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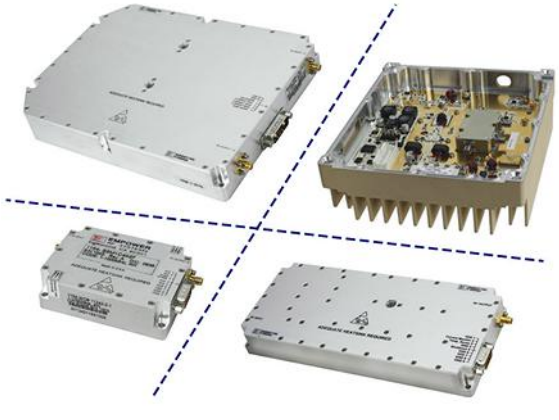

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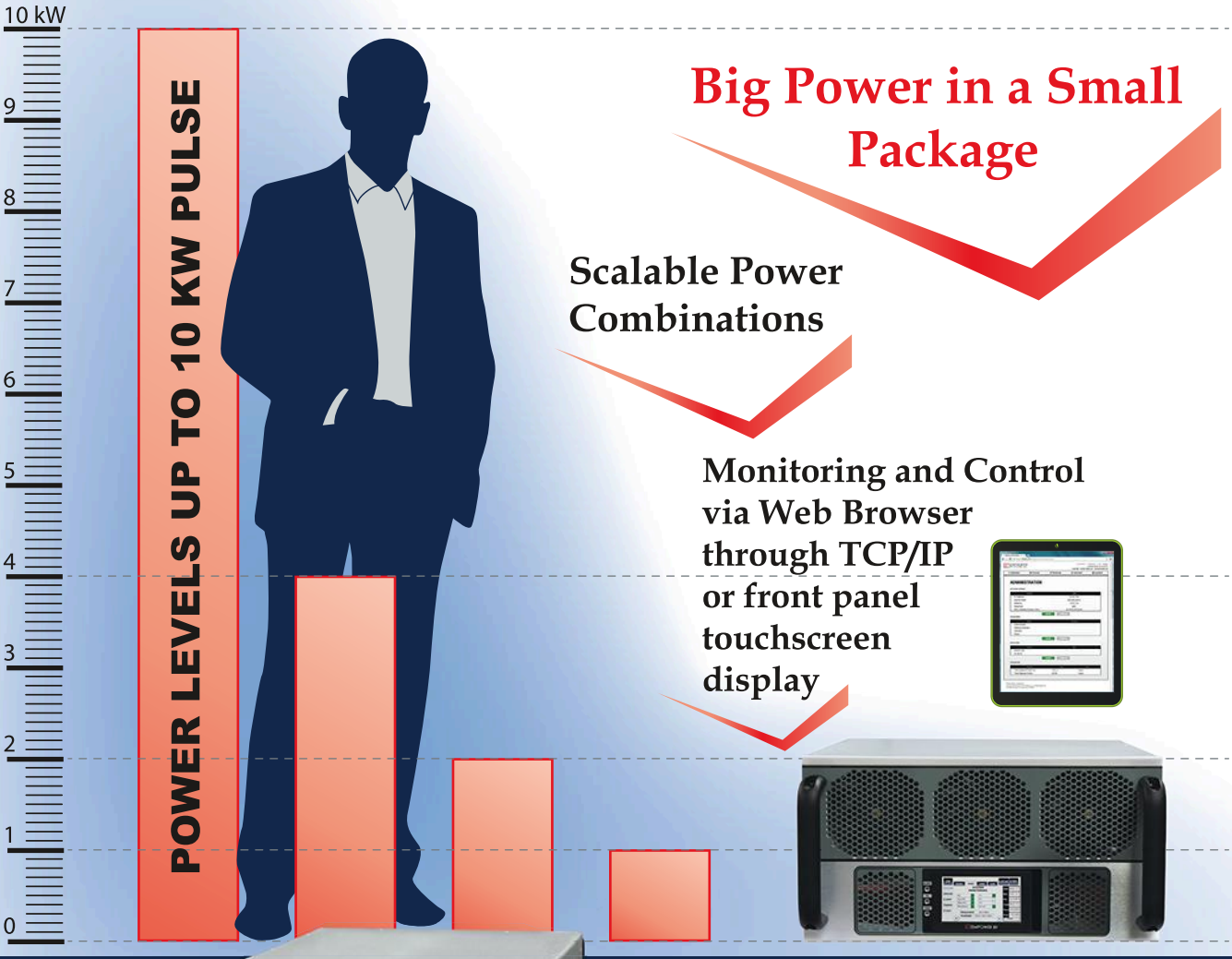

