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AUGUST 2015

HIGH FREQUENCY ELECTRONICS

Impact of Antenna Design, Tune and Match on Wireless Range

IN THIS ISSUE:

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

Meet the magic number for two-watt temperature-variable attenuators

Push the limits of frequency without sacrificing performance. Powerfilm surface-mount attenuators from Inmet, part of API Technologies Corp., vary with temperature and are the perfect balance of price, power, and dependability. They offer the flattest broadband performance of their kind and allow you to create automatic- and passive-link margin compensation on a wider variety of transmit and receive chain circuit applications.

Save money and space by throwing out your complicated gain-control circuitry and required bias and control voltages. Visit our website for complete details and request a sample today.

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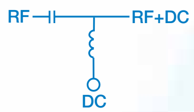

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TYPICAL SPECIFICATIONS

Model	Freq (MHz)	Insertion Loss (dB)	Isolation (dB)	Max Current mA	Price $ea. Qty.10
TCBT-2R5G+**	20-2500	0.35	44	200	6.95
TCBT-6G+**	50-6000	0.7	28	200	7.95*
TCBT-14+***	10-10000	0.35	33	200	8.45
TCBT-14R+***	10-10000	0.6	33	200	8.45

TCBT: LTCC, Actual Size .15" x .15"
U.S. Patent 7,012,486** U.S. Patent 8,644,029*

Model	Freq (MHz)	Insertion Loss (dB)	Isolation (dB)	Max Current mA	Qty.1-9
JEBT-4R2G+	10-4200	0.6	40	500	39.95
JEBT-4R2GW+	0.1-4200	0.6	40	500	59.95
PBTC-1G+	10-1000	0.3	33	500	28.20
PBTC-3G+	10-3000	0.3	30	500	38.20
PBTC-1GW+	0.1-1000	0.3	33	500	38.20
PBTC-3GW+	0.1-3000	0.3	30	500	49.20
ZFBT-4R2G+	10-4200	0.6	40	500	59.95
ZFBT-6G+	10-6000	0.6	40	500	79.95
ZFBT-4R2GW+	0.1-4200	0.6	40	500	79.95
ZFBT-6GW+	0.1-6000	0.6	40	500	89.95
ZFBT-4R2G-FT+	10-4200	0.6	N/A	500	79.95
ZFBT-6G-FT+	10-6000	0.6	N/A	500	79.95
ZFBT-4R2GW-FT+	0.1-4200	0.6	N/A	500	79.95
ZFBT-6GW-FT+	0.1-6000	0.6	N/A	500	89.95
ZFBT-282-1.5A+	10-2800	0.6	45	1500	59.95
ZFBT-352-FT+	30-3500	0.4	23	4000	49.95
ZNBT-60-1W+	2.5-6000	0.6	45	500	82.95
ZX85-12G+	0.2-12000	0.6	N/A	400	99.95

ZX85: U.S. Patent 6,790,049.

Note: Isolation dB applies to DC to (RF) and DC to (RF+DC) ports.
*Price is for quantity of 20

Mini-Circuits®

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Editorial

How to Make Your Booth a Winner at Your Next Trade Show

Tim Burkhard
Associate Publisher

If you've ever walked the entire exhibit floor at a trade show such as the MTT-S, you've no doubt seen the following two types of booths.

The first booth has company reps who are engaging with potential customers. Product demos are underway, literature is being passed out, and questions are being asked and answered. Visitors' badges are being scanned and there is a glass bowl on a table filling with business cards. This company's show expense is justified, because it is collecting sales leads—the very reason for being at the show. We'll call this Booth A.

The second booth has few or no visitors. A company rep is standing in the booth, clearly searching for the next opportunity to engage someone—anyone at all. You feel sorry for this poor soul, who will likely spend the next three days of his or her life on this fruitless pursuit. The money this company spent on an exhibit has been largely squandered. We'll call this Booth X.

If you have ever been part of Booth X, and want instead to be working in Booth A, here's how.

First, a clarification on terminology. Those engineers who are upstairs in ballrooms attending or presenting technical papers? They are attending a "symposium" or a "conference." Those of us who are instead down on the show floor, representing an exhibiting company in the hopes of drawing those engineers to our booth? We are part of a "trade show," or, more simply, a "show."

Invite people to your party. You would never go to the trouble and expense of arranging for your daughter's wedding, and then fail to send out invitations for the big day. The same applies for your trade-show presence. A good rule of thumb is that for a big show such as the IMS, you should begin promoting to your target audience at least six months in advance. In fact, there are savvy marketers in this issue of *HFE* that already have their 2016 IMS booth numbers listed in their ads. In every press or product release you send out, in every advertisement or web banner you place, in every way possible – tell people you will be there, and supply your booth number.

Send Your Best and Have a Plan

Send your best people and have a plan. Have you ever visited a booth, only to be turned off by company reps who give perfunctory answers to your questions or seem otherwise engaged? While far rarer now than in the past, this phenomenon still exists. In the old days, you would sometimes see a sales rep sitting in his booth, smoking a cigarette—no kidding—or eating a sandwich while visitors stood in the aisle. Today, the equivalent is someone fiddling with an iPhone. Incredibly, sometimes they are company management, viewing themselves as "above it all."

Very simply, these types should not be representing your company at the show. Send only people who know your products, who smile, who act like they want to be there. Our industry is blessed with many excellent sales reps—and they always have a plan. They make appointments well in advance of the show. They exhibit excellent time-management skills during the event to maximize sales opportunities. And they engage with customers and prospectives beginning over coffee in the morning, all the way through the show day, and then through dinners or cocktails at night. For all three days.

In many cases this will be a customer's first in-person contact with your company. Make it count by sending your best people so your new contacts will want to do business with you once the show's over.

"Push" your product or service to the aisle. Wherever possible, don't make people probe deep inside your booth to find out what you are selling. Why does everyone dread walking onto the lot of an automobile dealership? They don't want to be cornered by a pushy salesperson. The same applies here.

If you are showing product, try to configure the booth so that it is as close as possible to the aisle—that is to say, to the customer. When there is a group of people visiting your booth, sometimes your best prospective customer is the quiet one in the rear, listening to others ask questions. Make sure he/she can see your products and hear your presentation.

Prepare "headline" booth graphics. You have a few seconds to grab the attention of people walking by your booth. Make your booth graphics tell your story in the form of a newspaper headline, using as few words as possible. Complement that with excellent product images. Then follow that up with greater detail in the form of bullet points underneath.

Especially if you are a new exhibitor with a small booth, showing a large company logo at the expense of other info is not the best use of your space: it is not providing a solution to the prospective engineer/customer walking by. Instead, a good graphic might read, for example, "0.5 to 40 GHz Amps for Microwave Radio & VSAT." Now that customer knows what you do, and can decide on the spot whether to stop or move on.

Follow up. Now that the show's over, you have sales leads to follow up on. This should happen no more than two weeks after the close of the show. After that, leads become stale and interest wanes. Find a reason to have a continuing conversation with the people you met. After all, they can

(See page 8)

Meetings and Events

Conferences & Meetings

2015 IEEE MTT-S International Conference on Numerical Electromagnetic Modeling and Optimization for RF, Microwave and Terahertz Applications (NEMO 2015)
11-14 August 2015
Ottawa, Canada
http://nemo-ieee.org
Paper Submission Deadline: 16 February 2015

2015 40th International Conference on Infrared, Millimeter, and Terahertz waves (IRMMW-THz)
23 – 28 August 2015
Hong Kong
www.irmmw-thz2015.org

2015 IEEE International Symposium on Radio-Frequency Integration Technology (RFIT)
26 – 28 August 2015
Sendai, Japan
www.ieee-jp.org/japancouncil/chapter/MTT-17/rfit2015/

2015 IEEE MTT-S 2015 International Microwave Workshop Series on RF and Wireless Technologies for Biomedical and Healthcare Applications (IMWS-BIO)
21 – 23 September 2015
Taiwan
www.ieee-jp.org/japancouncil/chapter/MTT-17/rfit2015/

2015 IEEE International Conference on Ubiquitous Wireless Broadband (ICUWB)
4 – 7 October 2015
Montreal
www.icuwb2015.org

2015 IEEE 24th Electrical Performance of Electronic Packaging and Systems (EPEPS 2015)
25 - 28 October 2015
San Jose, California
http://epeps.ece.illinois.edu
Paper Submission Deadline: 26 June 2015

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

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/

(From page 7)

become your new customers. And that is the very reason you went to the time, trouble, and expense to be at the show in the first place.

Due to space limitations, we've only scratched the surface here. We'll have more in future columns, on trade shows, PR, advertising, and more—all to increase sales opportunities in our technical marketplace.

* * *

About the Author:

HFE Associate Publisher & Managing Editor Tim Burkhard has three decades of management experience in public relations, advertising, publishing, and trade shows in the tech field. He can be reached at tim@highfrequency-electronics.com.

Corporations: IoT Delivers Added Services to Business and Customers

Thirty percent of businesses worldwide have already begun limited Internet of Things (IoT) deployments, according to the new Strategy Analytics IoT 2015 Deployment and Usage Trends Survey. The independent Web-based survey polled over 450 businesses worldwide across 45 vertical markets in June 2015. All classes of businesses—SMBs, mid-sized and large businesses—were equally represented. Among the 30% of early IoT adopters, the majority of survey respondents indicated the main use cases were: IoT-enabled software and applications; IoT-enabled hardware and IoT standalone devices or systems. The survey results also indicated that interest in IoT is high and that 55% of respondents were familiar with IoT's benefits and services.

Other key findings from the survey include:

• Some 32% or one third of those polled said their firms plan to deploy IoT compared to one in four survey respondents that said their companies currently have no IoT deployment plans. The remaining 42% of survey participants are still studying the issue.

• Office security/video surveillance; Smart Building Controls; Billable Services; Financial Analytics; Healthcare Analytics and Healthcare Diagnostics were among the top IoT applications cited by survey respondents who intend to use IoT.

• Current and potential IoT customers plan to deploy the technology to solve pragmatic and pressing business issues that impact daily operations. These include: security of both the corporate data assets and physical facilities; receiving proactive alerts to avoid service disruptions and remote control of equipment.

• IoT Security; integration and interoperability with existing and legacy systems and the potential confusion arising from the need to deal with multiple IoT vendors and platforms, were cited by survey respondents as the biggest impediments to IoT deployments.

—Strategy Analytics
strategyanalytics.com

LTE-Unlicensed Angst Roils Wi-Fi Markets

Operating in the unlicensed 5 GHz band, LTE-U's coexistence with Wi-Fi has become a primary concern for the Wi-Fi industry which anticipates disruption on both the technical and business levels. Unlike Wi-Fi, LTE-U, as a propriety solution does not sense the channel activity before transmitting. Instead, it applies a form of time-sharing using periodic time slots. Such scheduled transmission of LTE-U not only adds interference and increases collisions for Wi-Fi's opportunistic transmission, but also defies the concept of fair sharing as it seizes complete control over the channel and Wi-Fi's transmission window.

LTE-U provides clear advantages for mobile operators. It uses the free unlicensed spectrum to expand network capacity and does so without having to integrate another network, like Wi-Fi, within the cellular core. However, the advantages for end-users are not so clear. "LTE-U advocates focus on promoting its spectrum utilization superiority over Wi-Fi; promising better data rates and QoS. But will this significantly affect the average mobile user preferences? Operators should make a compelling value proposition in order to compete with mostly free uncapped Wi-Fi service," says Ahmed Ali of ABI Research.

Enterprises and venues also play an important role in this debate as the main host for LTE-U and Wi-Fi. "LTE-U small cells in the enterprise still face the same challenges of site permission and the lack of neutral-host support. Concerns of possible interference with Wi-Fi make it even a harder sell," adds Ali.

—ABI Research
abiresearch.com

Demand Rising in Millimeter Wave Bands for Mobile Backhaul

LTE network expansion across different regions is driving the acceleration of LTE mobile adoption worldwide. According to ABI Research, in 2014, the global LTE subscriber base increased threefold from 2013 to 628 million. "Increasing LTE adoption combined with growing adoption of smartphones, tablets, and bandwidth hungry applications is continuously putting pressure on the capacity of backhaul networks across different markets," comments Jake Saunders of ABI Research.

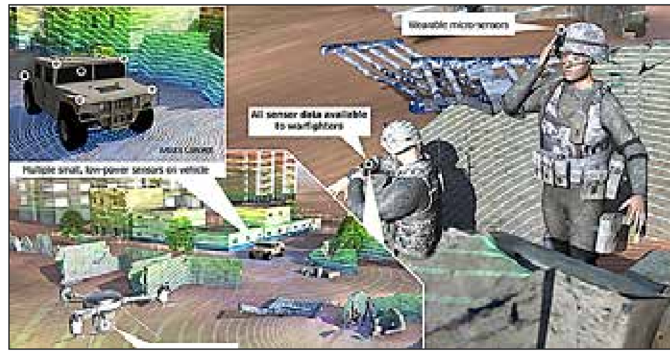
In many countries, telecom regulators are considering efficient allocation of spectrum for mobile backhaul. Many have completed consultation with telecom operators for spectrum planning.

"Microwave spectrum bands are still the most widely used for backhaul links and equipment vendors are also providing various solutions to enhance the capacity of microwave backhaul links. Microwave spectrum bands will remain the important option for mobile backhaul links," says Khin Sandi Lynn, Industry Analyst.

Spectrum bands in the sub 20 GHz bands are increasingly experiencing congestion, and a number of countries have taken steps to make spectrum in the higher bands available for backhaul use. Millimeter waves, which include the V-band (60 GHz) and the E-band (70 / 80 GHz) bands are proving of interest to operators for small cell backhaul deployment.

—ABI Research
abiresearch.com

In the News



Additive manufacturing, including emerging "3D printing" technologies, is booming. Last year an astronaut on the International Space Station used a **3D printer** to make a socket wrench in space, hinting at a future when digital code will replace the need to launch specialized tools into orbit. Here on Earth, **the Navy is considering applications for additive manufacturing aboard ships, and a commercial aircraft engine company recently announced its first FAA-approved 3D-printed part.** Despite its revolutionary promise, however, additive manufacturing is still in its infancy when it comes to understanding the impact of subtle differences in manufacturing methods on the properties and capabilities of resulting materials. Overcoming this shortcoming is necessary to enable reliable mass production of additively manufactured structures such as aircraft wings or other complex components of military systems, which must meet demanding specification requirements.

DARPA's Open Manufacturing program seeks to solve this problem by building and demonstrating rapid qualification technologies that comprehensively capture, analyze and control variability in the manufacturing process to predict the properties of resulting products. Success could help unleash the potential time- and cost-saving benefits of advanced manufacturing methods for a broad range of defense and national security needs.

"The Open Manufacturing program is fundamentally about capturing and understanding the physics and process parameters of additive and other novel production concepts, so we can rapidly predict with high confidence how the finished part will perform," said **Mick Maher,** program manager in DARPA's Defense Sciences Office. "The reliability and run-to-run variability of new manufacturing techniques are always uncertain at first, and as a result we qualify these materials and processes using a blunt and repetitive 'test and retest' approach that is inevitably expensive and time-consuming, ultimately undermining incentives for innovation."

