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Vol. 14 No. 9 September 2015

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

<u>Also Published Online at</u> www.highfrequencyelectronics.com

<u>Subscription Services</u> Sue Ackerman Tel: 651-292-0629 circulation@highfrequencyelectronics.com

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## Guest Editorial

## How Can Diversity Improve the Microwave, RF, and Wireless Workforce?



Sherry Hess VP of Marketing AWR Group, NI

This past April, I attended the WIE (Women in Engineering) Leadership Conference<sup>1</sup> in Silicon Valley. Outside of the initial shock of seeing an audi-

ence of 99 percent technical females, the next awe factor was the lineup of keynote speakers—CEO Lisa Su from AMD, CTO Sophie Vanderbroek of Xerox, CIO Rebecca Jacoby of Cisco, VP Patty Hatter of Intel, to name a few. For me, one of the most impactful talks was actually given by a male, Intel CEO Brian Krzanich<sup>2</sup>. Why? Because he raised my awareness of his presentation at CES (Gadget Show) in Las Vegas at the start of this year, where he issued a diversity challenge to his company and the entire industry.

Recapping this speech to all of the attendees at WIE, Krzanich said it is no longer good enough to just talk about valuing diversity. We need to have our workplaces and our industry reflect the full availability and talent pool of women and underrepresented minorities.<sup>3</sup>

The diversity topic is one I've discussed with IEEE MTT-S colleagues over the past few years, including a speech on diversity and women in engineering I gave at the International Wireless Symposium (IWS) in China a few years ago. It was also the topic of our Women in Microwaves (WIM) panel at this year's International Microwave Symposium.

#### **Diversity is Good for Business**

Many sources say diversity is good for business. *The New York Times'* "Women at Work" series, written by Facebook COO Sheryl Sandberg and University of Pennsylvania Wharton School professor Adam Grant, cites research that shows women bring different knowledge, skills, and networks to the table.<sup>4</sup> They take fewer unnecessary risks and are more inclined to contribute in ways that make their teams and organizations better, borne out by the fact that successful venture-backed start-ups have more than double the median proportion of female executives of failed ones. This article says raising women's participation in the work force to the same level as men could raise the GDP by:

- 5 percent in the U.S.
- 9 percent in Japan
- 34 percent in Egypt

At Internet giant Alibaba, 47 percent of all jobs and 33 percent of senior positions are held by women. Founder Jack Ma calls this "one of the secret sauces for Alibaba's success."<sup>5</sup>

Sophie Vandebroek said in her WIE presentation<sup>6</sup> that Xerox across the board has over 30 percent female researchers from all over the world. She says diversity at Xerox starts at the top. Forty percent of Xerox directors are women: the CEO for the past five years is an African American woman; and the CEO for the previous 10 years was a woman. She believes that women at Xerox are thriving for two reasons: the innovative environment and the inclusive culture. "You can't do anvthing alone," she said. "You need a team around you that can help you be more innovative, with people with different life histories that bring together different ideas and viewpoints, people who represent all walks of life. Diversity and inclusiveness is a business imperative, not only an innovation imperative."

Figure 1 (see p. 60), from the IMS2015 Women in Microwaves panel session, shows the ratio of female employees (blue bar) to female managers (red bar) for select countries.

Intel's Brian Krzanich says data suggests that best-in-class companies with the highest level of racial diversity generated 15 times more sales that those with the lowest levels. Companies with C-suite women earn 57 percent or \$44 million more than companies without C-suite women. Adding women to an allmale team increases the team's group intelligence (how they think and solve problems) by 40 percent.

#### **2020 Representation Goal**

According to a report on Intel's website, women made up 24 percent of Intel's workforce in 2013 and non-Asian minorities made up 14 percent. In his speech, Krzanich put up a slide (Figure 2, see p. 61) that not only challenges the tech industry to increase the hiring of women and minorities, but sets a goal of full representation in his company's workforce by 2020. He said the company will hold its managers accountable by tying their pay to progress. The company also is investing \$300 million to improve diversity, including initiatives to create a pipeline of women and minorities entering the technology field.

Pankaj Patel (EVP, CDO, Cisco) also gave a keynote at WIE, "The Power of Women Engineers."<sup>8</sup> He said that at Cisco diversity is their culture and that it is not simply part of the game, it is how you win the game. An organization is simply a (See page 60)



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#### **CONFERENCES & MEETINGS**

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

The IEEE North Jersey Section AP/MTT Joint Society chapter will hold its 30th annual symposium and mini-show on Thursday, October 1 at the Hanover Manor, 16 Eagle Rock Ave., East Hanover, NJ. The event will feature 10 - 12 technical talks and 50 exhibitor tables. The show is open to the technical community and there is no charge for admission. A complimentary breakfast and lunch will be provided for all attendees. For further information contact Kirit Dixit (kdixit@microcomsales. com), George Kannell (gkk@lgsinnovations. com), or Arthur Greenberg (a.h.greenberg@ ieee.org).

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#### **Report: MM-Wave to Have Big Impact** on Telecom Applications

The proliferation of smart devices and rising significance of interconnectivity is intensifying the demand for high-speed data connectivity, high-resolution data transfer, and cost-efficient data security; Millimeter wave (MMW) technology can address all of these demands. **Recognizing this, government agencies across the world are actively funding their R&D in the fields of aerospace and defense, while consumer electronics and network carrier original equipment manufacturers (OEMs) are eagerly adopting the technology to enrich the capabilities of existing applications.** 

New analysis from Frost & Sullivan, "Millimeter Wave Technology: Impact in Key Applications," finds that **the telecommunications industry will develop MMWbased applications, which will have a huge impact in the next five to six years.** This industry is seeking low-cost, high-capacity tools to transport data to the edge of the network, where small cells will reside.

"MMW will find significant application in complementing the usage of the higher frequency spectrum in wireless communications," notes Frost & Sullivan Research Analyst **Jabez Mendelson**. "The high frequency of MMWs would enable the creation of small-sized antennas and multiple-element phased arrays on a substrate chip. Furthermore, it would also aid in the design and development of compact MMW equipment."

While the advantages are significant, MMWs also exhibit certain technical deficiencies. Millimeter waves are susceptible to rain fade (60 GHz and 70/80 GHz), wherein the heavy oxygen absorption in the atmosphere at 60 GHz limits the distance of signal transmission. Although there are various vendors who claim to have minimized rain fade, no MMW technology has effectively addressed this issue.

Nevertheless, technological advances are spawning new applications and ultimately, new opportunities for MMW technology across diverse industry verticals such as telecommunications, healthcare, aerospace, defense, automobile and commercial security.

In particular, there is a wealth of opportunities for such technology in the telecommunication industry, since there is more spectrum available for usage in the MMW bands than in the wave bands presently used for mobile communications. Similarly, when used in driver assistant systems, MMW technology can accelerate the commercialization process of unmanned vehicles. Furthermore, the technology has considerable utility in the healthcare and commercial security industries due to its incorporation in scanning and imaging devices. Ultimately, MMWs can improve the accuracy and proximity of sensors in wireless sensor networks, while the greater precision of radar systems developed using the technology can boost satellite communication. Overall, it helps reduce the load pressure faced by lower frequencies and most importantly, enables the transmission of data without interference from nearby radio waves.

"Overall, with superior technology sophistication, the number of applications that can benefit from MMW will multiply, as will the business models and end-user markets," remarked Mendelson.