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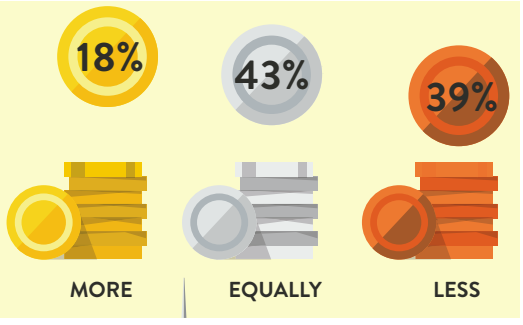

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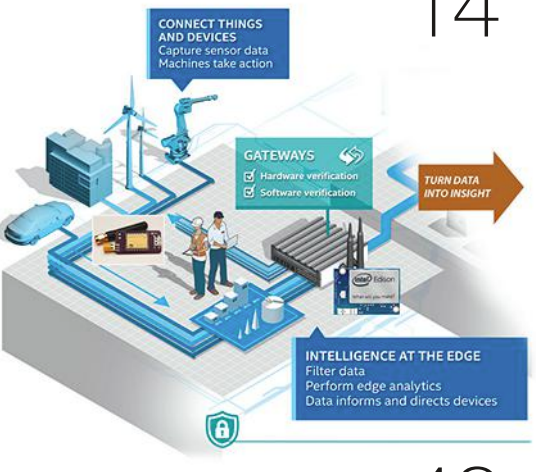

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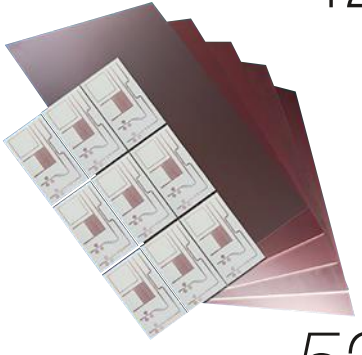

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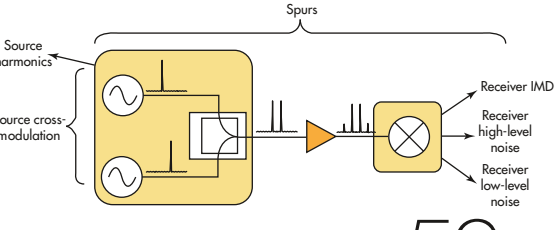

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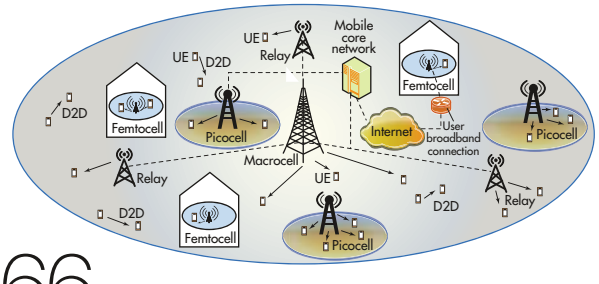

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Editorial

NANCY K. FRIEDRICH
Content Director
nancy.friedrich@penton.com

Catch Up with Today's Leaders

Welcome to our annual Leaders issue—an issue dedicated to profiling some of today's industry visionaries, trailblazers, and sources of inspiration across various engineering disciplines. This special issue was created specifically for key trade shows. After all, industry events are where we connect with current, former, and new customers, as well as forging partnerships and sharing ideas. We also win new business, which prompts us to drive our designs and products to reach new heights in performance, cost, and more.

