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Impact of Antenna Design, Tune and Match on Wireless Range

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Power Amplifier Testing For 802.11ac

In the News

Product Highlights

Tim Burkhard: Make Your Next Trade-Show Exhibit a Winner **DISTRIBUTION AND MANUFACTURER'S REPRESENTATIVES**

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Model	Freq	Insertion	Isolation	Max Current	Price \$ea.
	(MHz)	Loss (dB)	(dB)	mA	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***

					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+ ZFBT-6G-FT+ ZFBT-4R2GW-FT+ ZFBT-6GW-FT+ ZFBT-282-1.5A+ ZFBT-352-FT+ ZNBT-60-1W+ ZX85-12G+	10-4200 10-6000 0.1-4200 0.1-6000 10-2800 30-3500 2.5-6000 0.2-12000	0.6 0.6 0.6 0.6 0.6 0.4 0.6 0.6	N/A N/A N/A 45 23 45 N/A	500 500 500 1500 4000 500 400	

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



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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.

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Power Amplifier Testing For 802.11ac

By Christopher Ziomek

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

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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)



Get info at www.HFeLink.com

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

(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@highfrequencyelectronics.com. Tel Aviv, Israel http://www.comcas.org Paper Submission Deadline: 30 May 2015

2015 IEEE MTT-S International Microwave and RF Confer-

ence (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

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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/
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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 strategy analytics.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 timesharing 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

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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

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LL00110-1 LL00110-2 LL00110-3 LL00110-4	0.01 - 1.0	-10 - 5 0 + 5		41 - 6 - 1 +4
LL0120-1 LL0120-2 LL0120-3 LL0120-4	0.1-2.0	-10 - 5 0 + 5		41 - 5 - 1 +4
LL2018-1 LL2018-2 LL2018-3	2 - 18	:	-10 TO -5 - 5 TO 0 0 TO+5	-10 - 5 0

Notes:

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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 codevelopment 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.

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- IS680 materials offer a complete laminate materials solution for single- and double-sided printed circuit designs and are a costeffective alternative to PTFE and other commercial microwave materials. Dk available from 2.80 to 3.45.
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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 a	t one resin %. Please refer to the Isola	website for a complete list of Dk/Df value	es. The data, while believed to be accu	rate & based on analytical methods con	sidered to be reliable, is for			

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

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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



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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

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Rohde & Schwarz rohde-schwarz.com

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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

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SAGE Millimeter sagemillimeter.com



Amp Die

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extremely user friendly and enable simple, straightforward use.

Mini-Circuits minicircuits.com



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7 Preferred Power Products



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Frequency (MHz)	Coupling (db)	Power (watts)	Frequency Flatness (± dB)max.	Insertion Loss (dB) max.	Directivity (dB) min.	V: Pri.	SWR Sec.	Model Number	The man of
20-100	40 ± 1.0	1000	0.75	0.20	24	1.15	*Note1	PCD-20-100-1KN40	
20-100	40 ± 1.0	2000	0.75	0.20	24	1.15	*Note1	PCD-20-100-2KSCN40	Fastures
100-500	40 ± 1.0	1000	0.30	0.60	24	1.15	*Note1	PCD-100-500-1KN40	reatures.
100-500	40 ± 1.5	2000	0.60	0.40	24	1.15	*Note1	PCD-100-500-1KSCN40	 High CW & Pulse Power
100-2000	30 ± 0.5	100	1.50	0.35	20	1.25	1.25	PCD-100-2000-R1S20	Internal High Power Loads For High Directivity
200-6000	30 ± 1.5	500	1.50	0.50	15	1.25	1.25	PCD-200-6000-R5N30	- Breadhand Franciscon Banaca
400-1000	40 ± 1.5	1000	0.20	0.20	23	1.25	1.25	PCD-400-1000-1KN40	 Broadband Frequency Ranges
400-1000	40 ± 1.0	2000	0.25	0.20	23	1.15	1.25	PCD-400-1000-2KSCN40	 Low Insertion Loss / High Directivity
500-3000	30 ± 1.0	1000	0.25	0.20	23	1.15	1.25	PCD-500-3000-1KSCN30	Applications:
500-3000	40 ± 1.0	1000	0.25	0.20	23	1.15	1.25	PCD-500-3000-1KSCN40	Applications.
500-3000	60 ± 1.0	1000	0.25	0.20	20	1.15	1.25	PCD-500-3000-1KSCN60	 Accurate Power Sampling
800-4200	40 ± 1.5	300	0.30	0.25	20	1.25	1.25	PCD-800-4200-R3N40	 High Power Leveling Loops
1000-2000	30 ± 1.0	500	0.30	0.20	20	1.20	1.25	PCD-1000-2000-R5NS30	Automatic Erequency Control Loops
1000-2000	40 ± 1.0	500	0.30	0.20	23	1.20	1.25	PCD-1000-2000-R5NS40	- Automatic frequency control Loops
2000-4000	30 ± 1.0	300	0.80	0.30	20	1.20	1.25	PCD-2000-4000-R3N30	 Simultaneous Power Monitoring
*Note 1: Cou	pled ports ar	e matche	ed for use in §	50 Ω system					Wide variety of connector configurations available.