—Frost & Sullivan frost.com

#### Growing Threats Driving Increase in Global Defense Spending

Reversing a trend which saw global defense budgets remain essentially flat year-on-year across 2012-2013, defense spending experienced a sharp increase in 2014 as a result of a changing geopolitical threat environment based on both state and non-state activity and other factors. The Strategy Analytics Advanced Defense Systems (ADS) service report, "Global Defense Spending Outlook 2014-2024," forecasts that global defense spending will increase 2 percent year-on-year in 2015 and will grow at a CAGR of almost 3 percent to reach \$2.4 trillion in 2024.

A range of factors will drive spending but there are a number of common drivers that recur within and across the different regions which will underpin future spending on defense including:

- Combatting the expansion of ISIS and other asymmetric threats
- Contesting the ambitions of a resurgent Russia
- Maintaining spending levels in line with NATO and other coalition commitments
- Maritime and border protection
- Developing effective strategies to counter China

"While the North American defense budget will represent the largest expenditure, the rate of growth will be hampered by the continuing impact of sequestration despite being offset by discretionary supplementary spending in the medium- and long-term," predicts **Asif Anwar**, Director of the ADS service. "On the other hand, we forecast **defense spending will continue to accelerate in the Asia-Pacific region, growing at the fastest CAGR globally of 5.6 percent and surpassing <b>North American expenditure levels by 2020."** 

"This year's analysis expanded coverage to 89 countries, looking at a range of factors including GDP growth, threat perception and political intent on force modernization," noted **Eric Higham**.

—Strategy Analytics strategy analytics.com

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## In the News



By combining complementary mindsets on the leading edges of electronic and radiofrequency device engineering, a pair of researchers in DARPA's Young Faculty Award program has devised **ultratiny**, **electronic switches with reprogrammable features resembling those at play in inter-neuron communication**. These highly adaptable nanoscale switches can toggle on and off so fast, and with such low loss, they could become the basis of not only computer and memory devices but also multifunction radiofrequency (RF) chips, which users might reprogram on the fly to behave first like a cell-phone's signal emitter but then, say, as a collision-avoidance radar component or a local radio jammer.

**Reconfigurable RF systems** like these depend on the availability of minuscule RF switches that can be integrated into chips and whose switching characteristics can be readily reprogrammed to serve different RF functions. So far, however, reconfigurable RF switches have been of limited use because of their performance drawbacks including added noise, size, power consumption, functional instability and lack of durability.

As a step toward overcoming these constraints, two of DARPA's Young Faculty Award (YFA) recipients, Qiangfei Xia and Joseph Bardin, both Assistant Professors in the Department of Electrical and Computer Engineering at the University of Massachusetts Amherst, teamed up to invent and demonstrate new nanoscale RF switches based on so-called memristor technology. Bardin (in the YFA program since 2011) brought to the duo expertise in reconfigurable RF integrated circuits, while Xia (in the YFA program since 2012) contributed prowess in the design and fabrication of nanoscale memristor devices. Inspired by discussions with their YFA mentor-DARPA's Microsystems Technology Office Director Bill Chappell— Xia and Bardin combined their strengths to devise what they describe in a recent Nature Communications article as "nanoscale memristive radiofrequency switches."

Memristive devices are switches whose ease or difficulty of toggling between on and off states is determined by the history of voltage and/or current



**applied to the switch structure.** That means they have the potential to be programmed to serve a range of purposes by applying specific patterns of charges. The switches that Xia and Bardin are made of two conductive elements separated by a thin dielectric of just 35 nanometers, or about the width of a virus. Changes in applied voltages or currents in these switches trigger the formation or disintegration of conductive filaments between the elements—a process that resembles neuron signal transmission, where similarly tiny gaps are briefly and reversibly bridged by chemical neurotransmitters, allowing electrochemical signals to propagate from one neuron to the next.

Seven teams from around the country have earned the right to play in the final competition of **DARPA's Cyber Grand Challenge (CGC), a first-of-its-kind tournament designed to speed the development of automated security systems able to defend against cyberattacks as fast as they are launched.** The winners successfully squared off against dozens of other teams for the opportunity to compete head to head next year for nearly \$4 million in prizes—and the chance to help revolutionize cybersecurity going forward.

Computers are important for detecting known network vulnerabilities and the swarms of malicious programs that are constantly seeking to take advantage of those weaknesses, but cyber defense today still ultimately depends on experts to patch those weaknesses and stymie new attacks—a process that can take months or longer, by which time critical systems may have been breached. **CGC aims to automate the cyber defense process to identify weaknesses instantly and counter attacks in real time.** 

Out of 104 teams that had originally registered in 2014, 28 teams made it through two DARPA-sponsored dry runs and into last month's CGC Qualifying Event. In that contest, teams tested the high-performance computers they had built and programmed to play a round of "capture the flag" (CTF)—a game that experts use to

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## In the News

test their cyber defense skills. CTF games require competitors to reverse engineer software created by contest organizers and locate and heal its hidden weaknesses in networked competition. The CGC final event will take place in Las Vegas in August 2016, in conjunction with DEF CON, home of the longest-running annual CTF competition for experts.

"After two years of asking 'What if?" and challenging teams around the world with a very difficult series of preliminary events, we've shown that there is a place for computers in an adversarial contest of the mind that until now has belonged solely to human experts," said Mike Walker, DARPA program manager. "As we had hoped when we launched this competition, the winning teams reflect a broad array of communities-academic pioneers of the field, security industry powerhouses, and veterans of the CTF circuit. each of which brings to CGC its own strengths."

Each team designed an innovative system that achieves, to varying degrees, the difficult task of **finding and fixing software safety problems in the kind of code used everywhere every day.** "The results bode well for an exciting competition next year and confirm the value of using a grand challenge format," Walker said. "With no clear best approach going in, we can explore multiple approaches and improve the chances of producing groundbreaking improvements in cybersecurity technology."

\* \* \*

The IEEE North Jersey Section AP/MTT Joint Society chapter will hold its 30<sup>th</sup> annual symposium and mini-show on Thursday, October 1 at the Hanover Manor, 16 Eagle Rock Ave., East Hanover, NJ. The event will feature 10 - 12 technical talks and 50 exhibitor tables. The show is open to the technical community and there is no charge for admission. A complimentary breakfast and lunch will be provided for all attendees. For further information contact **Kirit Dixit** (kdixit@microcomsales.com), **George Kannell** (gkk@lgsinnovations.com), or **Arthur Greenberg** (a.h.greenberg@ieee. org).

\* \* \*

**Raytheon Company** has named **Southern Methodist University** (SMU) as a strategic partner in cyber research based on the company's collaborative efforts with the Darwin Deason Institute for Cyber Security in SMU's Bobby B. Lyle School of Engineering. The strategic partnership includes joint research projects in cyber security, Raytheon internships for SMU students, and strategic education initiatives benefiting both SMU and Raytheon.

"We are very proud to have earned this designation," said **Fred Chang**, director of the Deason Institute and the Bobby B. Lyle Endowed Centennial Distinguished Chair in Cyber Security. "The work we do together benefits SMU and Raytheon, government and industry, and ultimately anyone with a laptop or smart phone. It will also help train our students to become part of a desperately needed workforce of cyber defenders."