Such communications and connections are extremely crucial these days, as applications, technologies, and products evolve so quickly. Forecasts and plans have to be made on shorter cycles or updated often, as the business environment is extremely dynamic. For project managers and those up the chain, this means that they have to have an overriding longer-range vision, but be ready to adapt it in the near term at any time.

The individuals and companies profiled in this issue chose to share their current visions. Think of this as a time capsule that shows today's driving trends, applications, products, technologies, and design challenges. Right now, for example, the engineering world is putting a lot of focus on areas like 3D printing, automotives, medical innovations, and the Internet of Things (IoT)—along with its Industrial Internet of Things (IIoT) offshoot. What is the IoT? Think of billions of sensors collecting information and then transmitting it, leading to improvements in manufacturing, smart cities and homes, and much more.

As exciting as the IoT is in terms of opportunities, however, it raises some challenges and concerns. For example, how will we handle so much data? How will we secure it? What infrastructure do we need to support it? The companies leading IoT efforts are already figuring out the answers to some of these questions, and some of their leaders are profiled here. Like them, all of today's leaders face a profound challenge: enabling new technologies, innovations, and approaches in today's rapidly changing market while being sure to carry on a company's legacy and build on its greatness. MW

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CUSTOM-BUILT PRODUCTS FOR MILITARY & COMMERCIAL MARKETS

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dB Control's products can be quickly and easily configured to meet custom specifications and platform requirements for ground-based, shipboard, and high-altitude military manned and unmanned aircraft. By using a modular construction based on mature technologies and proven designs—and by working with standard modules and manufacturing processes—we produce products that cost less, are easy to maintain, and are available in production quantities.

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A LEADER IN RF/MICROWAVE SIGNAL GENERATION AND ANALYSIS

Berkeley Nucleonics' Model 845 Series RF Microwave Signal Generator is a low-noise and fast-switching microwave signal generator covering a frequency range from 100 kHz up to 26.5 GHz. The Model 845 Microwave RF Signal Generator offers a wide and accurately leveled output power range with high spurious suppression. Advanced frequency synthesis with fractional-N divider makes for low SSB phase noise and micro-Hz frequency resolution. BNC now offers 3, 6, 12, 20, and 26.5 GHz frequencies available in benchtop, module, 1U rack mount, and customizable OEM configurations.

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PHASE NOISE TESTERS AND REAL-TIME SPECTRUM ANALYZERS

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2015 MICROWAVES & RF SALARY SURVEY

While salaries remain stable, challenges such as new technologies and outsourcing are impacting overall job satisfaction.

The 1,659 engineers surveyed in *Microwaves & RF's* 2015 Salary Survey present an interesting outlook on the RF/microwave industry. On a positive note, the results demonstrate a relatively stable industry, as 89.2% expect their company to maintain or increase hiring in the coming year. In addition, 87.9% of respondents said their job title had remained the same within the last year. But those surveyed did voice other concerns.

New technologies and developments require engineers to remain updated. However, a common issue is the challenge to find the time needed to stay current with all the latest information. As one respondent explained, "There is a tremendous amount of helpful information online, but not enough time to utilize it."

Outsourcing is also another major topic of discussion among engineers, with 51.4% of respondents saying that their company does indeed outsource engineering work. The primary reasons for outsourcing vary, but cost savings as well as the lack of highly specialized in-house skills appear to be prevalent factors. Personal opinions of outsourcing are quite varied. Some point out its potential negative effects, while others believe it can actually reap benefits—for instance, by allowing a company to focus on its core competencies. As one respondent said, "Outsourcing is what allows us to focus all our efforts on the core design. It increases our know-how in the areas that the company has decided not to outsource."