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🕨 Antenna Design

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.



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NOTE: GVA-62+ may be used as a replacement for RFMD SBB-4089Z GVA-63+ may be used as a replacement for RFMD SBB-5089Z See model datasheets for details various combinations of gain, P1dB, IP3, and noise figure to fit your application. Based on high-performance InGaP HBT technology, these amplifiers are unconditionally stable and designed for a single 5V supply in tiny SOT-89 packages. All models are in stock for immediate delivery! Visit minicircuits.com for detailed specs, performance data, export info, **free X-parameters**, and everything you need to choose your GVA today! *Us patent 6,943,629*

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🕨 Antenna Design



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

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Impedence: 50 Ω Time delay: 1.4 ns/ft Cut off frequency: 62 GHz for RF 085 34 GHz for RF 141

700

660

200

160 120

80

40



RF leakage: Equivalent to semi-rigid cable Temp range: -55°C to 165°C Bend radius: 1/16 inch for RF 085 1/8 inch for RF 141



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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:

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

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

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



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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

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,

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

width (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	
а	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 - <mark>54</mark>	1	OFDM, DSSS	
-	0-1 2000	245	20	6.5 - 72.2		05014	
n	Oct 2009	2.4, 5	40	13.5 - 150	1-4	OFDIM	
			20	6.5 - 86.7			
ac (draft)	No. 2011		40	13.5 - 200		orphi	
	NOV 2011	5	80	29.3 - 433.3	1-8	OFDM	
			160	58.5 - 866.7	1		

Table 1 • 802.11 WLAN Protocols



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	Model	Frequency	Gain	Pout	@ Comp.	\$ Price*
		(MHz)	(dB)	1 dB (W)	3 dB (W)	(Qty. 1-9)
EM;	ZVM-273HP+ ZVE-3W-83+ ZVE-3W-183+ ZHL-4W-422+ ZHL-5W-422+ ZHL-5W-2G+	13000-26500 2000-8000 5900-18000 500-4200 500-4200 800-2000	14.5 35 35 25 25 45	0.5 2 3 3 5	0.5 3 4 5 5	2195 1295 1295 1160 1670 995
•	ZHL-10W-2G+ ZHL-16W-43+ ZHL-20W-13+ ZHL-20W-13SW+ LZY-22+ ZHL-30W-262+	800-2000 1800-4000 20-1000 20-1000 0.1-200 2300-2550	43 45 50 50 43 50	10 12 13 13 16 20	12 16 20 20 30 32	1295 1595 1395 1445 1495 1995
•	ZHL-30W-252+ LZY-2+ LZY-1+ ZHL-50W-52+ ZHL-100W-52+	700-2500 500-1000 20-512 50-500 50-500	50 47 42 50 50	25 32 50 63 63	40 38 50 63 79	2995 2195 1995 1395 1995
•	ZHL-100W-GAN+ ZHL-100W-13+ ZHL-100W-352+ ZHL-100W-43+	20-500 800-1000 3000-3500 3500-4000	42 50 50	79 79 100	100 100 100	2395 2195 3595 3595

Listed performance data typical, see minicircuits.com for more details. • Protected under U.S. Patent 7.348.854

2 an

*Price Includes Heatsink







Figure 1 • Test equipment block diagram for PA testing.