"Collaboration between academic centers of excellence like SMU and industry leaders like Raytheon is a powerful engine for innovation," said **Dave Wajsgras**, president of Raytheon Intelligence, Information and Services. "This strategic partnership is an example of Raytheon's commitment to growing the cyber workforce and enhancing the technology and capabilities needed to help our customers and society face the ever growing cyber threat."

\* \* \*

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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			
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400-1000	500 1000	0.6 0.6	2 2	20 15	0.25 0.2	1.25 1.2	PH90-400-1000-R5N PH90-400-1000-1KN
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## Doherty Amps

## High-Efficiency Doherty Amplifiers Using Class-F and Inverse Class-F Load Networks with a Quarterwave Transmission Line

#### By Andrei Grebennikov

In modern wireless communication, broadcasting, and industrial systems, it is required that the power amplifier operate with high efficiency and low harmonic output level simultaneously.

Increasing power amp efficiency while maintaining low harmonic output level. To increase efficiency of the power amplifier, it is possible to apply a switchmode Class-E, Class-F, inverse Class-F, or mixed Class-E/F technique [1, 2].

Highly efficient operation of the power amplifier can generally be obtained by applying bi-harmonic or polyharmonic modes when an additional single- or multi-resonant circuit tuned to the odd or even harmonics of the fundamental frequency is added to the load network. An infinite number of odd-harmonic resonators results in an idealized Class-F mode

with a half-sinusoidal current waveform and a square voltage waveform at the device output. Similarly, in inverse Class-F power amplifiers optimized by odd-harmonic short-circuit termination and even-harmonic open-circuit peaking, the fundamental and harmonic load-network impedances result in a half-sinusoidal voltage waveform and a square current waveform at the device output to obtain maximum efficiency.

The average efficiency of the power amplifier can further be increased by using a Doherty configuration with a Class-B or Class-AB bias in the carrier amplifier and a Class-C bias in the peaking amplifier [2]. In some cases, the Class-F design strategy can be applied to the carrier amplifier, whereas the peaking amplifier operates in a conventional Class-C mode [3]. For example, the load network of a Class-F/Class-C Doherty amplifier can be connected to the drain through the short-circuited quarterwave transmission lines providing inherent even-harmonic suppression [4]. In this case, the drain current of the Class-B biased carrier device contains the DC, fundamental-frequency, and even-harmonic components, whereas the drain current of the Class-C biased peaking device is purely sinusoidal. Implementation of both the carrier and peaking amplifiers with a Class-F load network containing a series quarterwave line can provide an increase of the overall efficiency and improvement of the harmonic suppression level [5]. In an unbalanced Doherty configuration when the carrier amplifier operates in a Class-F mode, while the peaking amplifier operates in an inverse Class-F mode, the backoff peak efficiency point can be shifted from the conventional 6 dB to 8.2 dB [6].

#### **Class F with Quarterwave Transmission Line**

Ideally, a control of an infinite number of the harmonics maintaining a square voltage waveform and a half-sinusoidal current waveform at the drain can be provided using a parallel quarterwave transmission line and a series resonant circuit tuned to the fundamental frequency [2]. Figure 1 shows the circuit schematic of a Class-F power amplifier with a parallel



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## Doherty Amps



Figure 1 • Schematic of Class-F power amplifier with parallel transmission line.

quarterwave line using a 28-V 10-W Cree GaN HEMT CGH40010F device. For even harmonics, the short circuit on the top side of the quarterwave line is repeated, thus producing a short circuit at the drain. However, the short circuit at the top side of the quarterwave line produces an open circuit at the drain for odd harmonics. Here, the loaded quality factor of the series resonant circuit tuned to the fundamental frequency is sufficient to provide the sinusoidal output current flowing into the 50- $\Omega$  load.

To better illustrate the drain voltage and current waveforms with minimum effect of the device parasitic output parameters, a sufficiently low operating frequency of 200 MHz was chosen. In this case, a simple lossy RL input shunt network is used to match the device input impedance to a 50- $\Omega$  source and to compensate for the device input gate-source capacitance of about 5 pF at the fundamental frequency that results in a return loss greater than 20 dB. The length of the parallel quarterwave line was optimized to maximize efficiency taking into account the device parasitic parameters such as the drainsource capacitance  $C_{ds}$  and series drain inductance provided by the combined bondwire and package lead inductance. The series  $40-\Omega$  resistor connected to the device gate is added to provide unconditional operation stability. The simulated drain voltage appears close to a square waveform and drain current similar to a half-sinusoidal waveform are shown in Fig. 2(a), where small waveform ripples (minimized by load-network parameter optimization) can be explained due to effects of the device output drain-source capacitance of about 1.3 pF and package parasitics at higher-order harmonic components. As a result, a maximum drain efficiency of 84.9% with a power gain of 17.2 dB at an input power of 23 dBm is obtained with a sine-wave driving signal, as shown in Fig. 2(b). Harmonic components are suppressed by greater than 42 dB.

Figure 3 shows the circuit schematic of a Class-F power amplifier with a series quarterwave line using a 28-V 10-W Cree GaN HEMT CGH40010F device. This type of a Class-F power amplifier was initially proposed to be used at higher frequencies where implementation of the load networks with only lumped elements is difficult and the parasitic device output (bondwire or package lead) inductance is sufficiently small [1]. For even harmonics, the short circuit on the load side of the transmission line is repeated, thus producing a short circuit at the drain. However, the short circuit at the load produces an open circuit at the drain for odd harmonics with resistive load at the funda-

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## Doherty Amps



Figure 2 • Simulated waveforms, gain, and efficiency of Class-F GaN HEMT power amplifier with parallel transmission line.

mental. Unlike the case with a parallel quarterwave transmission line, such a Class-F load network configuration with a series quarterwave line can provide an impedance transformation. The loaded quality factor of the shunt resonant circuit is high enough to provide the sinusoidal current flowing into the 50- $\Omega$  load.

In Class F, the optimum load resistance  $R_L$  can be obtained for the DC supply voltage  $V_{\rm cc}$  and fundamental-frequency output power  $P_{\rm out}$  delivered to the load as [2]

$$R_{\rm L} = \frac{8}{\pi^2} \frac{V_{\rm cc}^2}{P_{\rm out}} \qquad (1)$$

#### Inverse Class F with Quarterwave Transmission Line

An idealized inverse Class-F operation mode can be represented by using a sequence of the series resonant circuits tuned to the fundamental and odd harmonics. An infinite set of the series resonant circuits tuned to the odd harmonics can be effectively replaced by a series quarterwave line with the same operating capability [7]. Such a circuit representation of an inverse Class-F power amplifier with a series quarter-wave line loaded by the series resonant circuit tuned to the fundamental frequency and based on a 28-V 10-W Cree GaN HEMT CGH40010F device is shown in Fig. 4.

The high-Q series-tuned output circuit presents to the transmission line a load resistance at the frequency of operation. For even harmonics, the open circuit on the load side of the transmission line is repeated, thus producing an open circuit at the drain. However, the quarterwave line converts the open circuit at the load to a short circuit at the drain for odd harmonics with resistive load at the fundamental frequency.