The challenge with additively manufactured parts is that they are typically composed of countless micron-scale weld beads piled on top of each other. Even when well-known and trusted alloys are used, the additive process produces a material with a much different "microstructure," endowing the manufactured part with different properties and behaviors than would be expected if the same part were made by conventional manufacturing. Moreover, parts made on different machines may be dissimilar enough from each other that current statistical qualification methods won't work. Accordingly, each "new" material must be precisely understood—and the new process controlled—to ensure the required degree of confidence in the manufactured product.

To achieve this enhanced manufacturing control, Open Manufacturing is investigating rapid qualification technologies that could be applied not just to additive manufacturing but to any of a range of potentially new manufacturing methodologies.

* * *

Many essential military capabilities—including autonomous navigation, chemical-biological sensing, precision targeting and communications—increasingly rely upon laser-scanning technologies such as **LIDAR (think radar that uses light instead of radio waves).** These technologies provide amazing high-resolution information at long ranges but have a common Achilles heel: They require mechanical assemblies to sweep the laser back and forth. These large, slow opto-mechanical systems are both temperature- and impact-sensitive and often cost tens of thousands of dollars each—all factors that limit widespread adoption of current technologies for military and commercial use.

In an advance that could upend this status quo**, DARPA's Short-range Wide-field-of-view Extremely agile Electronically steered Photonic EmitteR (SWEEPER) program has successfully integrated breakthrough non-mechanical optical scanning technology onto a microchip.** Freed from the traditional architecture of gimbaled mounts, lenses and servos, SWEEPER technology has demonstrated that it can sweep a laser back and forth more than 100,000 times per second, 10,000 times

In the News

faster than current state-of-the-art mechanical systems. It can also steer a laser precisely across a 51-degree arc, the widest field of view ever achieved by a chip-scale optical scanning system. These accomplishments could open the door to a new class of miniaturized, extremely low-cost, robust laser-scanning technologies for LIDAR and other uses.

SWEEPER technology is to be developed further through DARPA's Electronic-Photonic Heterogeneous Integration (E-PHI) program, which has already successfully integrated billions of light-emitting dots on silicon to create an efficient silicon-based laser.

"By finding a way to steer lasers without mechanical means, we've been able to transform what currently is the largest and most expensive part of laser-scanning systems into something that could be inexpensive, ubiquitous, robust and fabricated using the same manufacturing technology as silicon microchips," said Josh Conway, DARPA program manager.

* * *

Richardson Electronics announced the launch of a new business group, **Power & Microwave Technologies ("PMT").** The PMT group encompasses Richardson Electronics' existing Electron Device Group ("EDG") and adds new technologies and engineered solutions for the power conversion and RF and microwave markets.

"The PMT group will focus on adding new suppliers and technologies to take advantage of high growth markets and leverage our global infrastructure, including sales, marketing, engineering solutions and logistics," said **Edward Richardson**, CEO and Chairman of the Board for Richardson Electronics. "Under the direction of Greg Peloquin, PMT combines new technologies and capabilities with our existing EDG business to maximize associated selling opportunities of both electron tubes and solid-state products."

Greg Peloquin, Executive Vice President, PMT, brings considerable experience and expertise in the RF and microwave, power and energy, and electron tube markets to his PMT group leadership role. Prior to joining Richardson Electronics in June 2014, as Executive Vice President, EDG, Mr. Peloquin served as president of Richardson RFPD, Inc. From 2002 to 2011, he was executive vice president and general manager of Richardson Electronics' RF & Wireless Communications Group. Earlier in his career he was director of global distribution for Motorola, Inc.'s wireless infrastructure division.

* * *

Cree announced the acquisition of **APEI**, a global leader in power modules and power electronics applications. Combining two highly complementary innovators, the acquisition enables Cree's Power and RF business to extend its leadership position and help to accelerate the market for high-performance, best-in-class SiC power modules.

This acquisition strengthens Cree's position for SiC power electronics, infusing the Power and RF business with additional intellectual property and applications expertise at the systems level from APEI. The companies' shared mission to deliver the industry's most innovative SiC power products has already led to successful collaboration on multiple government contracts. In 2014, the co-development of a High-Performance Silicon Carbide-based Plug-In Hybrid Electric Vehicle Battery Charger on an ARPA-E program resulted in an R&D 100 award, recognizing the 100 most innovative technology advancements of the year.

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.

RF Conversion Service

- Isola’s **Design Review Service** can facilitate your conversion to Isola’s RF/microwave products and get you to market faster with the newest, ultra-low-loss materials.
- As part of this new service, Isola’s technical staff will provide turn-key calculations, testing, characterizations and material recommendations to assist PCB fabricators and OEMs in converting to Isola’s RF-materials, which will help overcome the current material shortages of other vendors and accelerate time-to-market. The design review service also addresses the perceived conversion issues when migrating from a currently used material to an Isola material.

http://www.isola-group.com/conversion-service

FREE! Impedance and Power-Handling Calculator

- Isola’s free **Impedance and Power-Handling Calculator** predicts the design attributes for microstrips and striplines based on the design’s target impedance and dielectric properties of the company’s RF, microwave and millimeter-wave laminate materials.
- This software tool provides a design or an equivalent dielectric constant to facilitate modeling for PCB designers to predict impedance and other design attributes. The software computes changes in the effective dielectric constant due to dispersion at higher frequencies. The software then computes the total insertion loss—a measure of power lost through heat for power handling calculations, including the dielectric loss, conductor loss, and the loss due to the surface roughness. The main factors affecting the typical power-handling capability of a material are its thermal conductivity, the maximum operating temperature, and the total insertion loss.

https://isodesign.isola-group.com/phi-calculator

www.isola-group.com/RF

Featured Products

Coax Connectors

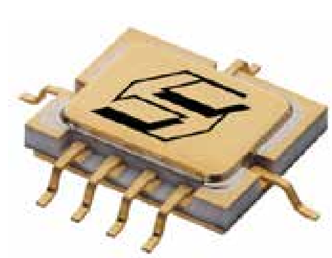
Southwest Microwave announced a new range of high-security SMKey 3.7 mm DC to 18 GHz Keyed Coax Connectors, which provide a failsafe mating solution for critical connections between mated connector pairs. SMKey coaxial connectors are offered in 10 keyed combinations, each with uniquely polarized key positions. Each connector also includes one non-keyed (Universal) option.

Southwest Microwave
southwestmicrowave.com

PHEMT

BeRex announced the BCL016B-343, a discrete ultra-low noise GaAs pHEMT, in an industry standard SOT-343 SMT package, for L through C band applications (DC to 8,000 MHz). It is ideal for use in highly noise sensitive designs such as front-end amplifiers for Wi-Fi, WLAN, GPS and radar up to 8 GHz in frequency.

BeRex
berex.com



Switch

Through its Isolink subsidiary, Skyworks introduced a low-loss, high performance wideband DC to 6 GHz hermetic GaAs IC single-pole, single-throw (SPST) non-reflective switch. The ISO13316 is ideal for high reliability space, satellite, and defense applications. The device performs with 45 dB isolation at 2 GHz and low loss of 1.1 dB at 6 GHz.

Isolink
isolink.com

Phase Shifter

PMI Model No. PS-255-2G18G-8B-SFF is a 2.0 to 18.0 GHz 8 Bit Digitally Controlled Phase Shifter with capability for phase shifting from 0° to 255° with resolution as fine as 1.0°. This unit has a typical insertion loss of 18 dB and a typical VSWR of 2.5:1. DC Voltage requirement is +12 V to +15 V with typical current draw of 200 mA. Unit is supplied in a housing measuring 2.0" x 2.1" x 0.5".

Planar Monolithics Industries
pmi-rf.com

Amplifier

RF Bay's newly released ultra wideband RF system amplifier, model RSA-50G, covers the frequency range from 10 MHz to 50 GHz. RSA-50G has nominal gain of 28 dB to 26 GHz and is capable to deliver P1dB of +24 dBm and Psat of +26 dBm at 40 GHz, suitable for test equipment, lab experiment and many wideband applications.

RF Bay
rfbayinc.com

Channel Monitor

The Channel Power Monitor is a compact rack-mount system that in conjunction with Bird sensors monitors each radio, power combiner, transmission line, and antenna in an analog or digital land-mobile radio system operating between 144 MHz and 960 MHz. It alerts users to out-of-spec conditions via the web or Bird's Android smartphone app and can monitor 16 channels with the ability to expand as needed.

Bird Technologies
birdrf.com

LNA

Model SBL-5037533060-1212-E1 is a low noise amplifier covering the full waveguide band from 50 to 75 GHz with small signal gain of 30dB and 6.0dB noise figure. The amplifier also exhibits +10 dBm typical P-1 dB output power. It draws about 120 mA current from a single DC power supply in the range of +8 to +12 volts.

SAGE Millimeter
sagemillimeter.com

Waveguide Couplers

Pasternack announced a family of instrumentation grade directional waveguide couplers boasting accurate performance up to 110 GHz.

Featured Products

These ultra-high frequency waveguide couplers are commonly used for signal sampling and other general purpose applications in wireless transmit/receive systems, test benches, satellite communications, radar systems, point-to-point backhaul and telecom.

Pasternack
pasternack.com

Cable Filters

RLC Electronics' cable filters can be designed as either lowpass, highpass or bandpass constructions, covering frequency ranges up to 50 GHz. They are available in conformable (FCLPF Series) & semi-rigid cable styles (CLPF Series) that are built to your cutoff, rejection and mechanical specifications, including cable length, bend position and angle. Computer designed and advanced coaxial techniques ensure optimal performance in a minimal space.

RLC Electronics
rlcelectronics.com

Power Splitter

The ZACS362-100W+ is a 2 Way-0°, 50Ω, Up to 100W, 600 to 3600 MHz Power Splitter/Combiner that features: high power, up to 100W as splitter; high power, up to 5.0W as combiner; low insertion loss, 0.5 dB typ.; high isolation, 22 dB typ.; excellent VSWR, 1.20 typ. Applications: PCS, GPS, Wimax, GSM, UMTS, WCDMA, DCS, communication transmitters & receivers.

Mini-Circuits
minicircuits.com

SSPA

The TTRM1008 is a high linearity GaAs FET bi-directional SSPA suitable for use with any modulation and signal type. It is currently utilized in UAV data links and long range point-point COFDM video links. High speed T/R switching and sequencing of the PA, LNA, and switch driver circuitry is performed by an onboard CPLD, where switching timing can be adjusted in firmware based on system requirements.

Triad RF
triadrf.com

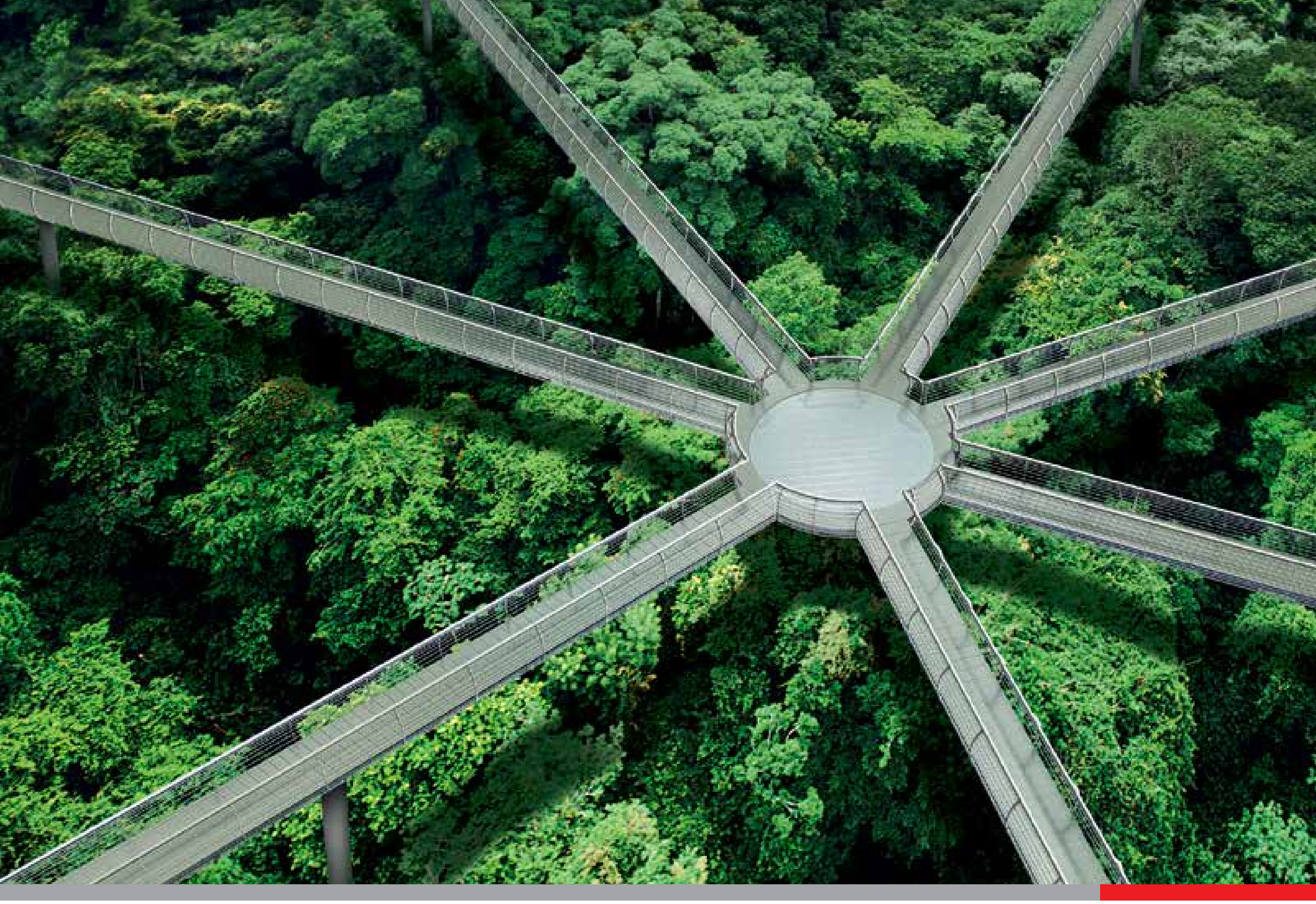
Spectrum Analyzer

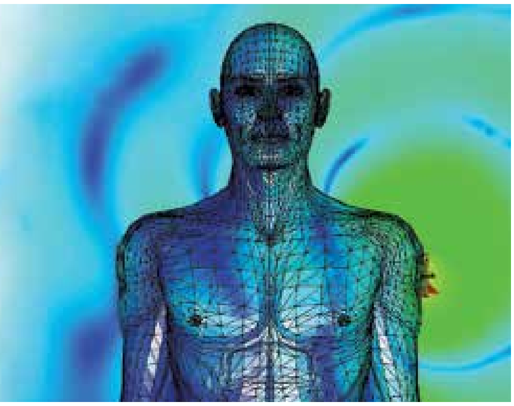
The FSW85 high-end signal and spectrum analyzer is the only instrument to cover the frequency range from 2 Hz to 85 GHz in a single sweep. This makes it possible for users to test baseband and RF with a single analyzer. Since no external harmonic mixers are required, the FSW85 makes the test setup much simpler. An internal preselection suppresses the image frequency and other spurious emissions that commonly occur during harmonic mixing.