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)

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)

Phase Adjusters

Part Number	Con- nec- tors	Fre- quency Range (GHz)	VSWR max.	Inser- tion Loss max. (dB)	Phase Shift min. (°)	No. of Turns	Phase Shift Deg/ GHz/ Turn	Time Delay min. (psec.)	Time Delay max. (psec.)	Tem- perature (°C)	Weight max. (g)
LS-0002-YYYY ¹⁾	div.	DC - 2	1.2:1	0.3	85	37		393	516		98-220 ²⁾
LS-0103-6161	Nf	DC - 3	1 15	0.4	540	cont	1 15	1826	2328	-65 to	700
LS-0203-6161	111	DC - 3	1.15	0.8	1080	cont.	1.15	3693	4694	+125	1200
LS-0012-YYYY ¹⁾	div.	DC - 12	1.3:1	0.8	520	37		406	530		114-234 ²⁾
LS-0112-XXXX ³⁾				-							70
LS-A112-XXXX ³⁾		DC-		0.4	230						47
LS-0212-1121		12.0		0.4	230						70
LS-A212-1121	SMA		1	-			1	120	203	-65 to	47
LS-0118-XXXX ³⁾	SIVIA		1 25.1			16.5	1.2	230	293	+125	70
LS-A118-XXXX ³⁾			1.23:1		1	10.5		XX			47
LS-0218-1121		DC-		-06	250	Sec. 1		1			70
LS-A218-1121		18.0			330	Nile-		- Alter	2		47
LS-0118-5161	N					O		200	255	-65/+70	105
LS-U118-5161	Ν			2 1	1	2	and the	300	335	-65/+165	105
LS-0018-YYYY ¹⁾	div.	DC - 18	1.5:1	1.0	770	37	1.15	406	530		114
LS-0121-XXXX ³⁾				4					(Aug		70
LS-A121-XXXX ³⁾		· max **	1 20.1		500	16.5		220	202		47
LS-0221-1121		ARS	1.50:1	0.8	300	10.5	51.2	230	295	(5 40	70
LS-A221-1121	SMA	DC-						1		-05 10	47
LS-0321-1121	SIVIA	26.0	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	25/	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	2.02	DC	1.2:1	0.6	500	12		169	208		51
LS-0140-KFKM	2.92 mm	40.0	1.4:1	0.0	390			100	200		49
LS-0040-KFKM		40.0	前發音		216	9					
LS-P150-HFHM	2.40	DC	1.3	0.0	400		1 0	170	105	-65 to	55
LS-0150-HFHM	2.40	50.0	1.5	0.8	400		1.2	172	195	+65	53
LS-0050-HFHM		50.0	1352	0	200	11					
LS-P165-VFVM	1.05	DC	1.4		600	11 o		167	105		55
LS-0165-VFVM	1.85	62.0	1.5	0.8	000	o		10/	- 195		53
LS-0065-VFVM		0.5.0			200						

iv.: Connector Configuration available: SMA, male and female; N, male and female; TNC male and female Veight depends on connector configuration MA 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

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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.

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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.



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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





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AMCOM GaN HEMT MMIC Summary

Model	Frequency (GHz)	G _{ss} (dB)	P _{5dB} (dBm)	Eff _(5dB) (%)	V _d (V)	I _{dq} (A)	ECCN
AM004047SF-2H*	0.05-4.0	33	47	44	25, 90	0.5, 0.9	EAR99
AM006044SF-2H*	0.05-6.0	22	44	42	30, 60	0.4, 1.0	EAR99
AM206542TM-00!	2.0-6.5	25	42	20	28	0.96	3A001.b.2.a
AM010130TM-00!	0.05-13.0	13	33	15	28	0.24	3A001.b.2.b

* 100uS pulse width, 10% duty cycle. They also work in CW mode at lower bias voltage with slightly reduced output power.



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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 zProtocolTM 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 zProto-col[™] 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
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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. Temp-Flex® Flexible Microwave Cable Assemblies

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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 stateof-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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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.

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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 multilane 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

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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

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Triad RF triadrf.com



EM Software

NI (formerly AWR Corp.) released its version 12 Analyst-MPTM 3D multiphysics 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).

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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



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Guest Editorial

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,

like companies 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

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

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 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 highperformance 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 Bejingbased 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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Coupler

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Renaissance Electronics rec-usa.com

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