In inverse Class F, the optimum load resistance RL can be obtained for the DC supply voltage  $V_{\rm cc}$  and fundamental-frequency output power  $P_{\rm out}$  delivered to the load as [2]



Figure 3 • Schematic of Class-F power amplifier with series transmission line.

$$R_{\rm L} = \frac{\pi^2}{8} \frac{V_{\rm cc}^2}{P_{\rm out}} \qquad (2)$$

Similarly to the conventional Class-F GaN HEMT power amplifier, a simple lossy RL input shunt network is also used to match the device input impedance to a 50- $\Omega$  source and to compensate for the device input gate-

source capacitance at the fundamental frequency. The length of the series quarterwave line was optimized to maximize efficiency taking into account the device parasitic parameters. The simulated drain voltage (close to halfsinusoidal) and current (close to square) waveforms are shown in Fig. 5(a), where small deviations from the ideal waveforms (with optimized load-network parameters) can be explained due to effect of the device output drainsource capacitance  $C_{\rm ds}$  and package parasitics. In this case, a maximum drain efficiency of 85.2% with a power gain of 14.6 dB at an input power of 27 dBm is obtained with a sine-wave driving signal at 200 MHz, as shown in Fig. 5(b).

#### Doherty Amplifier Using Class-F Mode

Figure 6 shows the circuit schematic of a Doherty configuration based on a Class-F mode with a parallel quarterwave line for the peaking amplifier and on a Class-F mode with a series quarter-wave line for the carrier amplifier using two 28-V 10-W Cree GaN HEMT CGH40010F devices. Here, a series quarterwave line also provides an impedance transformation required at backoff output power levels. According to Eq. (1), both carrier and peaking devices see the same load impedance close to 50  $\Omega$  at  $V_{\rm cc}$  = 28 V and  $P_{out} = 10$  W, assuming the saturation drain voltage of about 2-3 V. The output quarterwave transmission line with a characteristic impedance of 35.3  $\Omega$  is necessary to match with a standard 50- $\Omega$  load. The quadrature 90° hybrid coupler is used at the input to split signals between the carrier and peaking amplifying paths.

In this case, the conventional balanced Doherty structure, where both the carrier and peaking amplifiers are operated in a Class-F mode, provide a maximum output power of 43.2 dBm with a drain efficiency of 85.6% and a power gain of 13.2 dB and a backoff peak efficiency point at an output power of 37.0 dBm (6.2-dB backoff) with a drain efficiency of 68% and a power gain of 17 dB, as shown in Fig. 7.



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Figure 4 • Schematic of inverse Class-F power amplifier with transmission line.

#### Doherty Amplifier Using Class-F and Inverse Class-F Modes

Figure 8 shows the circuit schematic of a Doherty configuration using a Class-F mode with a parallel quarterwave line for the peaking amplifier and an inverse Class-F mode with a series quarterwave line for the carrier amplifier. Here, a series quarterwave line also provides an impedance transformation required at backoff output power levels. The quadrature 90° hybrid coupler is used at the input to split signals between the carrier and peaking amplifying paths. From Eqs. (1) and (2), it follows that the carrier device operating in an inverse Class-F mode sees the load impedance by 1.5 times greater than the peaking device operating in a Class-F mode, thus resulting in an unbalanced Doherty structure in nominal operation.

As a result, when using an impedance inverter with the characteristic impedance of  $Z_1 = 50 \ \Omega$  and an output transformer with the characteristic impedance of  $Z_2 =$  $35.3 \ \Omega$ , a maximum output power of 43.3 dBm with a drain efficiency of 87.0% and a power gain of 14.2 dB and a backoff peak efficiency point at an output power of 38.3 dBm (5-dB backoff) with a drain efficiency of 80.0% and a power gain of 16.3 dB are achieved, as shown in Fig. 9(a). In this case, the DC current flowing through the carrier



Figure 5 • Simulated waveforms, gain, and efficiency of inverse Class-F GaN HEMT power amplifier with transmission line.

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## Doherty Amps



Figure 6 • Circuit schematic of GaN HEMT Doherty amplifier using Class-F mode.

device is 0.53 A, whereas the DC current flowing through the peaking device is 0.34 A, demonstrating an unbalanced operation condition. To provide the balanced operation mode with the same DC current of 0.46 A in both the carrier and peaking ampli-fiers corresponding to a 6-dB backoff efficiency point, the characteristic impedances  $Z_1$  and  $Z_2$  should be set to 55  $\Omega$  and 32.3  $\Omega$ , respectively.

Further increase in the characteristic impedance of



the impedance inverter to  $Z_1 =$ 60  $\Omega$  and the corresponding decrease in the characteristic impedance of the output transformer to  $Z_{\scriptscriptstyle 2}$  = 30.3  $\Omega$  result in a maximum output power of 43.8 dBm with a drain efficiency of 85.2% and a power gain of 15.5 dB and a backoff peak efficiency point at an output power of 35.8 dBm (8-dB backoff) with a drain efficiency of 82.9% and a power gain of 14.0 dB, as shown in Fig. 9(b). Here, the DC current of the peaking device increases to 0.54 A, while the DC current for the carrier device reduces to 0.38 A. To achieve a 9-dB

Figure 7. Power gain and efficiency of GaN HEMT Doherty amplifier using Class-F mode.



Figure 8 • Circuit schematic of GaN HEMT Doherty amplifier using Class-F and inverse Class-F modes.

backoff peak efficiency point, it needs to increase the characteristic impedance of the impedance inverter to  $Z_1 = 65 \ \Omega$  and to decrease the characteristic impedance of the output transformer to  $Z_2 = 28.3 \ \Omega$ . In this case, the DC current through the carrier device becomes equal to 0.35 A, whereas the DC current through the peaking device grows to 0.72 A (maximum allowable drain current for CGH40010F is 1.5 A). Thus, a 4-dB improvement in backoff peak efficiency point can be achieved by simply increasing the characteristic impedance of the impedance inverter from 50 to 65  $\Omega$  (1.3 times) and decreasing of the characteristic impedance of the output transformer from 35.3 to 28.5  $\Omega$  (by less than 1.25 times).

#### About the Author

Dr. Andrei Grebennikov (Senior Member of IEEE) of Microsemi Corp., Aliso Viejo, Calif., received his Dipl. Eng. degree in radio electronics from the Moscow Institute of Physics and Technology and Ph.D. degree in radio engineering from the Moscow Technical University of Communications and Informatics in 1980 and 1991, respectively. He obtained long-term academic and industrial experience working with Moscow Technical University of Communications and Informatics (Russia), Institute of Microelectronics (Singapore), M/A-COM (Ireland), Infineon Technologies (Germany/Austria), Bell Labs, Alcatel-Lucent (Ireland), and Microsemi (USA) as an engineer, researcher, lecturer, and educator. He lectures as a Guest Professor at University of Linz (Austria) and presented short courses and tutorials as an Invited Speaker at International Microwave Symposia, European and Asia-Pacific Microwave Conferences, Institute of Microelectronics, Singapore, Motorola Design Centre, Malaysia, Tomsk State University of Control Systems and Radioelectronics, Russia, and Aachen Technical University, Germany. He is an author and co-author of more than 100 papers, 25 European and US patents and patent applications, and eight books dedicated to RF and microwave circuit design.

#### References

1. H. L. Krauss, C. W. Bostian, and F. H. Raab, *Solid State Radio Engineering*, New York: John Wiley & Sons, 1980.

2. A. Grebennikov, N. O. Sokal, and M. J. Franco, *Switchmode RF and Microwave Power Amplifiers*, New York: Academic Press, 2012.

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## Doherty Amps



Figure 9 • Power gain and efficiency of GaN HEMT Doherty amplifier using Class-F and inverse Class-F modes.