The actual quality of outsourced work was also mentioned. "Outsourcing can be beneficial. But sometimes the work done outside of the company does not meet the quality standards and has to be redone in-house. This negates the time and money saved by outsourcing," according to one respondent. This demonstrates that companies must be careful when deciding where to outsource their work.

A CAREER PATH WORTH FOLLOWING

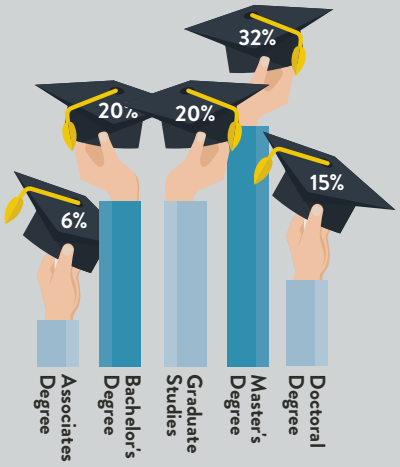
Despite the concerns, 89.3% of respondents would recommend engineering as a career path to a young person. A major reason for the high percentage is the rewarding work that an engineering career can provide. Engineers also mentioned the opportunities to express innovative ideas and solve problems. In addition, respondents cited good compensation as another reason why they would recommend an engineering career.

In general, the RF/microwave industry appears to look positive, with 88.3% of respondents saying they are satisfied in their current position. Engineers also reported an average base salary of $100,657, with 66.7% saying they felt adequately compensated for their work. Overall, the industry appears to be in good shape. Engineers remain well compensated for their innovative and challenging work—and with a generally high level of job satisfaction, the profession should remain strong for the foreseeable future. MW

TECHNICAL EDITOR CHRIS DEMARTINO wrote this report. Data conducted and compiled by Jay McSherry. For the complete report online, visit www.mwrf.com.

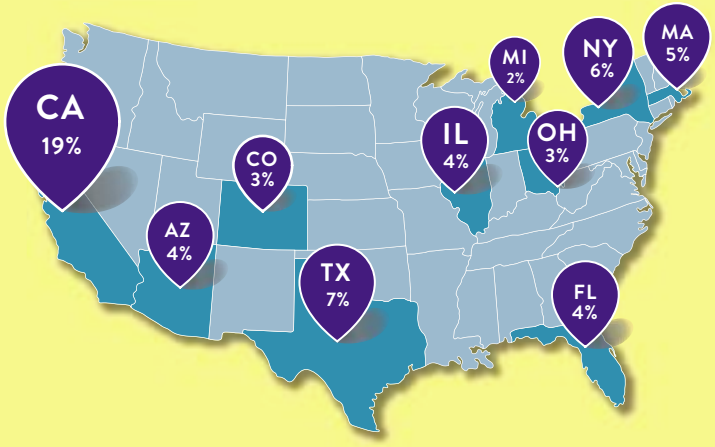
THE TYPICAL ENGINEER

Highest education level

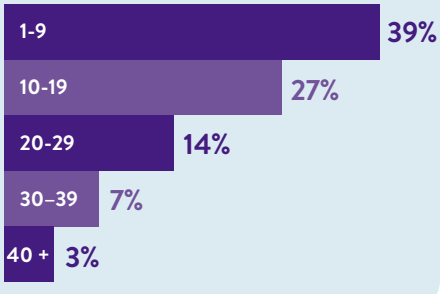


"This is probably one of the hardest fields to become proficient in, yet can be so incredibly fulfilling if one is committed to a lifetime of learning," said one respondent.