Rohde & Schwarz
rohde-schwarz.com

Power Divider

VidaRF offers a new 2-way power divider model VPD-20180A2. Frequency range from 2 - 18 GHz, operating temp -55 to 85 C. Sealed and painted to meet IP65 standards. VidaRF's 2 port SMA power divider/coaxial splitter has a 50 Ohm impedance and a maximum





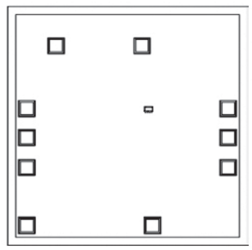
input power of 10 Watts. Its SMA coaxial RF splitter/divider has a female SMA input and 2 female SMA output ports.

VidaRF
vidarf.com

Multiplier

Model SFA-154SF-S1 is a broadband X4 active multiplier with output frequency covering 50 to 66 GHz. The required input signal is 12.5 to 16.5 GHz at +3 dBm and resultant output signal is 50 to 66 GHz at +16 dBm. Typical harmonic suppression is -20 dBc. The DC bias is +8 to +12 Vdc at 380 mA typically. The input connector of the multiplier is configured as SMA (F) and the output connector is a standard WR-15 waveguide with UG385/U flange.

SAGE Millimeter
sagemillimeter.com



Amp Die

The AVA-183A-D+ is an ultra-wideband microwave amplifier die operating over an extremely wide frequency range from 5 to 20 GHz. This model integrates the entire matching network with the majority of the bias circuit, reducing the need for complicated external circuits and simplifying board layouts. These advantages make the AVA-183A-D+ extremely user friendly and enable simple, straightforward use.

Mini-Circuits
minicircuits.com

Block Downconverter

Model SNG-12-01 is a full E-Band block downconverter whose primary function is to extend the testing capability of low-cost, low-frequency noise-figure meters. It also allow noise-figure testing of E-Band devices without a noise figure meter, using the Y-factor method. The block downconverter is also versatile for use with other applications.

Ducommun
ducommun.com

Impact of Antenna Design, Tune and Match on Wireless Range

By: Matthew Meiller

Exploring how wireless range can be reduced or optimized through RF and antenna design.

Abstract: Wireless device range can be the pivotal make or break characteristic of a successful end product. This paper will dig into the mystery and explore the mechanisms by which wireless range can be reduced or optimized through RF and antenna design. The discussion is relevant to board and system- level circuit and antenna design. The useful rule of thumb that every 1dB of additional RF loss reduces wireless range by 10% is presented.

Index Terms— Wi-Fi, Bluetooth, BLE, Zigbee, RFID, GSM, GPS, MBAN, HBAN, UWB, CDMA, Chip Antenna, Circuit Board Antenna, Wireless Range Reduction, Wireless Range Optimization, Radio Module, 802.11 and 802.15.4

Introduction

Any RF engineer who has optimized RF or microwave system hardware in the lab will agree that squeezing out the last 1 or 2dB from a design can be the most challenging aspect. After reading this paper you may better appreciate the value of such rigor. This is where the rubber meets the road for applying the art and science of RF design to the development of wireless products. At this point the product requirements may be defined, the theoretical path loss calculations may be complete and you want to ensure execution of the hardware development goes smoothly. Or, the product may be designed and prototypes delivered and debugged, but questions are being asked regarding the wireless range or lack thereof. This article will help the reader understand quantitatively how much wireless range may be lost if the antenna tuning and match steps are neglected, there is more RF loss in the design than anticipated or a related aspect of the design is out of control.

Unintended Loss in the Design

There are many possible sources of insertion loss, mismatch loss and general degradation of antenna gain. These are RF signal losses resulting from product design decisions and features. Collectively we will refer to these as unintended losses and all can have identical impact, which is to reduce the range of wireless products. By referring to them as unintended losses, we mean that they are a consequence of poor RF layout or antenna design and were not factored into the link budget calculation, which can be used early in the design to predict the range of a wireless device.

The RF engineer can prevent these problems and their disastrous consequences by optimizing the performance critical aspects of the design before the prototypes are built, and continuing the optimization and performance assessment in the lab when the hardware is available. This is not a long and drawn out process. It is a matter of simply involving the right expertise with access to the proper design, simulation, and test and measurement tools at the right times. The end result will be a product which provides the best possible wireless performance for your customers and shareholders, with predictable cost and schedule.

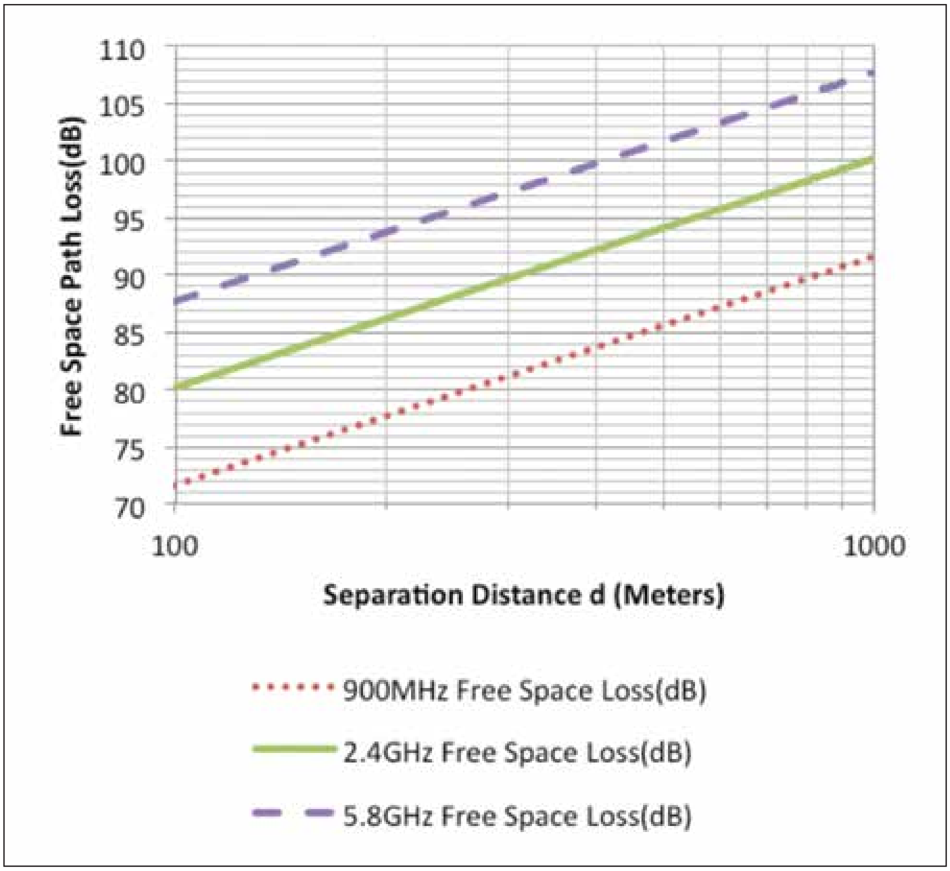


Figure 1 • Path Loss Over 1 Decade of Frequency.

Common Sources of Unintended Loss

The contributions from all sources of unintended loss are cumulative, including the separate losses of each of the 2 radios participating in a wireless link. For example, if we have 2dB of mismatch loss and the antenna gain is degraded by 2dB due to the layout, the impact of 4dB must be considered. If two such identical radios are communicating, then the total impact of 8dB must be considered.

Antenna Match

Antenna match refers to optimizing the impedance matching network classically located close to the antenna using a piece of test equipment called a RF Vector Network Analyser. The impedance matching network is typically composed of lumped element capacitors and/or inductors, which has values that must be chosen or transmission line stubs which must be trimmed. Once the impedance matching network is tuned based on precision laboratory measurement, subsequent product may be built using the values determined. The purpose of matching the antenna is to force it to resonate over the appropriate range of frequencies for the radio, and to couple as much energy as is possible between the 50 ohm antenna and transmit/receive circuitry.

Circuit Board Layout

If the antenna is mounted on or integrated into a circuit board, careful attention must be given to the layout and the Gerber files reviewed. Often times the antenna used is really only half of the antenna capability since the circuit board RF ground plane plays a key role in the antenna performance. Without the presence of the ground plane and proper control and checking of all the geometric positioning of the antenna and the matching and feed network, the design may be destined to provide poor wireless performance before it is fabricated. The board layout team must be given detailed guidance and instruction, including the positioning of vias critical to RF performance. Simulation tools as well as theoretical knowledge as to how signals behave on circuit boards are needed to get this part of the design right.

Integration of Antenna into Operating Environment

Your end product may use more than one circuit board or contain other large conductive objects such as shielded LAN or USB connectors, transformers or discrete wires and cables. All of these can profoundly impact the performance of your antenna as can proximity to materials such as plastics and conductors. The typical use case should be evaluated, including accessories. Proximity to the human body must be considered if the device is handheld or body worn. Integration of the antenna into the product enclosure refers to evaluating the entire product design with respect to the antenna(s), retuning the impedance matching network in the final assembled product since everything mentioned above can impact antenna performance. Tuning the board used for laboratory development is often different from the final product tuning!

Quantify Impact of Loss on Wireless Range

Free Space Path Loss

Once prototype hardware is built and the wireless link functioning in the lab, the easiest part of the link budget to modify is often the physical separation

between the two radios. Technically, we are changing the free space path loss (FSPL). The FSPL gets smaller (less loss) when the radios are moved closer together and vice versa. Here is a handy version of the equation for FSPL:

Equation 1:

$$Path\ Loss(dB) = 20log_{10}(d) + 20log_{10}(f) - 147.55$$

The distance between the two radios is d (meters), and the frequency of interest is f (Hz).

If we plot path loss vs. separation distanced, the slope of the line is 20dB/decade or 6dB/octave for any range of separation distance d. Figure 1 shows the path loss in dB for 3 different commonly encountered frequencies and a single decade of distance d in meters from 100 to 1000 meters.

Loss Compensation by Range Reduction

If the RF design has unintended loss not accounted for in the link budget, without changing any other variable, we can move the two radios closer together (reduce separation distance d) until they can maintain a wireless radio link. The effect of moving the radios closer together is to compensate for unanticipated loss by reducing the free space path loss defined earlier with an equation. Through inspection of the graph or mathematical analysis of the equation, we determine an approximate rule of thumb that regardless of the source of the loss or separation distance,

Every 1dB of unanticipated loss Reduces wireless range by 10%!

We are making a linear approximation to quantities plotted on logarithmic scales, and this approximation is reasonably accurate for the final 5dB of link budget power while investigating the maximum separation distance. For example, you expected 300 meter range but your antenna gain is 2dB low, the 2 dB translates into an approximate 20% loss of or wireless range so you measure a range of (300 meters)*(80%)=240 meters. This is a range reduction of 60 meters. If the range is 50% of what you expected, you are compensating for exactly 6dB of unintended loss.

Other Loss Compensation Techniques

Standard coping mechanisms include turning up the transmitter power to compensate for an underperforming RF design. This may appear to work well in the lab, however as we increase transmit power, we also increase the amplitude of spurious emissions and harmonics which often lead to failure when the FCC or ETSI compliance tests are performed. This is similar to stepping on the gas if you have a flat tire. You may move forward for a while, but you will get emissions that you weren't counting on such as your tire flying apart. If you do not have timely access to RF and antenna engineering capabilities when you need it, Peak Gain Wireless is ready to help with the expertise and equipment to solve these types of problems the right way. We can prevent these problems if we are involved early in the design or define and solve the problem if hardware is already complete.

Conclusion

What does this all mean? Many factors impact the wireless link budget. Examples include antenna selection, design, impedance matching and final product integration. If an antenna has not been properly designed, tuned and optimized in the final product enclosure, it is not uncommon to have a total unintended loss of 2 to 6dB. Since the impact is 10% range reduction per dB loss, this translates into a 20% to 50% range reduction. These types of problems can often be predicted, understood and designed out through EM simulation or the knowledge and insight of an experienced RF engineer with access to the right tools.

About the Author:

Matthew Meiller is President and Principal RF engineer at Peak Gain Wireless, LLC, which provides wireless product design and development services. He has over 20 years of experience in industry. His team has expertise with LoRa, Bluetooth, Bluetooth Low Energy (BLE), WiFi, Zigbee, wireless sensors and other sub 6GHz ISM radios. Many of Peak Gain Wireless's designs are low power RF running on disposable batteries or coin cells for app enabled connectivity. Services include system specification development, hardware, firmware, antenna design, assembly, and test and measurement. Peak Gain offers both full turnkey design services, or we can help your team succeed with the high risk RF parts of the design such as antenna design, tune and final integration into the end product. We support single and multiband antenna design and development including antennas for cellular M2M products. For more info: sales@peakgainwireless.com.

Power Amplifier Testing For 802.11ac

By Christopher Ziomek

The design validation, characterization and testing of power amplifiers for 802.11ac.

Introduction

The first Wireless LAN (WLAN) standards were used primarily to provide low data rate wireless connectivity to a wired broadband connection for web browsing and email. Over time, new 802.11 wireless protocols were adopted to offer higher data rates for new applications. Table 1 shows the progression of the 802.11 WLAN standards.

The latest 802.11ac WLAN standard, which is still in draft format, will achieve up to 867 Mbps data rate over a single RF channel, and up to 6.93 Gbps using MIMO channels. These high 802.11ac data rates are accomplished by extending the 802.11n standard with more instantaneous bandwidth (up to 160 MHz), more MIMO channels (up to 8), and higher density modulation constellations (up to 256QAM). Within this paper, we examine the demands that these new requirements place upon the design validation, characterization and testing of power amplifiers for 802.11ac.

802.11 protocol	Release	Frequency (GHz)	Bandwidth (MHz)	Data rate per stream (Mbit/s)	MIMO streams	Modulation
- (obsolete)	Jun 1997	2.4	20	1 - 2	1	DSSS, FHSS
a	Sep 1999	5, 3.7	20	6 - 54	1	OFDM
b	Sep 1999	2.4	20	5.5 - 11	1	DSSS
g	Jun 2003	2.4	20	6 - 54	1	OFDM, DSSS
n	Oct 2009	2.4, 5	20	6.5 - 72.2	1 - 4	OFDM
			40	13.5 - 150		
ac (draft)	Nov 2011	5	20	6.5 - 86.7	1 - 8	OFDM
			40	13.5 - 200		
			80	29.3 - 433.3		
			160	58.5 - 866.7		

Table 1 • 802.11 WLAN Protocols

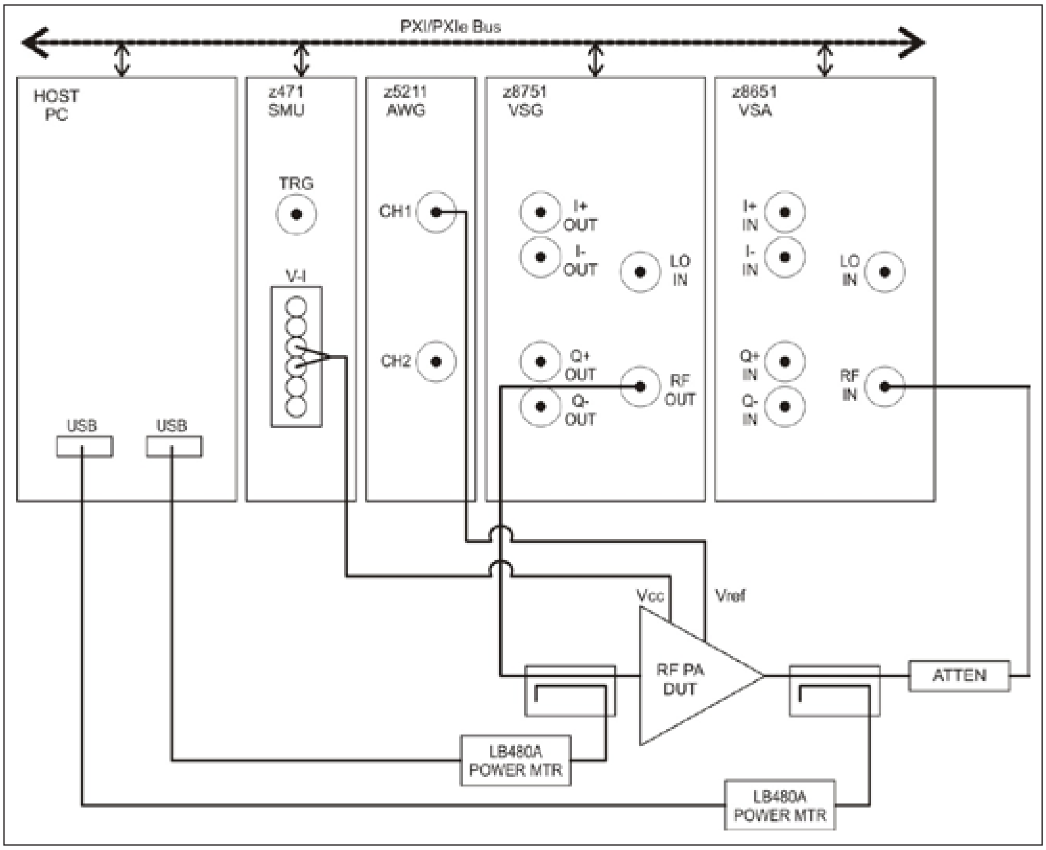


Figure 1 • Test equipment block diagram for PA testing.