3. P. Colantonio, F. Giannini, R. Giofre, and L. Piazzon, "Theory and experimental results of a Class F AB-C Doherty power amplifier," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-57, pp. 1936-1947, Aug. 2009.

4. K. W. Eccleston, K. J. I. Smith, and P. T. Gough, "A compact Class-F/ Class-C Doherty amplifier," *Microwave and Optical Technology Lett.*, vol. 53, pp. 1606-1610, July 2011.

5. Y. S. Lee, M. Woo, and Y. H. Jeong, "High-efficiency Doherty amplifier using GaN HEMT Class-F cells for WCDMA applications," *Proc. 2008 IEEE Int. Microwave Millimeter-Wave Technol. Conf.*, vol. 1, pp. 270-273.

6. S. Goto, T. Kunii, A. Inoue, K. Izawa, T. Ishikawa, and Y. Matsuda, "Efficiency enhancement of Doherty amplifier with combination of Class-F and Inverse Class-F schemes for S-Band base station application," 2004 IEEE MTT-S Int. Microwave Symp. Dig., pp. 839-842.

7. M. K. Kazimierczuk, "A new concept of Class F tuned power amplifier," *Proc. 27th Midwest Circuits and Systems Symp.*, pp. 425-428, 1984.

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## Using Power Sensors in Unattended Applications

#### By Orwill Hawkins

Power sensors are one of the most universal test devices in the microwave industry. They are utilized in a broad range of applications such as laboratory, manufacturing, and in the field

New sensors are capable of unattended or autonomous operation including storing measurements to internal flash. testing and verification. Power sensors are the "Gold Standard" when comes to calibrating other equipment or determining or verifying actual power.

Recent advances in Power Sensors include broadened connectivity including Ethernet and TTL interfaces such as I2C/SPI TTL along with added capability such as unattended, autonomous operation, the subject of this article.

These new sensors are capable of unattended or autonomous operation including storing the measurements to internal flash. Also a calibrated DC

voltage is available that is proportional to measured power. This is often referred to a Recorder Out. It is important to note that in unattended operation, these capabilities are available with no computer connected.

#### No Computer or Power Meter Connected

One such example is the LadyBug LB5918A Sensor with option UOP (Unattended Autonomous Operation) employed for this paper. This sensor is capable of making and storing measurements with no computer or power meter connected. Only 5 Volt power is required. The self-contained, high-accuracy, fully calibrated sensor includes a user programmable internal real-time clock with backup, a substantial non-volatile memory for measurement storage, and

programmable ล measurement consystem. In trol addition to non-volatile storage, the sensor's Recorder Output can be utilized in unattended providing mode. accurately calibrated analog output for various uses. A LB5918A with UOP option installed is shown in Figure 1, along with the sensor's included full featured application operating in the background. The



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	PWR-6GHS	CW	1 to 6000	USB	695.00
	PWR-8GHS	CW	1 to 8000	USB	869.00
NEW!	PWR-8GHS-RC	CW	1 to 8000	USB & Ethernet	969.00
NE	PWR-8FS	CW	1 to 8000	USB	969.00
	PWR-4RMS	True RMS	50 to 4000	USB	1169.00

\*Measurement speed as fast as 10 ms for model PWR-8-FS. All other models as fast as 30 ms

† Dynamic range as wide as -35 to +20 dBm for model PWR-4RMS. All other models as wide as -30 to +20 dBm. Excel is a registered trademark of Microsoft Corporation in the US and other counties. Neither Min-forcuits nor Min-Circuits Power Sensors are affiltated with or endorsed by the owners of the above-referenced trademarks.



## Power Sensors





Figure 3 • Set Frequency to 1.8 GHz & Averages to 10.

UOP features are complemented by *Just Measure*— LadyBug's patented No-Zero No-Cal system that eliminates user calibration requirements.

Figure 2 • LB5918A in Unattended Mode.

The no-zero, no-cal feature is an essential to usability in autonomous applications. This sensor is capable of highly accurate measurements under varying environmental conditions without user intervention.

In Figure 2 the sensor is logging measurements in unattended mode. It is not connected or controlled by a PC. Instead it is powered by a 5 volt USB power adaptor. After a period of time the sensor can be connected to an external PC and the logged measurements can be retrieved. Each measurement is accompanied by a time and date stamp.

The LB5918A Sensor's Option UOP has four modes of operation, *Off, Basic, Advanced* and *Reset*. The sensor is fully self-contained and the settings are stored in the sensor. When UOP mode is set to *Off;* the sensor functions as a normal power sensor.

*Basic* mode is designed to assure maximum functionality with minimum setup. Once UOP is set to *Basic* and powered up, the sensor will collect measurements until its memory is full. If power is lost and then restored the sensor will resume unattended operation. Setting *Basic* when using the sensor's factory default settings (Preset), will cause the sensor to immediately begin making and storing measurements. Adjusting the measurement setup is easy. *Basic* Unattended mode utilizes the sensor's current measurement setup and parameters. Simply set up the measurement parameters with UOP set to *Off*. Then set UOP mode to *Basic*. Once this is done, the sensor begins making and storing measurements. No computer or power meter is required. The sensor only requires 5VDC to operate. Again, if power is lost, then restored, the sensor will automatically resume unattended operation.

UOP mode must be set to *Off* to use the sensor for normal operation. As with all power sensors, frequency and averaging are important parameters. These should be set to achieve high accuracy, refer to Figure 3. To start unattended operation, set the Measure button to Single then click *Start UOP* as shown in Figure 4.

Measurements and storage commence as soon as *Start UOP* has been clicked. If power is removed and restored at a later time, the sensor will simply start appending additional measurements to the sensors non-volatile memory.

All measurements are stored sequentially in memory on a real-time basis. Measurements are time stamped using the internal RTC (real-time clock). The RTC system includes a backup that will maintain the clock for at least a day when the sensor is not powered. The real-time clock's crystal is disciplined by the sensor's high accuracy time base when the sensor is powered. This system provides the user very accurate time stamp unattended measurements.

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Figure 4 • Sensor Settings.

#### Demonstration

To demonstrate unattended operation, a PLL demonstration board was used as shown in Figure 5. The board was set to generate 1.8 GHz at various power levels. Prior to running the demonstration, the sensors unattended memory was cleared by selecting *UOP* then *Clear UOP Memory* in LadyBug's Precision Power Meter Application. Frequency and Averaging were set as shown in Figure 3.

A separate source was connected to the sensor when the computer was used to initiate UOP. Since the sensor begins storing measurements as soon is UOP is set to *Basic*, measurements were stored while the computer was still connected. The source level was toggled before the sensor was disconnected from the computer. The initial signals were logged as shown below in Figure 6, which details a portion of the 231 stored measurements that were made during the entire demonstration. When UOP memory is retrieved, the sensor returns an index number; date & time stamp; measured power and flags, if present, for each measurement.

Upon completion of the unattended PLL measurements, the sensor was reconnected to the computer and the UOP mode returned to *Off.* Prior the setting the condition to *Off,* a few measurements were automatically logged at the noise floor when the sensor was connected. These are shown and noted on the right of the graph in Figure 7.

Data was retrieved from the sensor using the PMA-12 application by selecting the UOP dropdown then *Retrieve Data*. A window opens that lists the available measurements. Maximum was selected and all available data was downloaded. The list of 241 stored measurements is partially displayed in Figure 6, the entire list was several pages long.