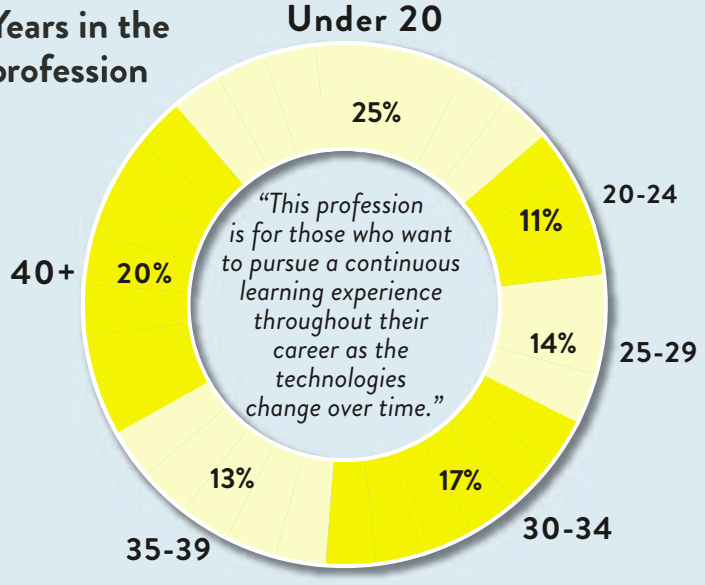
Work locations



Years at present company

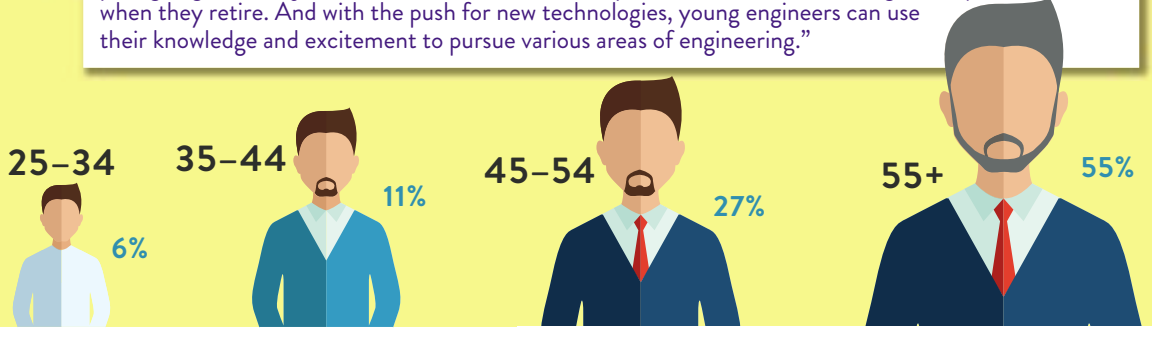


Years in the profession



Age

The RF/microwave engineering workforce is aging, as many older engineers are inching closer to retirement. As a result, younger engineers will have the opportunity to fill many senior-level engineering positions. As one respondent declared, "The engineering workforce is aging and opens opportunities for young engineers to join and learn from the best. They can then fill the senior engineers' positions when they retire. And with the push for new technologies, young engineers can use their knowledge and excitement to pursue various areas of engineering."



Average Compensation

$109,533

Average compensation increase

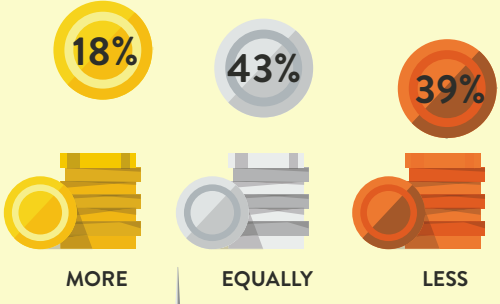
$ 1.29% $

COMPENSATION

Average bonus

Cash $4,064
Stocks/options $2,404
Other $2,408

How competitive is the average engineer's compensation?



Engineering salaries have remained relatively consistent in recent years, with many engineers reporting no significant changes in their compensation. However, a large number of engineers reported increased health insurance costs. "Health insurance goes up slightly each year while salaries have been relatively constant for the last five to six years," noted one respondent.