EVM Test

This paper further expands upon Error Vector Magnitude (EVM) testing, a comprehensive and widely used technique for PA testing [2-3]. EVM is a measurement used to quantify the performance of a digital communication channel, and provides a measure of the deviation of captured encoded data symbols from their ideal locations within the I/Q constellation. The root mean square EVM is a comprehensive measurement that is degraded by any imperfection in the RF signal or device.

For a WLAN transmitter design, the PA requires an acceptable EVM contribution over its full operating range of output power levels and channel frequencies. Because 802.11ac includes 256QAM constellations with a 2.5% (-32dB) EVM specification limit, the PA linearity and corresponding EVM contribution requirements are more stringent than earlier 802.11 standards. Whereas the EVM contribution of a PA for 802.11n was limited to around 3%, the EVM contribution of the PA is limited to around 1.5% for 802.11ac [4]. In addition, the new 256QAM signal modulation has a higher peak-to-average ratio (PAR) which also increases the linear output power necessary for a PA within an 802.11ac transmitter design.

Figure 1 shows a block diagram of a typical test setup for PA testing using ZEC Instruments' z8201 RF test set. The typical equipment list includes:

- z8651 6 GHz Vector Signal Analyzer (VSA), 80 or 160 MHz analysis bandwidth options
- z8751 6 GHz Vector Signal Generator (VSG), 250 or 500 MHz modulation bandwidth options
- z5211 200MS/s Arbitrary Waveform Generator
- z471 Source Measure Unit (SMU)
- Optional Ladybug Technologies LB480A USB Power Meter(s)
- PXI/PXIe chassis & host computer
- Cables, directional coupler(s) & attenuator(s)

Power Amplifier Testing

The power amplifier (PA) is a critical component within a WLAN transmitter circuit because PA performance affects wireless coverage area, data rate capacity, and battery life. The goal for any transmitter PA is to generate sufficient linear RF output power while using as little DC power as possible. PA performance can dominate the system-level WLAN transmitter performance due to PA non-linear distortion as the output power level increases into the amplifier's gain compression region. Mobile devices and wireless access points typically transmit between 100 mW (+20 dBm) and 1 W (+30 dBm) of RF output power, and the PA must be able to generate sufficient power with minimal non-linear distortion. For PA testing, the complete set of IEEE 802.11ac specified transmitter compliance tests apply, including [1]:

- Spectrum Mask
- Spectral Flatness
- Peak Power
- Center Frequency Error
- Symbol Clock Frequency Error
- Center Frequency Leakage
- Error Vector Magnitude (EVM)

Phase Adjusters

Part Number	Connectors	Frequency Range (GHz)	VSWR max.	Insertion Loss max. (dB)	Phase Shift min. (°)	No. of Turns	Phase Shift Deg/GHz/Turn	Time Delay min. (psec.)	Time Delay max. (psec.)	Temperature (°C)	Weight max. (g)
LS-0002-YYYY[1]	div.	DC - 2	1.2:1	0.3	85	37	1.15	393	516	-65 to +125	98-220[2]
LS-0103-6161	Nf	DC - 3	1.15	0.4	540	cont.		1826	2328		700
LS-0203-6161				0.8	1080			3693	4694		1200
LS-0012-YYYY[1]	div.	DC - 12	1.3:1	0.8	520	37		406	530		114-234[2]
LS-0112-XXXX[3]	SMA	DC-12.0	1.25:1	0.4	230	16.5	1.2	238	293	-65 to +125	70
LS-A112-XXXX[3]											47
LS-0212-1121											70
LS-A212-1121											47
LS-0118-XXXX[3]		DC-18.0		0.6	350						70
LS-A118-XXXX[3]											47
LS-0218-1121											70
LS-A218-1121											47
LS-0118-5161	N							300	355	-65/+70	105
LS-U118-5161										-65/+165	
LS-0018-YYYY[1]	div.	DC - 18	1.5:1	1.0	770	37	1.15	406	530		114
LS-0121-XXXX[3]	SMA	DC-26.0	1.30:1	0.8	500	16.5	1.2	238	293	-65 to +125	70
LS-A121-XXXX[3]											47
LS-0221-1121											70
LS-A221-1121											47
LS-0321-1121			1.31:1		500	35	0.6	236.7	290.5		30
LS-0070-1121			1.26:1	0.26	127	13.5	0.36	109.2	122.8		10
LS-0170-1121			1.26:1	0.26	127	13.5	0.36	109.2	122.8		9
LS-S008-1121			1.50:1	0.4	155	10	0.6	118.6	135.1		20
LS-P140-KFKM	2.92 mm	DC-40.0	1.2:1	0.6	590	12		168	208		51
LS-0140-KFKM			1.4:1								49
LS-0040-KFKM					216						
LS-P150-HFHM	2.40 mm	DC-50.0	1.3	0.8	400	7	1.2	172	195	-65 to +65	55
LS-0150-HFHM			1.5								53
LS-0050-HFHM					200						
LS-P165-VFVM	1.85 mm	DC-63.0	1.4	0.8	600	8		167	195		55
LS-0165-VFVM			1.5								53
LS-0065-VFVM					200						

[1] div.: Connector Configuration available: SMA, male and female; N, male and female; TNC male and female
[2] Weight depends on connector configuration
[3] SMA Connector Configuration available: male/female; male/male; female/female; female/male

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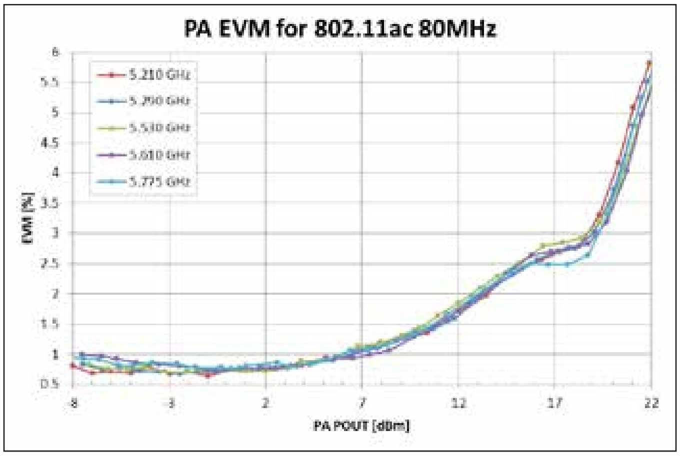

Figure 2 • PA EVM versus Output Power.

The USB Power Meters and associated directional couplers are optional because the PA input and output power levels are set and measured by the VSG and VSA. The power meters provide more precise calibrated measurements of the PA input and output power measured at the device-under-test (DUT) with directional couplers. Whereas the VSA and VSG are typically accurate to < 0.5 dB, the power meter provides accuracies to < 0.1 dB. Correction factors for the attenuator(s) must be pre-calibrated, and for the directional couplers when using the Power Meter configuration.

PA EVM

A typical EVM test for a PA will measure EVM versus PA output power over a number of test frequencies. Figure 2 shows actual measured data plots for a typical PA EVM test using the z8201 RF Test Set. The plots show all five 80 MHz 802.11ac channel frequencies tested over a 30 dB range on the input power applied to the PA. The actual PA output power is measured using a power meter and provides the data for the horizontal axis of the plot in figure 2. In this test, there are 5 channel frequencies and 30 power levels for a total of 150 test points. An advantage of the highly-integrated test equipment architecture of PXI/PXIe is the fast data throughput and processing speeds. With 150 test conditions, the total test time can be significantly reduced over other test equipment with interfaces such as LAN or GPIB. For the z8201 RF Test Set and zProtocol™ WLAN software, example code is provided that optimizes setup and operation for 802.11ac testing to as fast as 20 ms per EVM measurement.

When examining the actual PA test data shown in figure 2, note that EVM degradation occurs at high output power levels. As the PA output power level increases into its gain compression region, non-linear distortion occurs and causes an increase in EVM. This EVM power

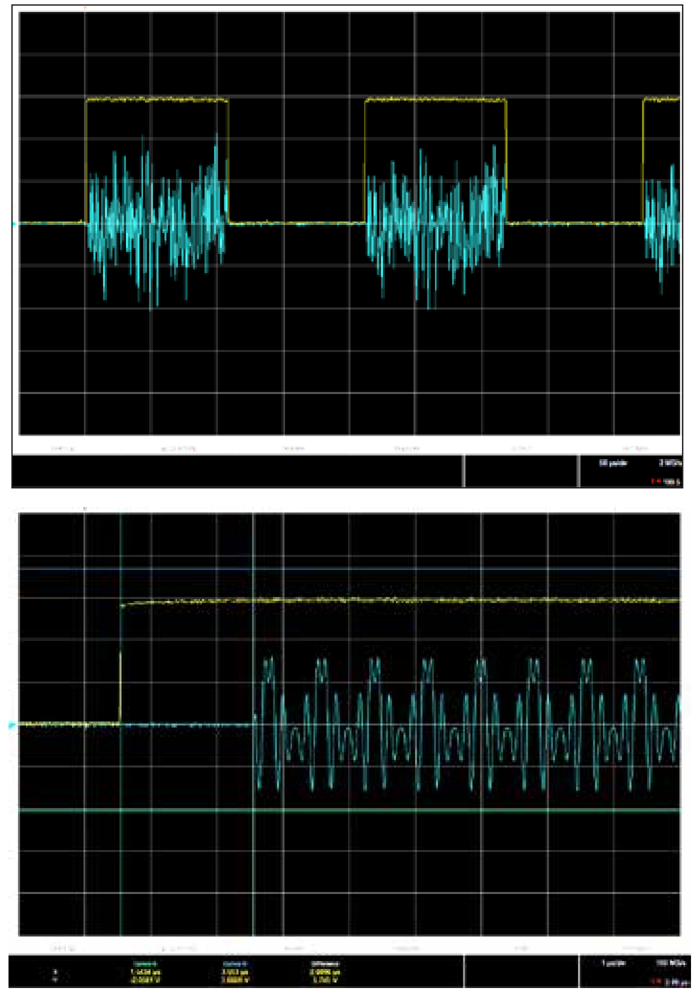

Figure 3 • Time Domain Plots of PA Enable (yellow) and RF Pulse (blue).

sweep test identifies the linear power region for the PA, which is critical for WLAN transmitter design considerations. Note that in order to achieve the threshold of less than 1.5% EVM for 802.11ac, this particular PA can achieve a maximum of +10 dBm linear output power. Whereas this PA was designed and works well for 802.11n transmitters, its linear output power is insufficient for an 802.11ac transmitter design without additional linearization techniques such as digital pre-distortion.

Dynamic EVM

Battery life and power consumption are important considerations for a system-level WLAN transmitter design. Because the transmit PA consumes a significant portion of the total system DC power, a number of techniques are employed to reduce PA power usage. Many PAs offer an adjustable DC supply voltage to optimize the maximum RF output power level versus its DC power consumption. Also, most PAs can be powered-down or

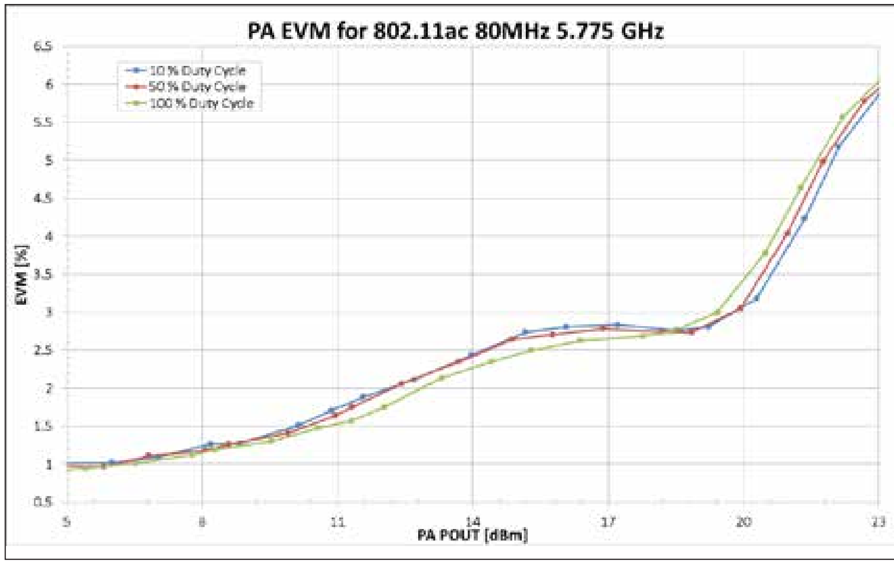

Figure 4 • PA Dynamic EVM versus Duty Cycle.

disabled when not in use to conserve power, such as while receiving or between packets during transmission. In order to maximize power efficiency, the PA must have fast turn-on and turn-off switching times. Figure 3 shows oscilloscope acquisitions of the relative timing of the PA Enable (PA EN) and RF signal for a PA in pulsed operation with 50% duty cycle. Notice that the adjustable delay between the PA EN pulse and the RF signal is set to 2.0 µs within this test setup. The highest DC power efficiency occurs when the time delta between PA EN and the RF signal is minimized, but a short delay can exacerbate transient effects on the RF signal.