#### **Demonstration Graph**

The graph in Figure 7 was created in EXCEL with data entered using the copy button visible in Figure 6 and described above. The entire demonstration used only 231 measurements of the sensor's 50,000,000+measurement storage capability while using Basic mode. The data marked Initial UOP Start up was collected after starting UOP and before the sensor was disconnected from the computer. Data marked PLL Output Measurements began at measurement index 21 and is the data collected from the board. Power was set to three differ-

ent levels measuring -38.9 dBm, - 9.7 dBm and 0.4 dBm. Finally, the data marked *Measurements made while connected to stop UOP* were made when the sensor was reconnected to the computer just prior to turning off UOP. These data are all shown in the graph shown in Figure 7.

At the demonstrated averaging and storage rate, the sensor could log measurements without interruption for over 250 days provided power was supplied.

#### **Other Information**

Specific measurement data can be downloaded by specifying a beginning and ending index number. Large blocks of data can be downloaded from the sensor by selecting two or more ranges of measurement indexes. Using the copy button shown in Figure 6, very large or small blocks of data can be pasted into EXCEL or various other programs that use Windows' copy and paste system.



Figure 5 • Test Setup.

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Impedance:	50 ohm	RF leakage, min:	-100 dB to 18 GHz
Time delay:	1.2 ns/ft.	Temp range:	-65°C to +165°C
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4	8/7/2015	8:3:17.057	+13.033		
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49	8/7/2015	8117138-563	-58.887		
50	8/7/2015	8:17:38.895	-35.574		
21	8/7/2935	012/139.227	-10.912		
24	8/7/2015	8117139.559	-36.903		
23	8/7/2015	611/159.691	-36.905		
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Figure 6 • Table of Collected Data.

Alternatively, data can be saved to a CSV (comma separated value) text file that can be opened by various programs including EXCEL. This can be particularly useful for large amounts of data and for users that wish to share data by email etc.

Advanced measurements can also be made while the sensor is operating in unattended modes. This includes internal and externally triggered measurements. For



#### AMCOM GaN HEMT MMIC Summary

Model	Frequency (GHz )	G <sub>ss</sub> (dB)	P <sub>5dB</sub> (dBm)	Eff <sub>(5dB)</sub> (%)	V <sub>d</sub> (V)	I <sub>dq</sub> (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. ! CW Operation.



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Figure 7 • Graph of Logged Measurements.

example, internal or external triggering functions can be setup while the sensor is not in UOP. Once the measurement is setup and confirmed, UOP Basic can be started and the measurements will be made based on the triggering that was just setup and confirmed.

Recorder Output can be activated and used while in unattended autonomous mode. Recorder Output and Trigger Output share the same physical connection, and are controlled in the Output section in the sensors left control pane. Trigger Out is disabled when Recorder Out is in use.

The sensor can be powered by a USB power only cable, or if it is equipped with option SPI it can be powered through the SPI connection. A USB battery pack of sufficient capacity may be utilized (similar to the USB power supply shown in Figure 2). The sensor requires 5 volts at 500 Ma.

Unattended Autonomous applications include remote monitoring, unattended analog output applications, transmitter monitoring and triggered warning systems, portable equipment, and defense applications. The example sensor is designed for use in automated test equipment as well as isolated usage. It's very stable and accurate time base makes it suitable for long term monitoring as well as short term applications.

#### About the Author

Orwill Hawkins serves as Vice-President of Marketing at LadyBug Technologies, Santa Rosa, Calif. He has over three decades of management, marketing, engineering and manufacturing experience, and extensive hands-on design and manufacturing experience in the RF, analog, and digital fields. Among the many products he has designed and marketed are a self-contained RF field disturbance burglar alarm system, a sailboat speedometer, and various robotic servo systems. Additional inventions include a prototype oscilloscope, a CNC cutting system, and various other analog, digital and RF projects.

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## Product Highlights



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ZVA-183X+	0.7-18	26±1	24	33	3.0	845.00		
ZVA-213X+	0.8-21	26±2	24	33	3.0	945.00		
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## **Product Highlights**



#### Power Sensor Software Controls Multiple Sensors, Enables Comparative Measurements

LadyBug Technologies' new Precision Power Meter PMA-12 supports a broad range of Power Sensor functions. The application provides an ideal user interface for measuring a host of RF signal parameters and is included with LadyBug's LB5900 series True RMS Sensors. In addition to reporting and visualizing RF power in many ways, the software manages the sensor's extended functions such as its advanced Unattended Operation feature (Option UOP). The application is capable of controlling many sensors at once and can make comparative measurements between sensors. These advanced features combined with LadyBug's patented no-zero no-cal make an ideal solution for the laboratory, production facility and ATE industry.

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#### Handheld Analyzer

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## Product Highlights



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Power (min) dBm	+17	+17	+10	
Output Connector	2.92 mm	1.85 mm	WR-12	



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## Product Highlights



#### **Power Amp**

Richardson RFPD, Inc. announced that it is stocking a new benchtop power amplifier from TriQuint/Qorvo. The RM022020 features Qorvo's patented Spatium<sup>™</sup> combining technology to provide unprecedented performance in a general purpose laboratory bench top amplifier for applications that include lab work, test and measurement, load pull, EMI test, and anechoic chambers and test ranges.

## Richardson RFPD richardsonrfpd.com



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#### **Total Cost Solution**

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- Ideal for multilayer circuits
- Suitable for automated assembly lines
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## Product Highlights





#### **Power Dividers**

MECA announced the latest in its broad band line of power dividers with the type N model (80X-4-3.250WWP). Available in; 2, 4, 8 & 16-Way, 30W Wilkinson Power Dividers, optimized for excellent performance with industry leading specifications from 500 MHz – 6.00 GHz. IP67 rated and suited for indoor and outdoor app'ns. Typical VSWRs from 1.20:1 to 1.30:1, Isolation of 17 - 20 dB minimum while offering phase and amplitude balance typically only seen in narrower/octave band models.

#### MECA Electronics e-meca.com

# Cable App Note

SV Microwave released the Application Note for its Rapid Response Cable Assemblies. Use its interactive RF cable builder to build cables that ship in 5 business days. Customers can choose from a variety of in-stock standard connector series and cable types for miniature and low loss coaxial assemblies. The RF Cable Builder generates a custom data sheet complete with part number, technical specifications and pricing.

SV Microwave svmicrowave.com

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#### Switches

Ducommun offers two types of single-pole-double-throw (SPDT) manual coaxial switches for all applications. Current options range from DC to 3 GHz up to 50 Watts (CW) of power. For additional information regarding Ducommun's manual coaxial switches, please contact a sales representative. Ducommun Inc. RF Products has design Engineers who can create custom versions for your specific applications.

Ducommun ducommun.com



#### **One-Component Epoxy**

Combining simple handling properties with high strength, Master Bond Supreme 10HTF-1 is a single part adhesive/sealant for a variety of applications in the aerospace, electronics, optical, specialty OEM and related industries. At room temperature, this smooth paste system has an "unlimited" working life and cures rapidly at elevated temperatures. For example, typical cure schedules for Supreme 10HTF-1 are 5-10 minutes at 300°F or 15-20 minutes at 250°F.

Master Bond masterbond.com





#### **Impedance Matching Pads**

Models 851-879-FM3 and 851-879-MF3 are 50 to 75 Ohm impedance matching pads that operate DC - 3 GHz. The RF connector configurations for both are 50 Ohm SMA (male or female) to 75 Ohm F (male or female). Insertion loss is 5.7 dB nominal and VSWR is 1.50:1 maximum. The passive elements used to manufacture these resistive matching pads insure good impedance translation in wideband applications.