EMPLOYMENT OUTLOOK

60% SAY HIRING WILL MAINTAIN

29% SAY HIRING WILL GROW

11% SAY HIRING WILL REDUCE

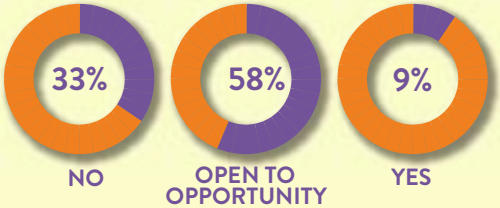
As the world becomes more technological, engineers remain positive that their skills will continue to be in demand. However, some engineers also believe their contributions are undervalued. As one respondent said, "Even though we as a society love our gadgets, we do not seem to value those with the technical expertise to create them."

Is an engineering career as promising today as it was five years ago?

62% SAY YES

"Over the last five years, I don't think there has been as much of a change in the market as, say, 15 years ago."

Actively seeking a new position



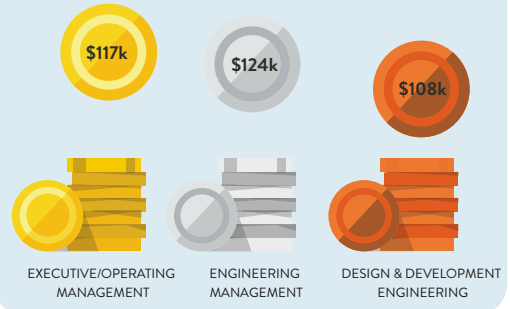
Is your organization more focused on employee retention this year?