Because the power-up/power-down operation of the PA can cause transient and thermal effects that degrade transmitter performance, another

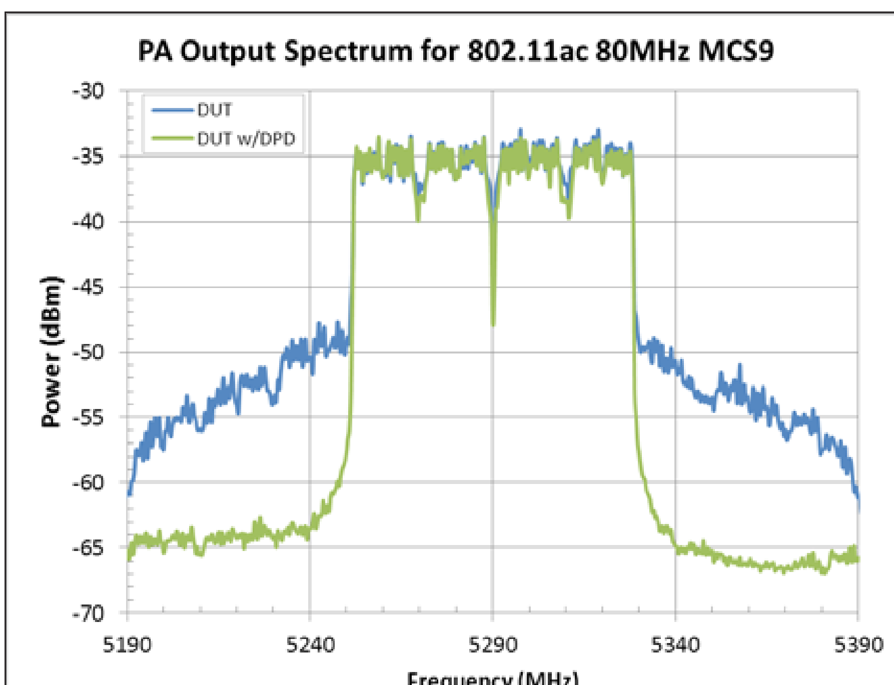

Figure 5 • PA Adjacent Channel Leakage Reduction with DPD.

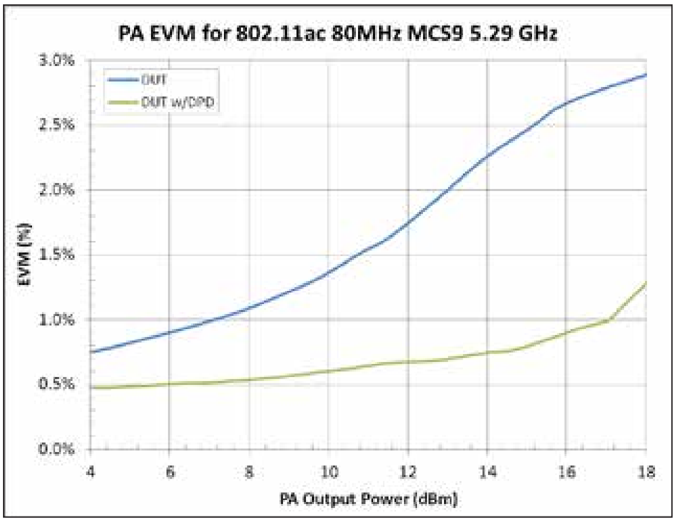

Figure 6 • PA EVM Improvement with DPD.

metric called dynamic EVM is often tested. Dynamic EVM is measured with a square wave pulse applied to PA EN to emulate the actual dynamic operation conditions of the transmitter. The degradation in dynamic EVM is due to the PA transient response affecting the preamble at the start of the packet and causing an imperfect channel estimate. Studies have shown that dynamic EVM with a 50% duty cycle square wave applied to PA EN to be worse than the static EVM (PA EN with 100% duty cycle) [5].

Using the test equipment shown in figure 1, dynamic EVM testing is completely automated with the PXI/PXIe system. All time synchronization for the dynamic EVM measurement is accomplished using the PXI/PXIe backplane trigger and clock signals. The block diagram of figure 1 shows the z5211 arbitrary waveform generator (AWG) that generates the PA EN pulse with an adjustable voltage magnitude, pulse width, pulse delay and repetition rate. The actual PA test data of figure 4 shows dynamic EVM to be worse than the static EVM up to +18 dBm output power. For this particular PA, dynamic EVM is better than static EVM above +18 dBm output power. As noted previously, this type of PA dynamic EVM measurement is important for transmitter design considerations because dynamic EVM measures the performance of the PA as it is used within the actual pulsed operating mode.

Digital Pre-Distortion

Improving linearity within the PA at high output power is a challenge. Digital pre-distortion (DPD) is one technique that is used to essentially remove distortion by digital signal processing techniques. Software tools such as ZProtocol™ DPD simplify and automate DPD for a combined VSA/VSG test system such as the z8201 RF Test Set. Essentially, software models are used to measure the nonlinearity of the PA with the VSA, and create an inverse operation that is applied to the VSG. When DPD compensation is complete, a predistorted VSG RF

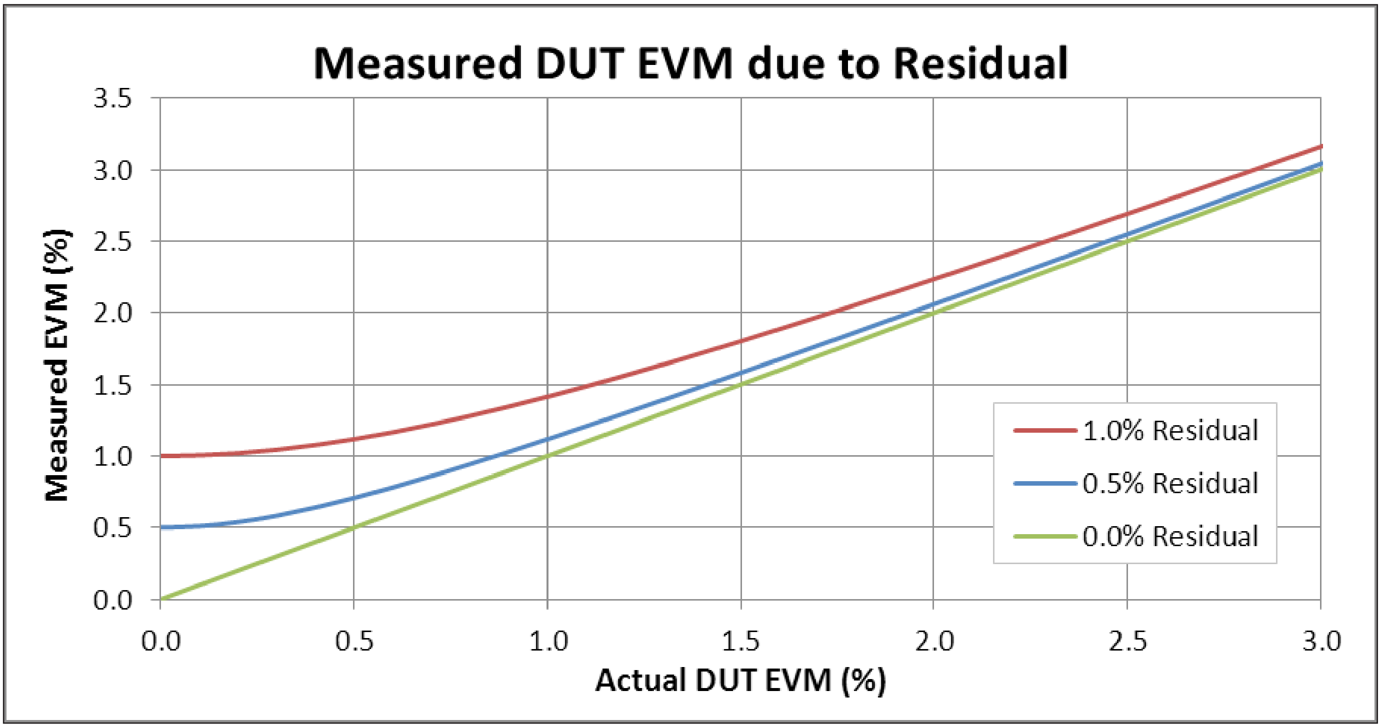

Figure 7• Effects of Test Equipment Residual EVM on Measured DUT EVM.

Planar Monolithics Industries, Inc.

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1.6 kW Peak, 250 us PW, 8% D.C.
130 Watts CW

6.0 to 18.0 GHz

P2T-6G18G-40-R-570-TFF-1D6KW

- Insertion Loss: 2.2 dB max.
- Isolation: 40 dB
- Switching Speed: 200 ns max.
- VSWR: 2.0:1 max.

5 kW Peak, 17 us PW, 2% D.C.
100 Watts CW

1.0 to 1.1 GHz

P2T-1G1R1G-25-R-TFF-100W
P2T-1G1R1G-25-R-TFF-40W

(4 kW, 3 us PW, 1% DC, 40 Watt CW Available)

- Insertion Loss: 0.8 dB max.
- Isolation: 25 dB min.
- Switching Speed: 275 ns typ..
- VSWR: 1.5:1 max.

2 Watts CW

0.5 to 18.0 GHz

P4T-500M18G-80-T-515-2W-IND

- Insertion Loss: 4.5 dB typ.
- Isolation: 80 dB min.
- Switching Speed: 200 ns max.
- VSWR: 2.0:1 max.

5 Watts Peak
2 Watts CW

9.25 GHz (+/- 30

P1T-9D25G-90-T-SFF-5W

- Insertion Loss: 1.5 dB goal
- Isolation: 80 dB min.
- Switching Speed: 10 ns max.
- VSWR: 1.9:1 max.

25 Watts CW

10 MHz to 6.0 GHz

P2T-10M6G-45-R-5V-SFF-HIP20W

- Insertion Loss: 2.5 dB typ., 2.8 dB max.
- Isolation: 25 dB typ., 20 dB min.
- Switching Speed: 100 ns max.
- VSWR: 2.0:1 typ.

4 Watts CW

500 MHz to 18.0GHz

P2T-500M18G-80-T-515-SFF-4W

- Insertion Loss: 3.5 dB typ.
- Isolation: 70 dB min.
- Switching Speed: 200 ns max.
- VSWR: 2.0:1 max.

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Figure 8 • z8201 PXI or PXIe RF Test Set.

signal is applied to the PA which effectively linearizes the PA output.

Some 802.11ac WLAN transceiver chip sets employ DPD techniques to improve PA linearity. In order to quantify the improvement that will be achieved in-circuit with DPD, test equipment must be able to perform DPD during PA characterization. Along with the z8201 RF Test Set and zProtocol™ WLAN software, ZEC Instruments' DPD software tool and corresponding example code provide a quick and easy method to evaluate DPD for a PA or transmitter design. Because DPD algorithms require the VSG/VSA instruments to capture multiple adjacent channels, a wide measurement bandwidth such as that of the z8201 RF Test Set is required for DPD applications.

Figure 5 shows the improvement that DPD has upon the adjacent channel leakage due to non-linear distortion as the PA operates within its non-linear region. Equally important is the EVM improvement that can be accomplished with DPD as shown in figure 6. Both graphs depict actual data taken with the z8201 RF Test Set using the zProtocol™ WLAN and DPD software.

Test Equipment

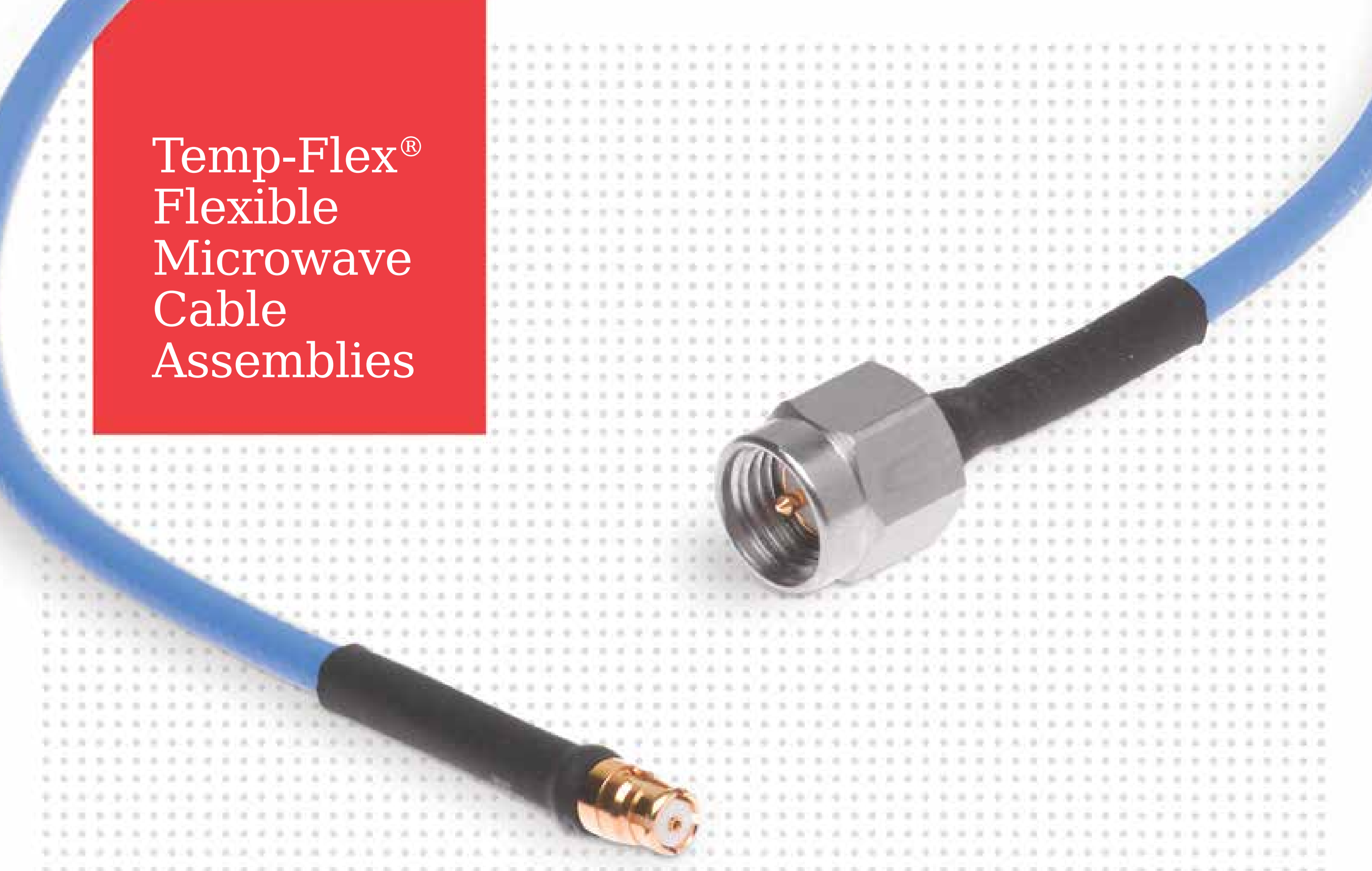
For 802.11ac testing, the noise floor, phase noise, intermodulation distortion, and in-band spurious signals of the test equipment must be minimized to avoid degradation of the measured PA EVM performance. Figure 7 shows the effects of test equipment residual EVM on the measured PA DUT EVM.

As discussed throughout this paper, the z8201 RF Test Set shown in figure 8 is comprised of a 6 GHz VSG/VSA combination with measurement bandwidths up to 160 MHz [6-7]. Along with the wide measurement bandwidth, the z8201 RF Test Set provides the low noise and distortion necessary for characterization and testing of 802.11ac devices. The z8201 RF Test Set provides an exceptional loop-back residual EVM floor as low as 0.3% for 20MHz 802.11ac and 0.7% for 160 MHz 802.11ac (phase tracking on, preamble-pilot-data equalization). In addition, the z8221 RF Test Set which adds z8801 LO modules achieves a residual EVM floor as low as 0.2% for 20MHz 802.11ac and 0.4% for 160 MHz 802.11ac.