#### BroadWave Technologies broadwavetechnologies.com



#### **High Pass Filter**

Bree Engineering model number 803358 is a 2.0 - 18.0 GHz High Pass Filter with less than 1.2 dB (<1.0 dBa typical) of insertion loss at 2.0 GHz to 18.0 GHz, 14 dB return loss (17 dB typical) over 2.0 - 18.0 GHz, and rejection of 40 dBa minimum at <1650 MHz and 70 dBa minimum at DC-1500 MHz. Package size is 1.50 X 0.50 X 0.40 inches. SMA-F Connectors. Otherconfigurations available upon request.



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## Product Highlights



#### LNA

Model SBL-6539032040-1212-E1 is a low noise amplifier with a typical small signal gain of 20 dB and a nominal noise figure of 4 dB in the frequency range of 65 to 90 GHz. DC power requirement is +8 VDC/20 mA nominal. Input and output port configurations are both WR-12 waveguides with UG-387/U flanges. The mechanical configuration is an inline structure. Other configurations, such as

right angle (90 degree) and coaxial (1 mm) inline structure, are also available.

## SAGE Millimeter sagemillimeter.com





#### **Splitter**

Mini-Circuits EP2C+ is a MMIC splitter/combiner designed for wideband operation from 1800 to 12500 MHz. This model provides excellent power ratings in a tiny device package (4x4x1 mm), with up to 1.85W power handling (as a splitter) and up to 0.4A DC current handling. Manufactured using GaAs IPD technology, it provides a high level of ESD protection and excellent reliability.

Mini-Circuits minicircuits.com



#### **GaN Transistors**

Richardson RFPD announced availability and full design support for two new GaN transistors from Qorvo. The 5W TGF3020-SM and 30W TGF3021-SM input-matched transistors enable high linear gain and power efficiency in low-cost, space-saving surface-mount plastic QFN packages. The integrated input matching network enables wideband gain and power performance, and the output can be matched on-board to optimize power and efficiency for any region within the band.

Richardson RFPD richardsonrfpd.com

## Product Highlights



#### VNA Extension Modules

OML's VNA Extension modules extend from 50 to 500 GHz and are compatible with many modern vector network analyzers. Enabling engineers to conduct mm-wave S-parameter measurements; these modules also include options for variable attenuation, amplification in RF & LO paths, low power and intermodulation. Contact OML to specify the needs for your solution.

OML omlinc.com



#### GaN Amp

Model AMP4002P is a Solid-State X-Band High Power GaN Amplifier featuring 500W typical and 400W minimum pulse peak power over 9.1 - 9.5 GHz, Class AB linear operation GaN housed in a small form factor 19"rack. It incorporates an internal filter for -60 dBc Max harmonics and features a state of the art controller capable of supporting Ethernet TCP/IP, RS422/485 and remote Bluetooth connectivity. Other configurations available include 9.5 - 10 GHz, 400W and 9.1 - 9.5GHz, 1KW.

## Exodus Advanced Communications exoduscomm.com



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

#### Amplifier

Model SBL-9031042540-1010-E1 is a low noise amplifier with a typical small signal gain of 20 dB and a nominal noise figure of 4 dB in the frequency range of 90 to 100 GHz. DC power requirement is +8 VDC/30 mA nominal. Input and output port configurations are both WR-10 waveguides with UG-387/U-M flanges. The mechanical configuration is an inline structure. Other configurations, such as right angle (90 degree) and coaxial (1 mm) inline structure, are also available.



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



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## Myriad Trends Drive Micro Connector Growth

#### By Mike Higashikawa and Darren Schauer

It's not enough for micro connectors to be small. They must also be tough, meeting the same performance standards as larger connectors while being robust enough to survive being assem-

From smartphones to radar installations, micro connectors enable more powerful, smallerfootprint devices bled into a finished product. As the quality and durability of micro connectors has grown, so has their use in a wide range of products. The market for micro connectors—including subminiature, micro miniature, and ultra-micro miniature connectors—is growing for several reasons.

One is the booming market for commercial products, such as mobile phones and other handheld devices. As the use of these products grow, so does demand for smaller and lower-profile components. Other key markets

include aerospace and defense (A&D) and medical. As electronic devices are downsized and become more complex, printed circuit board (PCB) real estate becomes more valuable, hence the need for smaller and smaller connectors.

Getting a Handle on Handheld

The enormous size of the handheld device market is driving the development of micro connectors capable of very high data speeds. For example, 10 Gbps board-to-board connectors are com-



Figure 1 • SlimStack ArmorTM 0.35mm-pitch connectors from Molex, which are designed for mobile device and other tight-packaging applications, deliver up to 3.0A of extra power via protective metal covers. Molex image.

mon, and some advanced miniature board-to-board connectors can handle up to 20 Gbps.

The connectors used in these applications are extremely small. For example, Molex offers board-to-board connectors as small as 0.35mm pitch and flexible printed circuit (FPC) connectors as small as 0.20mm pitch. Connector size depends on the application. For example, PCB production places a very high premium on space, and smaller connectors will provide more space for other components, making the designer's job easier.

In addition to being robust, micro connectors must also be user-friendly. For example, Molex added metal cover nails on some board-to-board connectors to protect the connector housing wall by making it stronger and less prone to breakage during assembly. SlimStackTM Armor boardto-board connectors, which have mated heights as low as 0.60mm, are available with metal cover nails that can handle power while also protecting the housing wall during assembly. Also, micro connectors with more-generous lead-in alignment help assembly technicians find the "sweet spot" when mating connectors.

Maintaining good retention force after mating is especially important with micro connectors. Also, features such as audible-click and tactile-feel tell technicians when connectors are properly mated.

#### **A&D** Applications Flying High

In the A&D industry, lightweight, high-frequency RF micro connectors are commonly used. For example, subminiature push-on (SMP) connectors with 26 GHz ranges and subminiature push-on micro (SMPM) connectors with 40 GHz ranges (which are 30 percent smaller than SMP connectors) are widely used in board-to-board and cable-toboard applications.

These applications include ground-based radar and aircraft communications systems. While a ground-based radar installation is not small, it may include hundreds of thousands of components; micro connectors help reduce its total footprint. Likewise, lightweight micro connectors can help reduce the total weight of jet aircraft. Also, RF connectors are effective in low-power settings while offering low signal-to-noise ratios, and are capable of transmitting complex signals.

Growing demand for micro connectors has led to the development of products designed for new applications, such as extreme conditions. For example, Molex recently introduced the Multi-Port RF (MPRF) coaxial cable-toboard connector, a subminiature I/O device that provides secure electrical connection in high-vibration conditions and is capable of a minimum of 500 mating cycles. Though newly released, MPRF connectors are expected to be used in key A&D applications. For example, an application where the MPRF would be beneficial is within military transport vehicles, which sustain heavy vibration when in use. Medical devices will be another important application.

#### **Non-Magnetic Personalities**

Medical is already a key application for other types of micro connectors, which are typically used in devices such as scopes and probes. Connectors for medical devices must be non-magnetic, which requires replacing the nickel plating traditionally used in connectors with electroless nickel phosphorous. Other applications include medical devices such as MRI machines and CAT scanners, but these devices typically utilize larger connectors.