COMPENSATION BREAKDOWN

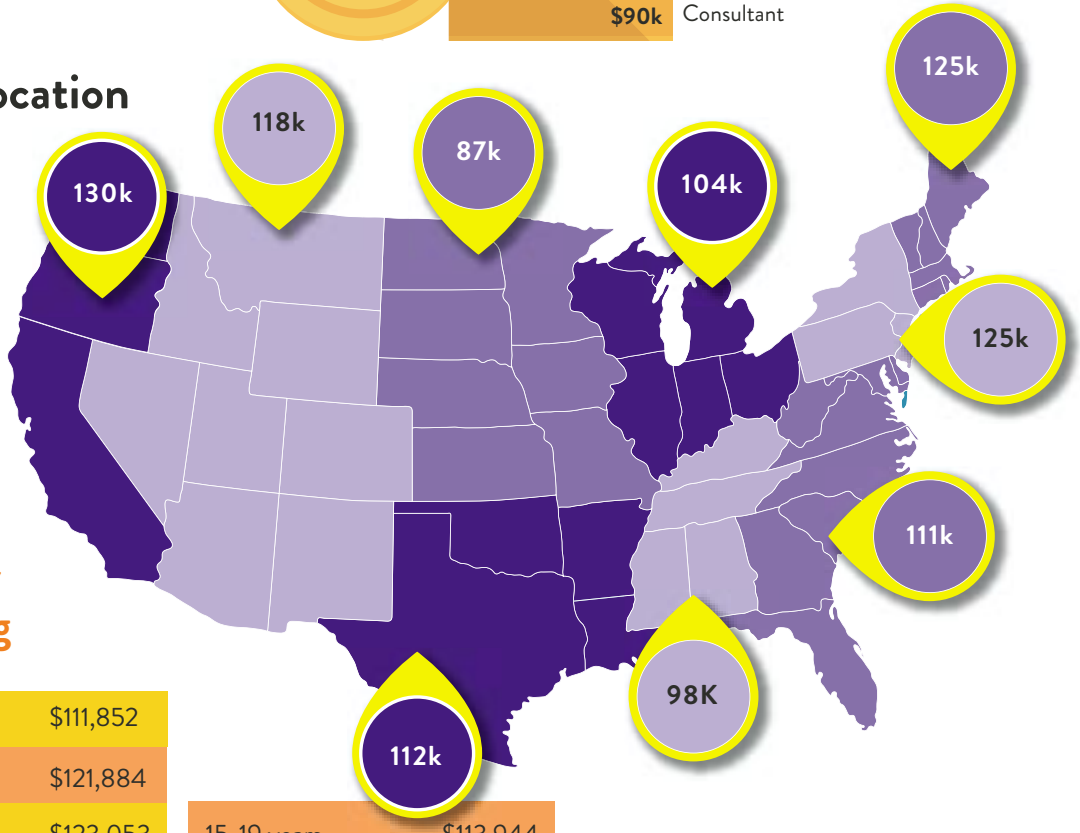
By industry

ICs and semiconductors	$134k
Components and subassemblies	$104k
Avionics/marine/space	$113k
Medical electronics	$132k
Computer systems/boards/ peripherals/software	$107k
Government / military	$124k
Communications systems/equipment	$119k
Test and measurement equipment	$106k
Automotive electronics	$95k
Research & development	$101k
Software	$111k
Consumer electronics	$100k
Industrial controls systems/ equipment	$93k
Contract design or manufacturing	$95k
Consultant	$90k

By job function



By location



By years of engineering experience

40 years or more	$111,852
35-39 years	$121,884
30-34 years	$123,053
25-29 years	$113,593
20-24 years	$106,979
15-19 years	$113,944
10-14 years	$85,350
5-9 years	$72,044
1-4 years	$75,026
Less than 1 year	$74,889

(Survey continued on p. 20)

MACOM

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Lowell MA 01851

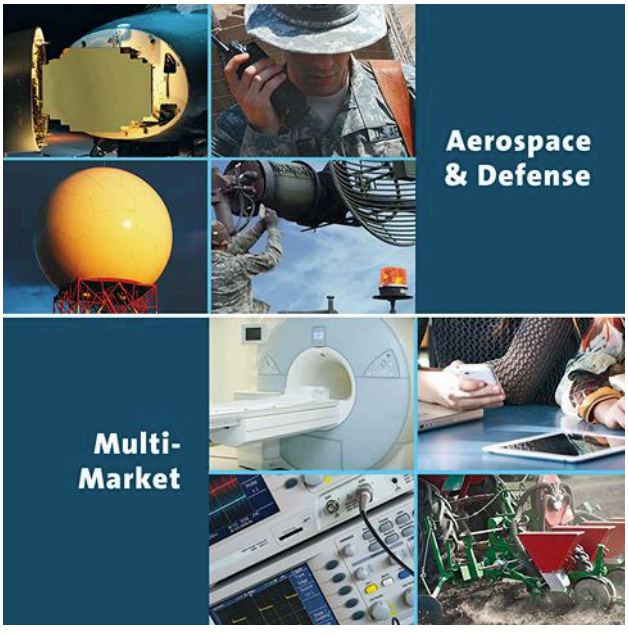
BROAD PORTFOLIO OF OVER 3,000 PRODUCTS ACROSS 40 PRODUCT LINES

MACOM (NASDAQ: MTSI) is a leading supplier of high-performance analog RF, microwave, millimeterwave, and photonic semiconductor products that enable next-generation Internet and modern battlefield applications. Recognized for its broad catalog portfolio of technologies (GaN, GaAs, InP, SiGe, SiPh, HMIC, and Silicon) and products, MACOM serves diverse markets, including high-speed optical, satellite, radar, wired and wireless networks, automotive, industrial, medical, and mobile devices. A pillar of the semiconductor industry, we thrive on more than 60 years of solving our customers' most complex problems, serving as a true partner for applications ranging from RF to Light.

We design and manufacture standard and custom devices, integrated circuits, components, modules, and assemblies for customers who demand high performance, quality, and reliability. Our heritage in the RF industry dates back to the founding of Microwave Associates in 1950. Today MACOM offers over 40 product lines with a broad portfolio of over 3,000 products.