The zProtocol™ WLAN software toolkit includes an intuitive graphical user interface (GUI) shown in figure 9 and comprehensive C/C++/LabVIEW software drivers for ease of automation. In combination with the zProtocol™ WLAN software, the z8201 RF Test Set offers a complete solution for 802.11 testing covering all aspects of the WLAN protocols including:

- All Modulation Bandwidths: 160 MHz, 80 MHz, 40 MHz & 20 MHz
- All Modulation Coding Schemes (MCS) and Bit Rates: BPSK to 256QAM
- All Channel Frequencies: 2.4 GHz and 5 GHz bands
- MIMO Streams: X2 to X8

Example automation code provides a valuable reference to demonstrate the automated use case and to allow users to begin characterization or design verification with little additional programming or integration. All of the specific PA tests described within this paper are available as example code that can be downloaded from our website.



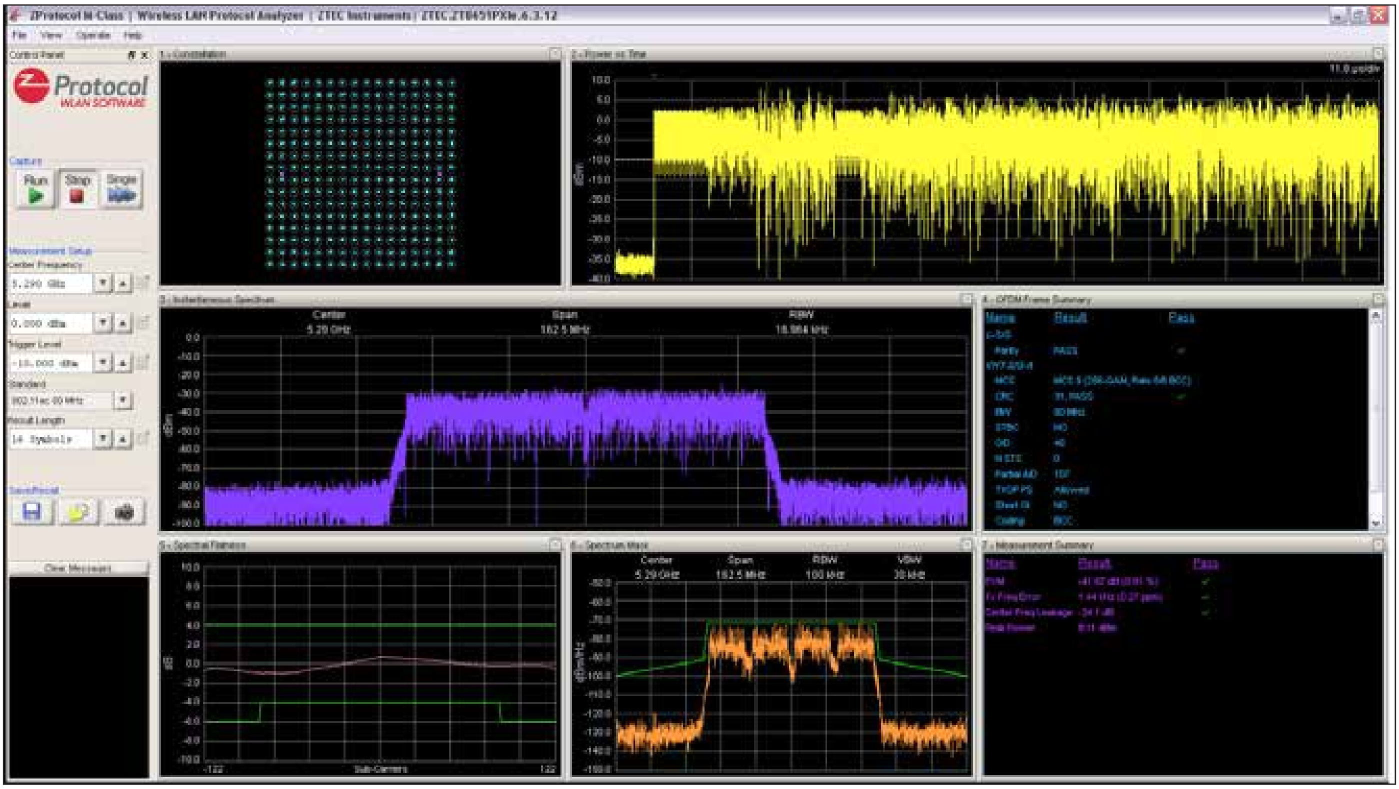


Figure 9 • zProtocol™ WLAN Test Software GUI.

Conclusion

This paper examines the demands that the new 802.11ac WLAN standard places upon the design validation, characterization and testing of power amplifiers (PA). With the EVM contribution of the PA limited for 802.11ac to around 1.5%, greater linearity and dynamic range requirements are needed for the PA and the RF test equipment. This paper defines a number of techniques that assist in test equipment optimization for PA testing for 802.11ac. These techniques are used with the z8201 RF Test Set and zProtocol™ WLAN software to provide a complete solution for qualifying PA performance for operation within an 802.11ac WLAN transmitter design.

About the Author

Christopher Ziomek is Vice President and General Manager of LitePoint Design Test Solutions (DTS), a LitePoint division focused on wireless design verification test (DVT). LitePoint DTS is helping its customers speed their wireless electronic products to market with state-of-the-art wireless DVT technology. Christopher has over 25 years' experience in the test equipment industry, as an instrument designer, engineering manager, entrepreneur, and business unit manager. Prior to LitePoint DTS, Christopher was President and founder of ZTEC Instruments, a technology startup that was acquired by LitePoint/Teradyne in 2013. Before ZTEC Instruments, he worked as a section leader at the Los Alamos National Laboratory and as a microwave engineer at the Stanford Linear Accelerator Center. Christopher holds BS and MS degrees in Electrical Engineering and is a licensed Professional Engineer in the state of New Mexico.

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[7] LitePoint, "z8750 Series Vector Signal Generator Specifications" [online] available: http://www.ztecinstruments.com/products/rf-test-equipment/series/Z8750/

Double-Balanced Mixer Features Wide Frequency Range, High Linearity

Linear Technology announced the LTC5549, a double-balanced mixer that can operate either as an upconverter or downconverter, with a very wide RF frequency range from 2 GHz to 14 GHz. The LTC5549 offers exceptionally high linearity of 24.4 dBm IIP3 at 9 GHz. It enables efficient microwave transmitter and receiver designs with an integrated LO buffer that needs only a 0 dBm drive level, effectively eliminating an external high power LO amplifier circuit.

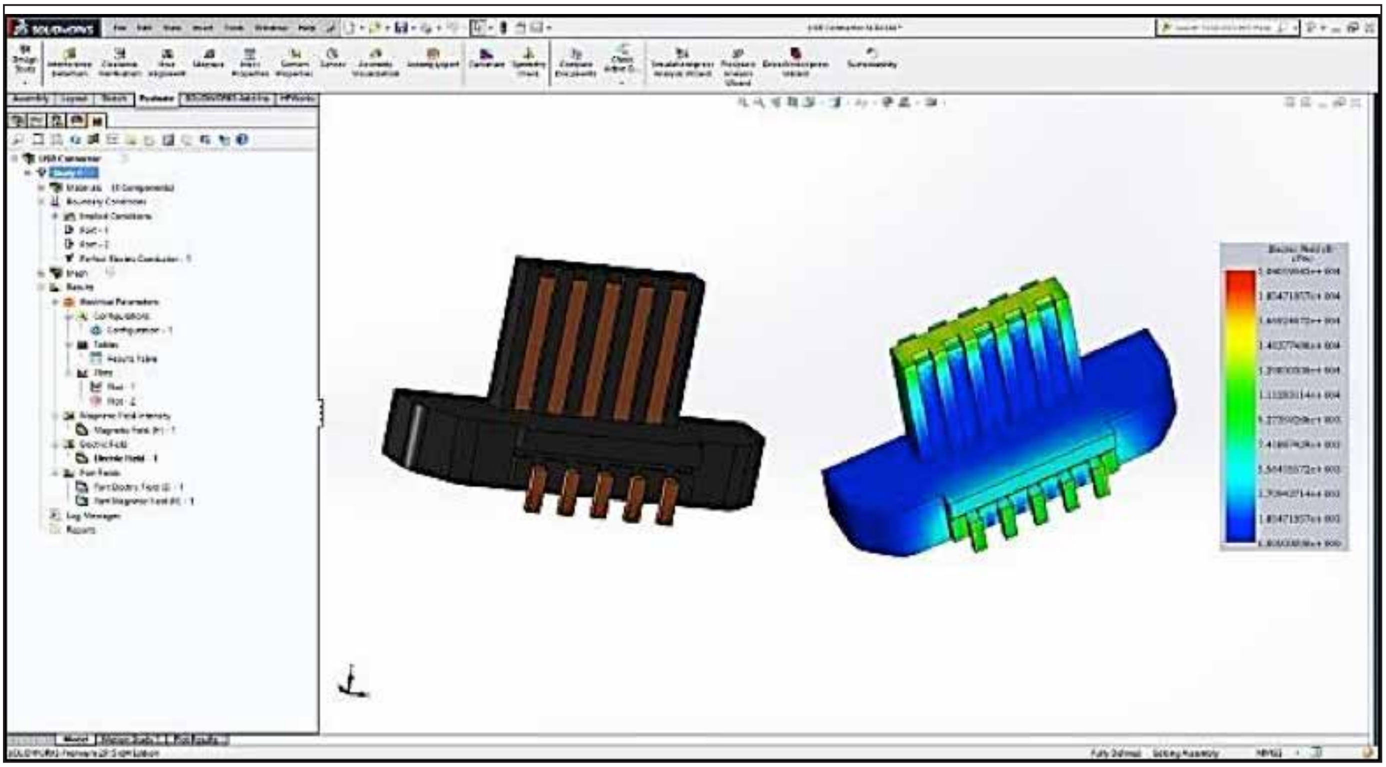
It has an integrated on-chip, switchable frequency doubler for LO signal, providing an option to use lower cost, commonly available low frequency synthesizers. The LTC5549 employs a wideband integrated balun transformer optimized to extend RF frequency bandwidth from 2 GHz to 14 GHz while enabling single-ended operation. Its IF port also has wide bandwidth up to 6 GHz. All three ports are 50Ω matched.

The mixer offers high port-to-port isolation, minimizing undesirable LO leakage, and easing external filtering requirements. The LTC5549's performance enhances a wide range of microwave applications including microwave backhaul, high unlicensed band LTE-Advanced base stations, satellite broadband radios, radar systems, X-band and Ku band transceivers, test equipment and satellite modems.

The LTC5549 offers improved ESD protection with its 2,000V ESD human body model (HBM) rating on all pins. The device is available in a tiny 12-lead, 3mm x 2mm plastic QFN package. With its minimal external component design, the LTC5549 results in a compact solution footprint. It is rated for operation from –40°C to 105°C case temperature to support extended environmental operating temperature. The mixer is optimized for single 3.3V supply operation, drawing a nominal supply current of 115mA.

Additionally, the LTC5549 has an enable pin to disable the IC. When deactivated, the device draws only 100µA maximum standby current. The enable pin can be driven directly to turn the device on and off rapidly in less than 0.2µs, supporting time-division duplex (TDD) or burst mode type radios.

Linear Technology
linear.com



3-Dimension Field Simulation Software Offers Fully Parallel Solvers

HFWorks is a complete 3-dimensional field simulation software for RF/Microwave and Wireless applications, based on the finite element method. This microwave design and antenna pattern software is the only high-frequency electromagnetic package that is completely integrated inside SOLIDWORKS.

HFWorks is Gold Certified by SOLIDWORKS and it is fully embedded in the software so you won't have to toggle between programs or deal with various CAD file formats. The HFWorks RF/microwave design software includes three main solvers: Antennas, S-parameters, and Resonance.

HFWorks 2015 was released in July 2015 and has the following new features.

Multi-core solver: HFWorks now offers fully parallel solvers, with these new solvers HFWorks studies solve in a record time.

Adaptive meshing: HFWorks has adaptive meshing capability. The adaptive mesh refinement technique is a dynamic process that recursively refines the mesh in regions that exhibit field discontinuities and steep gradients. This ensures accurate result without ever bothering to check for convergence manually.

"HFWorks is a complete 3-dimensional field simulation software for RF/Microwave and Wireless applications"

Accuracy level: HFWorks allows users to select an accuracy level before solving: two levels are available: normal accuracy and high accuracy.

New Port Field plot: Using this option, users will be able to plot electric and magnetic field surface plot on defined ports.

Differential Port: Differential ports represent two circuits both positive and negative; it should be used where an electric field is likely to build up between two ports (odd modes propagate).

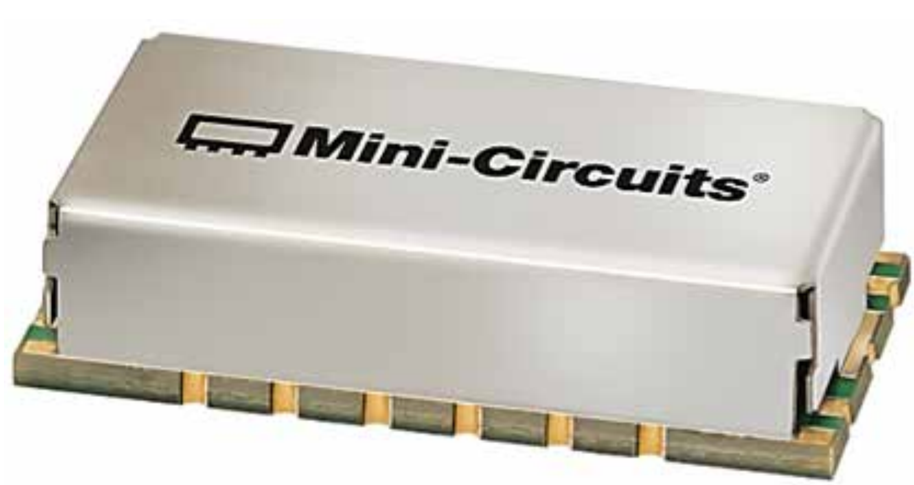
EMWorks
emworks.com

Product Highlights

Precision-Grade Receptacles

SGMC Microwave introduced a new line of precision-grade receptacles. Type N Male and Female (4) hole flange receptacles with extended pin and dielectrics (epoxy captivated). Electrical: 50 Ohm, Low VSWR, Low Insertion Loss, Mode Free through 11 GHz (18 GHz version also available). Materials: Passivated 303 Stainless Steel Housings with Gold plated Center Conductors. (Brass, Nickel Plated housings are also available). Dielectrics are Virgin PTFE Fluorocarbon.

SGMC Microwave
sgmcmicrowave.com



Filter

BPF-F184+ is a 50W bandpass filter in a shielded package fabricated using SMT technology. This bandpass filter covers from 154.32 to 214.32 MHz. Low insertion loss: Broad bandwidth and it can be used in television networks. Good rejection: This enables the filter attenuate spurious signals and reject harmonics for broad frequency band. Shielded package: The small surface mount package enables the BPF-F184+ to used in compact design.

