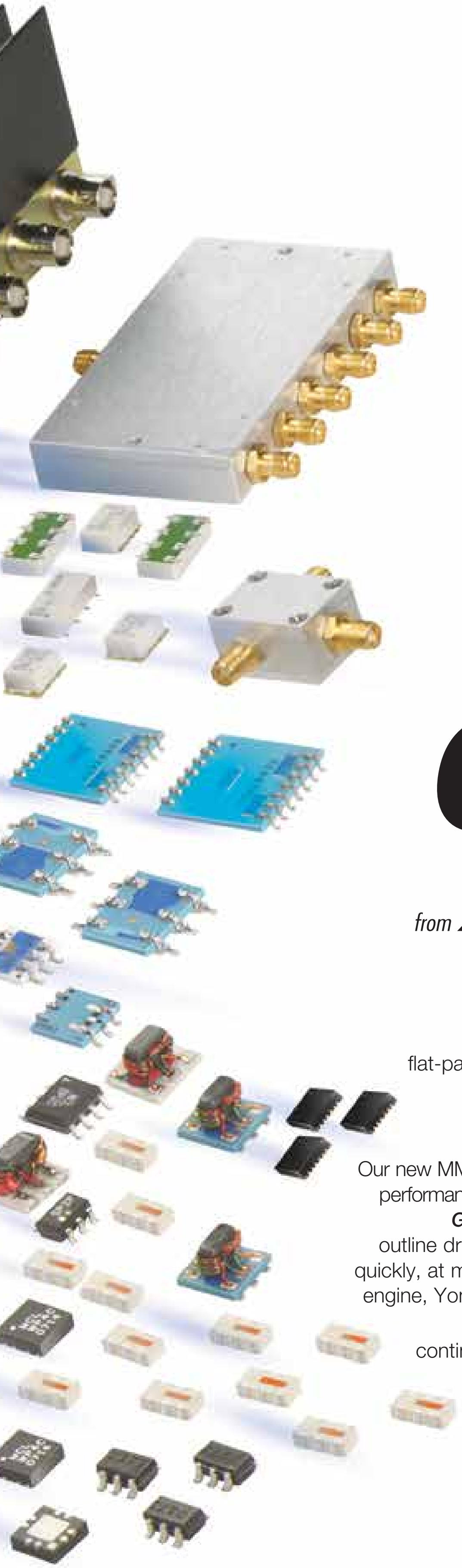

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