#### **Assembly Challenges**

One challenge faced by all users of micro connectors is building cable assemblies. It takes a skilled technician to trim small cables and terminate micro connectors. For example, an SMP connector has a contact OD of just 0.015" and an SMPM connector has a contact OD of just 0.012".

As a result, assembly processes that involve micro connectors usually require at least some automation, such as tape-and-reel packaging processes where components are supplied on paper or plastic tape in reels loaded on automated pick-and-place machines, which in turn place the components onto PCBs.

#### **Smaller and Denser**

As noted above, one of the trends driving the use of micro connectors is the need to maximize PCB real estate. As a result, designers are "trading down" the size of the connectors they use. For example, designers currently using screw-type SMAs (subminiature version A connectors) may migrate to more-compact SMPs because their next-generation module is being downsized. Also, more users are using multiport connector blocks, such as the MPRF, in 4-up, 6-up and 8-up formats. These blocks allow assembly technicians to thread in or solder down one block instead of multiple individual units. This helps reduce tolerance stack up and makes assembly simpler and faster.

While designing and assembling devices containing micro connectors can be challenging, assembly know-how is available to make this process easier. As devices continue to shrink, designers need to embrace—and take advantage of—today's micro connector technology.

#### **About the Authors:**

Mike Higashikawa is Regional Product Manager, Micro Products Division, for Molex Incorporated. Mike has over 17 years of experience in sales, account and product management, focusing on the design and development of micro connectors. He has a BA in International Business Relations from Nihon University in Japan. Prior to joining Molex, he worked in Sales and Program Management.

Darren Schauer is Product Manager, RF/Microwave Products for Molex Incorporated. Darren has over 13 years of experience in sales, account and product management, focusing on the design and development of microwave RF connectors and RF cable assemblies. He has a BS in Electronics Engineering Technology from DeVry University.

## Guest Editorial

(Continued from page 7)



Figure 1 • Chart from the IMS2015 Women in Microwaves panel session shows the ratio of female employees (blue bar) to female managers (red bar) for select countries.

collective capacity of its people to create value. An innovative culture accepts that the world has changed and is receptive to more changes coming in the future. "We all know it is the right thing to do," Patel says, "But most importantly, it is great for business."

Diversity in the workforce is not simply a matter of fairness. Diversity is good for business, and, as such, is a vital part of the future of high technology. Sandberg and Grant support this approach in their New York Times series<sup>9</sup> by pointing out that in order to increase diversity, the usual focus has been on fairness: "To achieve justice, we need to give women and minorities equal opportunities." But, history shows greater success is achieved when the focus is on societal benefit rather than fairness: "Equality is the desirable thing for us all."

This concept of a humanitarian benefit statement is also one that resonates with IEEE MTT-S President Tim Lee, who's leading our society into more humanitarian beneficial projects through IEEE Sight.<sup>10</sup> In recent years, IEEE has placed great emphasis on humanitarian technology activities, instituting the Humanitarian Ad Hoc Committee (HAHC) in 2011. As part of a strategic effort toward member engagement, HAHC has instituted a program called Special Interest Group on Humanitarian Technology (SIGHT). Some of the objectives of this group include bringing together members working in or wishing to work in humanitarian fields and encouraging and promoting them in activities that use humanitarian technologies, increasing awareness of IEEE members and engineers of the potential of their work to improve the standard of living of underserved populations, and encouraging them to increase efforts in this direction.

#### Conclusion

The momentum is building. Patel at Cisco is starting with a commitment to 1) recruit women and enable them to be connectors, mentors, and sponsors, 2) provide women with leadership opportunities, 3) be an advocate for work environment equalization, 4) structure an environment for women to have long term careers in engineering, and 5) anchor women's development efforts around leadership. He sees a day when women will be the majority in engineering.

Krzanich has committed to full representation at Intel by 2020. He says there is a massive change coming that we cannot begin to fathom. He goes on to say, "Like Likes



Figure 2 • Intel's Brian Krzanich displayed this slide that challenges the tech industry to increase the hiring of women and minorities and sets a goal of full representation in his company's workforce by 2020.

Like." Everyone is biased towards others like them. The only way to overcome bias is to have enough people with opposing biases on teams to balance that and make decisions that are different.

Hopefully more tech companies will begin to see the value of diversity in their workforces and will follow the lead of companies like Intel, Cisco, and Alibaba in taking real action to implement change.

#### **Call to Action**

Join the conversation on diversity in the months ahead either online at LinkedIn at linkedin.com/grp/ home?gid=6955695&trk=my\_groups-tile-grp or in person at upcoming IEEE MTT-S WIM sponsored diversity panel sessions at COMCAS in Israel (November 2, 2015), APMC in China (December 7, 2015), and iMarc in India (December 11, 2015).

#### **References:**

1. Videos of all presentations given at WIE 2015 can be viewed at http://bit.ly/ieeewie2015

2. https://ieeetv.ieee.org/ieeetv-specials/wie-ilc-2015-leadership-in-today-s-tech-industry-a-keynote-with-intel-ceo-brian-krzanich?rf=events%7C64&

3. *New York Times,* "At the Gadget Show, Intel CEO Issues Diversity Challenge," 1/6/15, http://www.nytimes.

com/aponline/2015/01/06/technology/ap-us-tec-gadgetshow-the-day-at-ces.html?\_r=1

4. New York Times, "How Men Can Succeed in the Boardroom and the Bedroom," 3/5/15 http://www. nytimes.com/2015/03/08/opinion/sunday/sheryl-sandbergadam-grant-how-men-can-succeed-in-the-boardroomand-the-bedroom.html

5. CNBC, "Jack Ma on One of Alibaba's 'Secret Sauces': Hiring Lots of Women," 1/23/16, http://www. cnbc.com/2015/01/23/alibabas-jack-ma-on-why-heemploys-a-lot-of-women.html

6. https://ieeetv.ieee.org/video/wie-ilc-2015-interactive-fireside-chat-on-innovation-with-sophievandebroek?rf=events | 64

7. Kate Remly, "Let's Talk About the Demographics," IMS 2015 NEED LINK

8. https://ieeetv.ieee.org/video/wie-ilc-2015-the-powerof-women-engineers-a-keynote-with-pankaj-patel-ofcisco?rf=events | 64

9. S. Sandberg and A. Grant, "When Talking About Bias Backfires," *The New York Times Sunday Review*, Dec. 6, 2014

10. http://www.ieee.org/special\_interest\_group\_on\_ humanitarian\_technology.html





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High Frequency Electronics (USPS 024-316) is published monthly by Summit Technical Media, LLC, 3 Hawk Dr., Bedford, NH 03110. Vol. 14 No. 9 September 2015. Periodicals Postage Paid at Manchester, NH and at additional mailing offices. POSTMASTER: Send address corrections to High Frequency Electronics, PO Box 10621, Bedford, NH 03110-0621. Subscriptions are free to qualified technical and management personnel involved in the design, manufacture and distribution of electronic equipment and systems at high frequencies. Copyright © 2015 Summit Technical Media, LLC

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Following ADI's acquisition of Hittite, the industry's broadest portfolio of RF and microwave solutions is now available through Richardson RFPD.

Look to us for the combined lineup that now covers the complete signal chain, from antenna to bits and back, across the entire frequency spectrum up to 110 GHz. Devices include ADI's industry-leading data converters and more than 2,000 high-performance products, from functional blocks to highly-integrated solutions, development platforms and modules.



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