Mini-Circuits
minicircuits.com

Product Highlights

VNA

The latest Cobalt series are affordable vector network analyzers that deliver faster measurement speeds while maintaining a wide dynamic range. The Cobalt series, which currently consists of models C1220 and C1209, offers a unique combination of compact design and extremely fast measurement speed that makes them optimal for engineers looking for fast production and BTS filter tuning applications where space is at a premium.

Copper Mountain Technologies
coppermountaintech.com

Isolator

Model STF-15-S1 is a full band Faraday isolator that covers the frequency range from 50 GHz to 75 GHz. It exhibits 28 dB minimum isolation and 1.2 dB typical insertion loss over entire V band. The return loss of the isolator is 1.4:1 maximum. The Faraday isolator is equipped with standard WR-15 waveguide and UG385/U flange. The insertion length of the isolator is 2.5” long and the weight is 1.8 Oz typically.

SAGE Millimeter
sagemillimeter.com

Product Highlights

Power Amps

Fairview Microwave released a portfolio of coaxial high-rel power amplifiers with broadband frequencies ranging from 0.5 MHz to 20 GHz that can operate over extreme temperatures across -55°C to +85°C. These amps are commonly used in demanding environments for applications involved with electronic warfare, instrumentation, military communications, radar, point-to-point radio, telecom, test & measurement, medical, and SATCOM.

Fairview Microwave
fairviewmicrowave.com

BERT

Keysight Technologies expanded its PAM-4 measurement solutions with support for PAM-4 data formats and built-in error counters on the M8000 Series BER test solutions. PAM-4 support and the ability to integrate a device's built-in error counter helps R&D and test engineers characterize and test high-speed digital receivers for the data-center networking, storage and computer industries. The M8000 Series accelerates insight into digital designs with fast and accurate receiver characterization for single- and multi-lane devices.

Keysight Technologies
keysight.com

Amplifiers

Richardson RFPD announced availability and full design support for a family of DOCSIS 3.1 active components from M/A-COM Technology Solutions. The new family of amplifiers covers upstream and downstream bands and complement MACOM's recently-introduced portfolio of DOCSIS 3.1-compliant passive components. These are designed for head-end, node, system and line access equipment requiring broad bandwidth, high output power and low distortion.

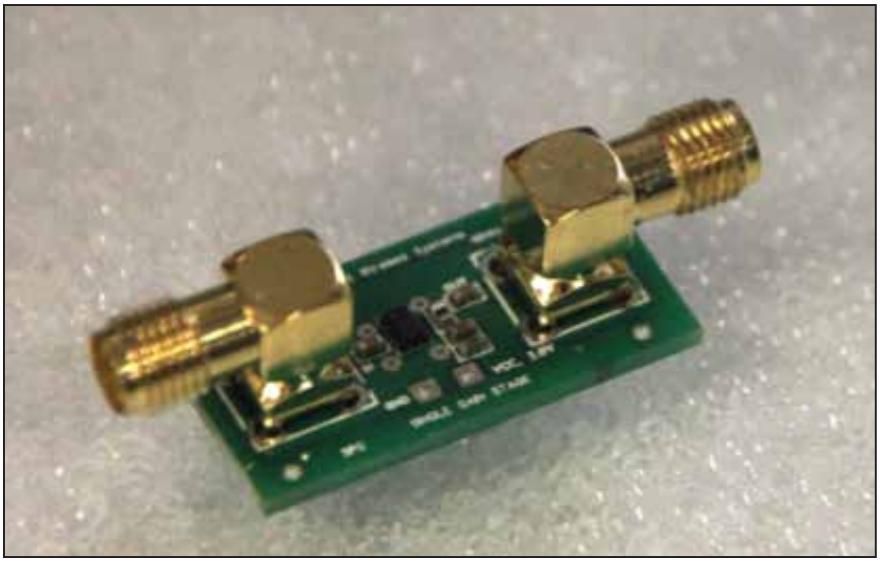
Richardson RFPD
richardsonrfpd.com

Product Highlights

In-Stock Power Sensor

LadyBug Technologies' LB480A with extended Type-N connector is now kept in stock. The sensor is ideal for many laboratory, manufacturing and field applications. The high quality extended Type-N male connector (option XNM) is available on other LadyBug Power sensors including its True RMS, Peak & Pulse sensors. LadyBug sensors provide high accuracy NIST traceable RF Power measurements to below -60 dBm. A virtual power meter application is included with each sensor. The new connector combined with LadyBug's *No Zero Just Measure* patented no-zero no-cal technology adds even more flexibility for power sensor users.

LadyBug Technologies
ladybug-tech.com



Amplifier Board

B-Alert Wireless Systems, a subsidiary of Signal Processing Group, introduced a newly designed BAW-1001 radio frequency amplifier board. With a dimension of 41mm L x 15 mm W x 13 mm H, it operates over a range of 40.0 MHz to 2.0 GHz with a gain of 19.5 dB at a supply voltage of 3.3V. Input and output impedance is 50 Ohms. Applications include VCO buffers, general Tx/Rx amplification, power amplifier pre-drivers and low power antenna drivers.

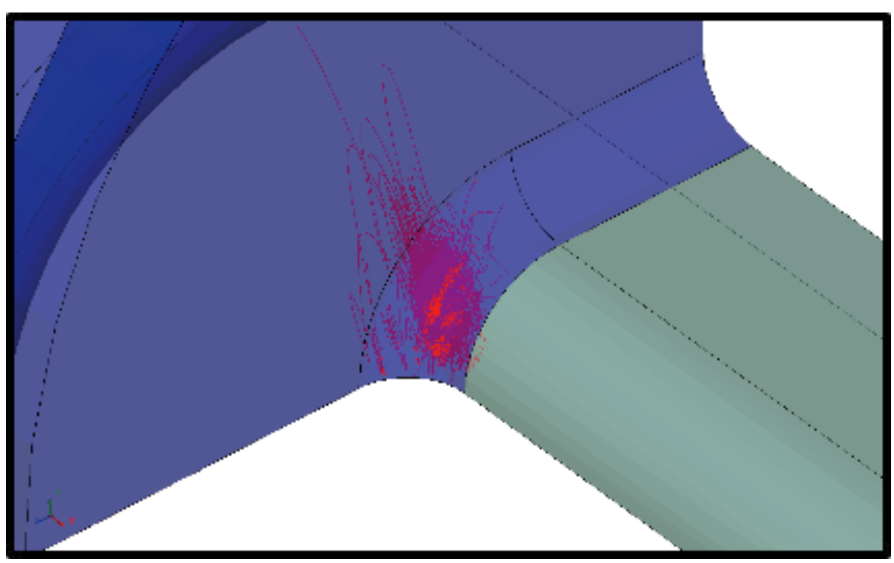
B-Alert Wireless Systems
signalpro.biz

Product Highlights

SSPA

The TA1007 is a Class A GaAs FET SSPA that produces linear power from 500 to 2800 MHz. Unlike GaN amplifiers, the TA1007 produces linear output power as it typically achieves an output third order intercept point (OIP3) of a 20W amplifier but only consumes the DC power of a 5W unit. The amplifier produces 40 dB of linear gain, and operates between +11V to +13V.

Triad RF
triadrf.com



EM Software

NI (formerly AWR Corp.) released its version 12 Analyst-MP™ 3D multi-physics finite element method (FEM) electromagnetic (EM) analysis software. This latest version delivers up to 10X improvement in speed from the previous version, making it even faster for analyzing extremely complex high-frequency, multiphysics structures like the X- and L-band accelerators designed by Japan’s High Energy Accelerator Research Organization (KEK).

NI
awrcorp.com

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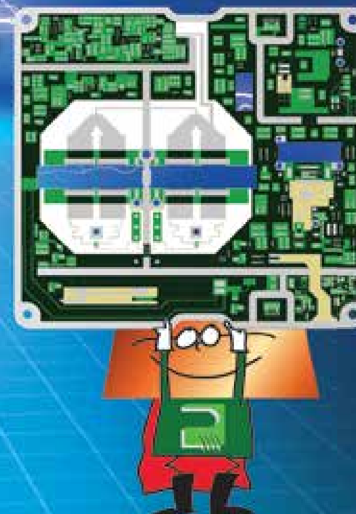

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RO4360G2 laminates deliver the low loss and high thermal conductivity sought by amplifier designers. Suitable for a variety of commercial and industrial applications, RO4360G2 laminates can be processed similar to FR-4 & support lead-free, RoHS-compliant manufacturing practices.

Features

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- Low loss
- High thermal conductivity
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Total Cost Solution

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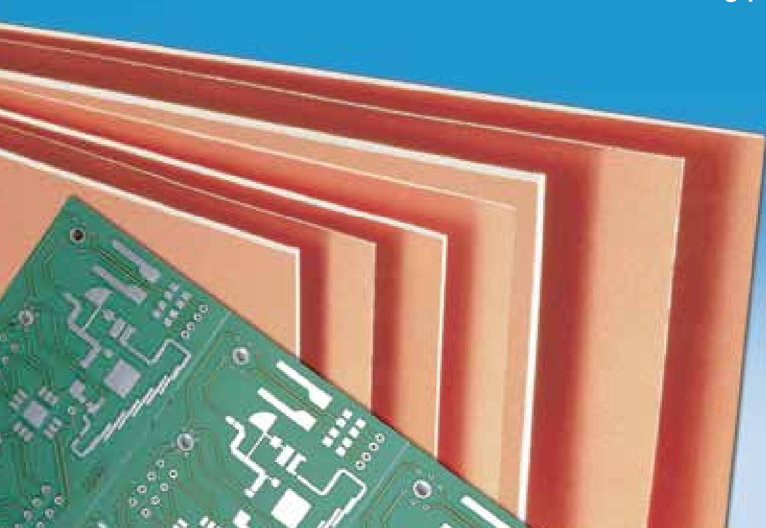
- Low fabrication cost

Ease of Fabrication

- Ideal for multilayer circuits
- Suitable for automated assembly lines
- Processes similar to FR-4
- Lead free, RoHS compliant



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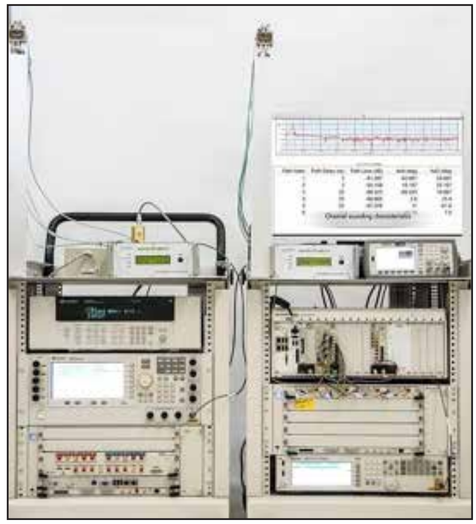
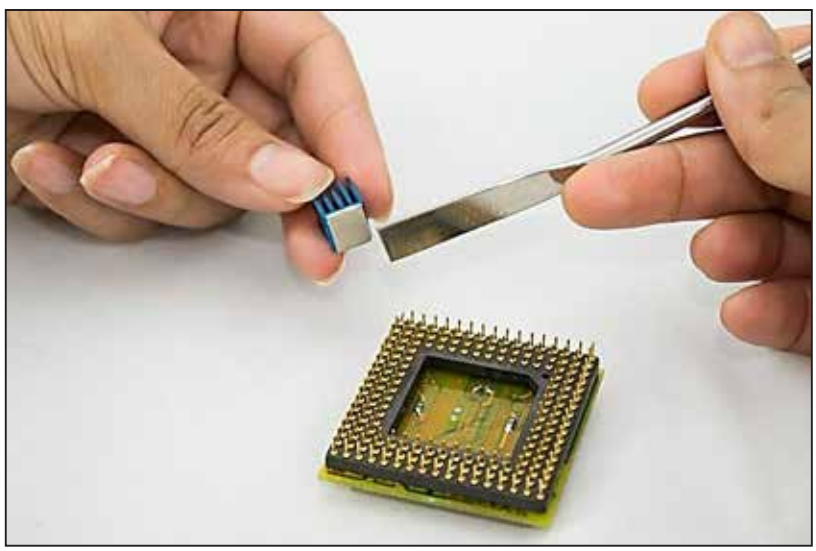
Product Highlights



5G Reference Solutions

Keysight Technologies introduced its 5G channel sounding Reference Solution, designed for accelerating advanced research of millimeter-wave 5G channel models. It includes ultra-broadband and MIMO, key requirements to measure the millimeter-wave channel and validate new air interface standards. It combines metrology-grade hardware, software and expertise to allow customers to quickly characterize channel behavior in these frequency bands.

Keysight Technologies
keysight.com

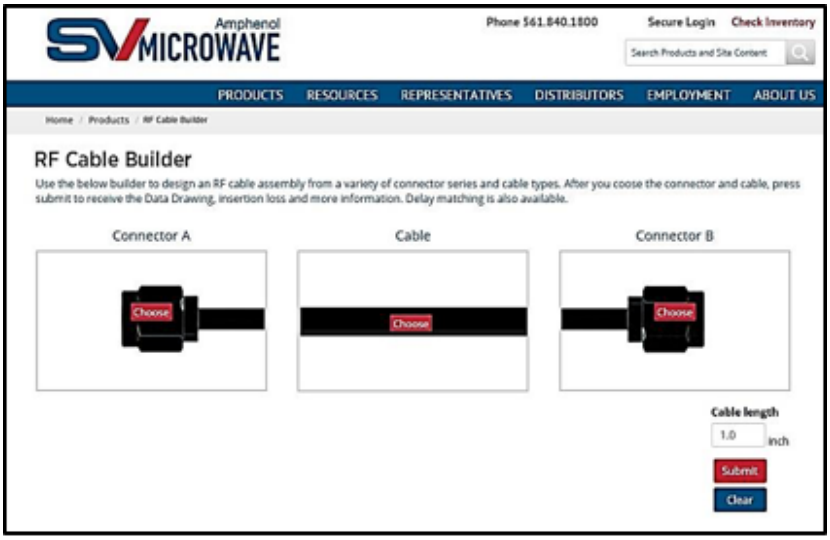


Epoxy Paste

Master Bond EP48TC is two part epoxy paste that can be applied in bond lines as thin as 10-15 microns. This material offers exceptionally low thermal resistance of 5-7 x 10-6 K•m2/W, which imparts impressive heat transfer capabilities and thermal conductivity of 20-25 BTU•in/ft2•hr•°F [2.88-3.60 W/(m·K)]. It can be used in applications in the aerospace, electronics, optical, specialty OEM and many other high-tech industries.

Master Bond
masterbond.com

Product Highlights



Cable Builder

SV Microwave's Rapid Response RF Cable Assemblies are built-to-order and ready to ship within five business days. These cables can be custom-configured and purchased using SV's new interactive RF cable builder app. Choose from a variety of in-stock standard connector series and cable types for miniature and low loss coaxial assemblies. The RF Cable Builder will generate a custom datasheet complete with part number, data drawing, technical specs and pricing. Go to www.svmicrowave.com/products/rf_cable_builder.

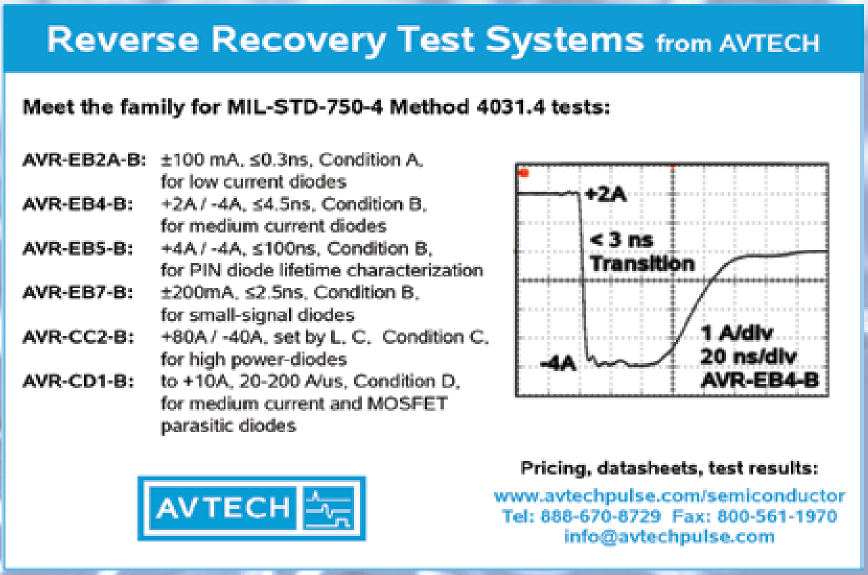
SV Microwave
svmicrowave.com

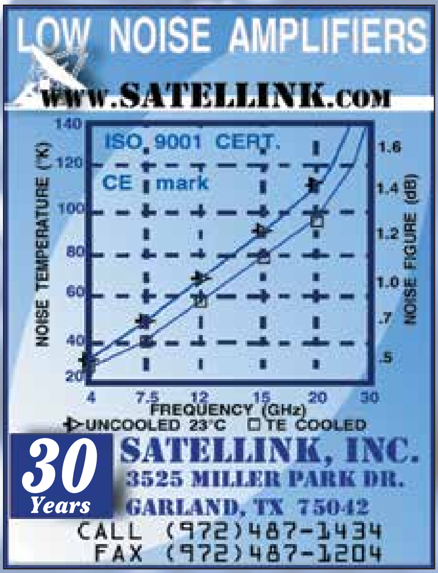
Test Set

Model STG-15-S1 is a V band noise figure and gain test set, which including a high performance solid-state V band noise source (STZ-15-I1) and a full waveguide band down converter (STC-20-15-S1). It extends the noise and gain measurement capacity to the frequency range of 50 to 75 GHz. The full waveguide band down converter requires a +3 dBm LO signal in the frequency range of 12.5 to 18.75 GHz.

SAGE Millimeter
sagemillimeter.com

Product Showcase





Are Modular Solutions What's Next for RF/Microwave Test Solutions?

Mario Narduzzi
Marketing Manager
Modular Solutions
Keysight Technologies

What's the next big thing for RF and microwave test solutions? It's a question that's been asked hundreds of different ways and the answer is usually the same: new product capabilities, a new technology or even a new type of instrument. Perhaps what we really ought to be asking is: Will what's coming next have a significant impact on the electronics industry? In this case, the answer is a resounding yes, because what's coming next is a wave of modular instruments in reference solutions that promise a host of advantages—not only for the engineers using them, but also for the end users of the new electronic products being developed.

To be clear, modular instrumentation is not a new concept. It's actually been around for some time, and in fact, companies like Keysight Technologies have offered modular instrumentation for many years. Bolstered by standards like AXIe and PXI, such instrumentation is popular for its flexible test system configuration, space and cost savings, and scalability. Recent advances in PC technology enable modular instrumentation to deliver ever greater performance and speed. And that is what's prompting the oncoming wave of modular instruments in reference solutions that promises to more efficiently solve engineers' greatest challenges for a range for applications. Solutions that include AXI- or PXI-based instruments, developed in collaboration with key customers, not only speed time-to-first-measurement (TTFM), but they also provide integrated advanced measurement techniques for specific applications; ensuring measurement confidence and faster results.

Reference Solutions

Reference solutions are test configurations that include multiple AXIe or PXI modules with associated software drivers, measurement algorithms and sample programs. Instrument hardware selection is made to optimize speed and performance for specific applications, while at the same time, taking advantage of the modular benefits of flexibility and scalability. These solutions not only deliver the test results engineers need today, but they also enable new capabilities for future test demands that simply weren't possible in the past.

Virtually any type of module can become a component within a large, application specific reference solution. Speed-optimized PXI signal generator modules, for example, can be used for production testing of wireless devices, while high-performance PXI digitizer and high-fidelity AXIe arbitrary waveform generator (AWG) modules can be used for research and radar simulations, respectively. And

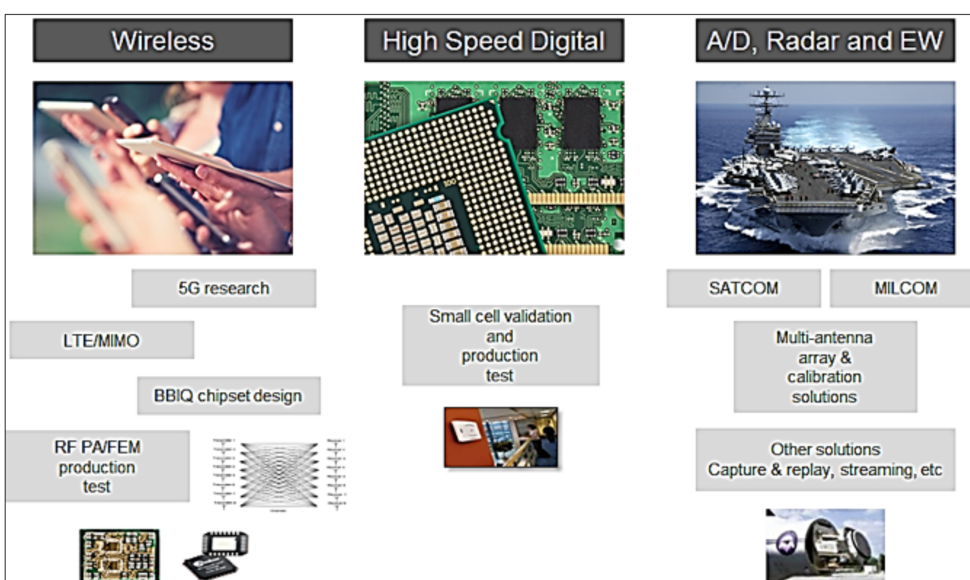


Figure 1 • The applications shown here today face challenges that demand modular solutions.

that bodes well for applications in the analog, digital and RF/microwave technology arenas, each of which has their own unique set of test needs and challenges that must be addressed (Figure 1).

In the aerospace and defense industry, for example, Radar applications require continually increasing modulation bandwidths at higher frequencies. Here, high-precision AXIe AWG modules can be combined with vector signal generators to generate wide bandwidth radar waveforms, which can then be analyzed using either a high-performance oscilloscope running vector signal analysis software or wideband signal analyzer. These modular instruments can also be used for multi-emitter environment test signals, phased-array T/R module networks, and wideband satellite communications. In the cellular industry, reference solutions can be used for LTE and LTE-A test, 5G, GNASS and A-GNASS, HSPA Test and HSPA+ test, and small cell and wireless backhaul (Figure 2).

Likewise, reference solutions can also play a critical role in high-speed digital applications to address Peripheral Component Interconnect Express (PCIe®) generation design challenges and in advanced research. Here, PCIe digitizers help maximize data bandwidth and ensure rapid measurements—even at the extremes of science. These capabilities provide superior throughput in applications such as the control and monitoring of particle and electron beams in physics research, and in real-time processing for microwave spectrometry in atmospheric research.

Additional Advantages

Of course, the use of modular instruments for a range of applications is not the only compelling advantage of reference solutions. Reference solutions provide lower cost of ownership, delivered through longer term standard warranties, precise factory calibration traceable to NIST with regularly scheduled calibration cycles, and Assurance Plans that allow users to lock in ongoing performance by investing in guaranteed turnaround repair service for a specified time. Reference solutions also typically feature a specifically designed self-test that exercises and verifies key instrument functionality and reports individual, as well as overall solution status. And, because the solutions include "modular" instruments, users can purchase just what they need and quickly add modules for more channels or additional features as the need arises, without having to replace instruments.

To further drive down the cost of ownership, some reference solution vendors may offer a core exchange program to ensure fast repair and turnaround of problem modules. While a defective module is returned for repair, a fully functioning pre-calibrated replacement is provided to be used in its place. The replacement module is able to maintain the original serial number for ease of maintenance and test system documentation.

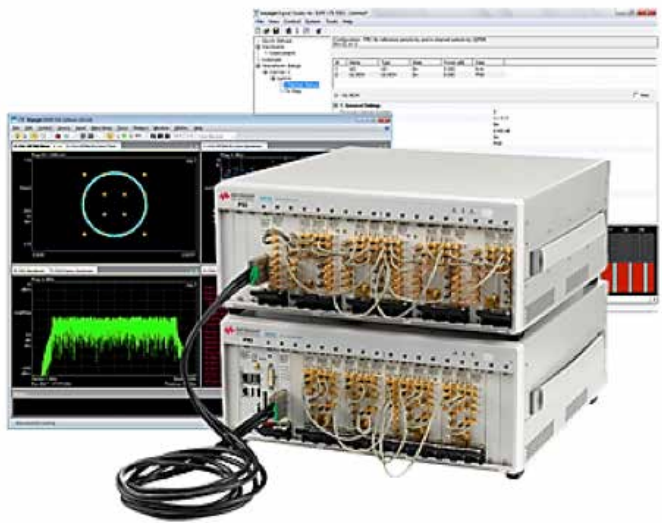


Figure 2. With this LTE-A multi-channel modular solution engineers can accelerate their LTE-A designs and gain deeper insight faster.

Without a doubt, reference solutions with integrated modular instruments are a game changer for real-world applications, providing optimized test solutions that address current and emerging standards and technology. Modular instruments not only deliver capabilities not previously possible and drive down the cost of ownership, but they also provide the standard benefits associated with modular instrumentation; namely, flexibility, scalability, and space and cost savings. Engineers and consumers both benefit from the use of modular instruments used in reference solutions.

About the Author:

Mario Narduzzi serves as Marketing Manager, Modular Solutions for Keysight Technologies. He has been working with Keysight Technologies/Agilent Technologies/HP for over 30 years, with 25 years of experience in leadership and management. He joined the Software and Modular Solutions team as the Modular Solutions Marketing Manager in March 2013.

Prior to his current assignment, Mario spent seven years in China, where he set up a marketing team and held the role of Marketing Manager for Agilent's Bejing-based China Communications Operation Marketing. Before relocating to China, he spent five years as the Marketing Manager and three years as the Product Planning Manager for the Signal Sources Division located in Santa Rosa, Calif.

Mario's educational background includes a Bachelor of Science degree in Electrical Engineering from California State University, Chico, in addition to many formal leadership training programs as well as executive leadership training at MIT's Sloan School of Management.

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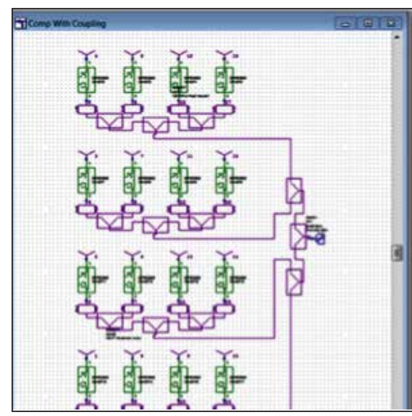

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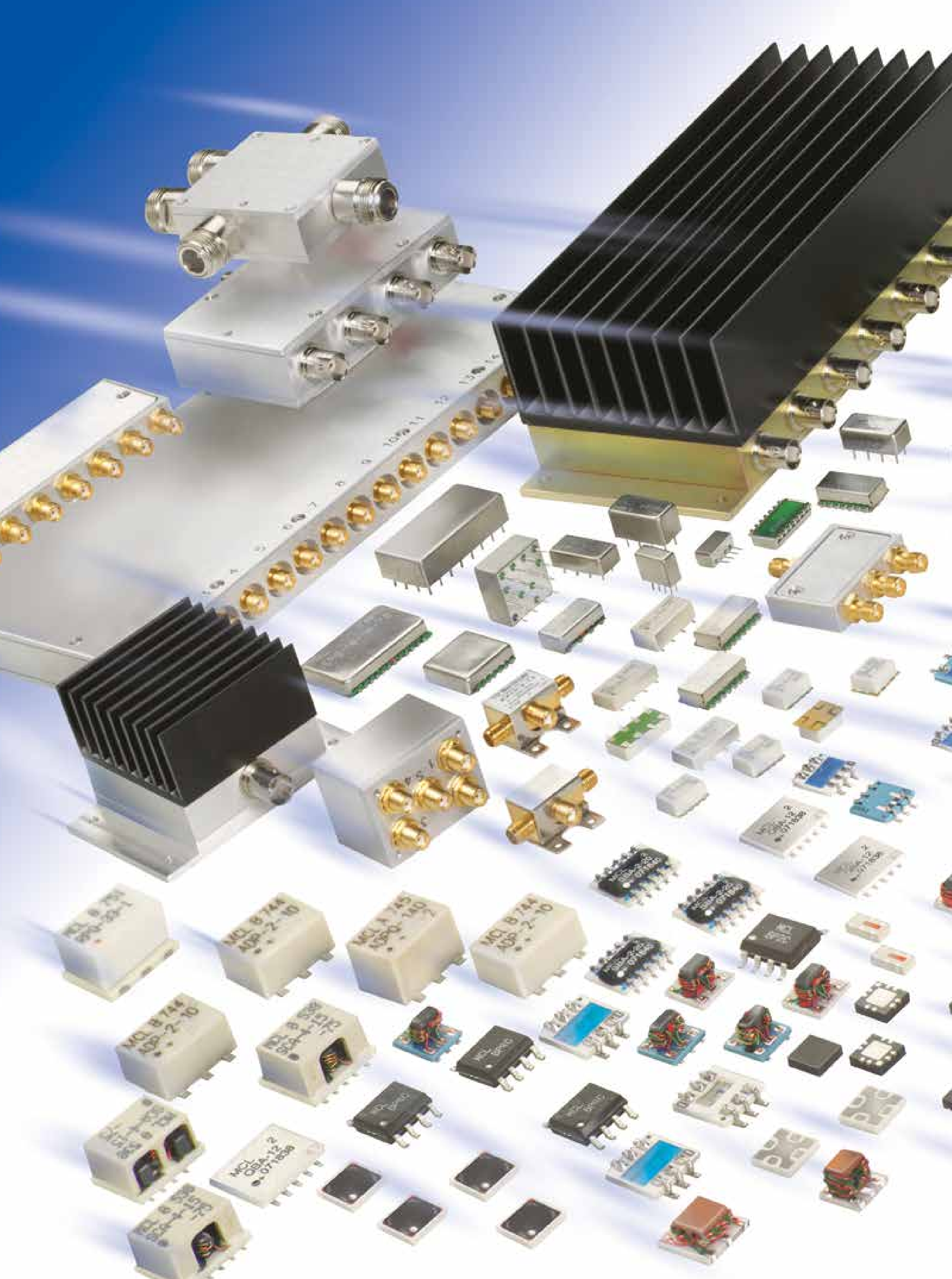
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