GLOBAL ORGANIZATION OF SKILLED ENGINEERS

AT MACOM we aim to solve your most complex challenges. From Aerospace to Automotive, Infrastructure to Industrial, Military to Medical, the toughest applications yield to our team. MACOM has multiple design centers, Si, GaAs and InP fabrication, manufacturing, assembly and test, and operational facilities throughout North America, Europe, Asia and Australia. In addition, MACOM offers foundry services that represent a key core competency within our business. The foundry provides access to and control of our broad range of proprietary technologies in an asset-light, cost-effective structure.

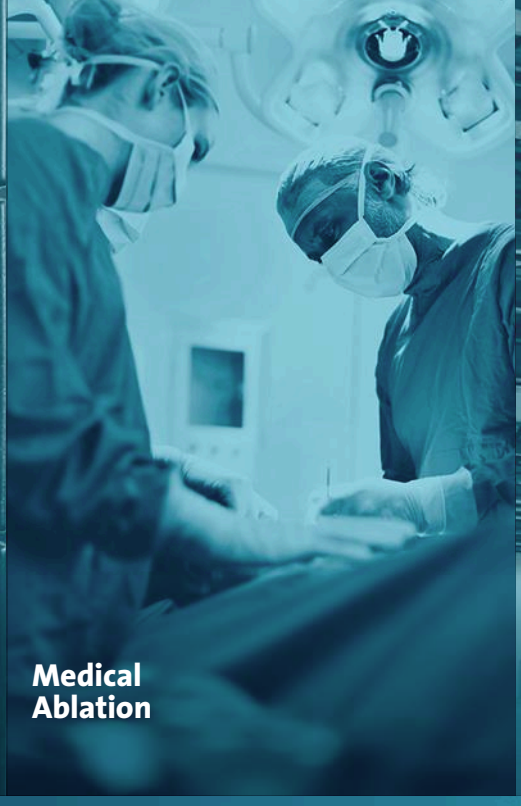


MACOM sells and distributes products globally via a sales channel comprised of a direct field sales force, authorized sales representatives, and leading industry distributors. Our sales team is knowledgeable about all of our products, and are able to give our customers insights into the entire MACOM product portfolio.

Our global organization of skilled engineers is driven every day to solve the world's most demanding wireless and wireline application challenges. We're proud of our more than 60 years of hands-on experience designing and building analog semiconductor technology across the RF to Light spectrum.

For more information about MACOM, please visit www.macom.com; follow @MACOMtweets on Twitter; join MACOM on LinkedIn; or visit the MACOM YouTube Channel.

MACOM™
Partners from RF to Light



Shattering the Barriers to Mainstream GaN Adoption

Only MACOM offers the portfolio, partnerships & people to fully leverage GaN technology in a wide range of commercial applications such as medical ablation, microwave oven magnetron replacement, plasma lighting and RF energy transfer.

We're shattering the final barriers to mainstream GaN adoption with an industry-leading portfolio of cost-effective RF power devices available in Si and SiC. Our GaN transistors and amplifiers improve upon the high-power handling and voltage operation of LDMOS with the high-frequency performance of GaAs.

Our growing product family delivers the cost, bandwidth, density and efficiency advantages of GaN in a variety of form factors—5W-90W Pk transistors in DFN and SOT-89 plastic packaging, up to 1000W ceramic packages and L-, S-band fully matched modules. We also offer ceramic GaN on silicon transistors up to 200W, DFN packages from 5W to 25W and TO-272 plastic packages from 50W to 200W CW.

For over 40 years, MACOM engineers have been redefining RF power and are now applying their GaN expertise to an array of commercial, industrial, scientific and medical applications. Only MACOM delivers GaN performance at silicon cost structures to drive adoption.

MACOM™

Partners from RF to Light

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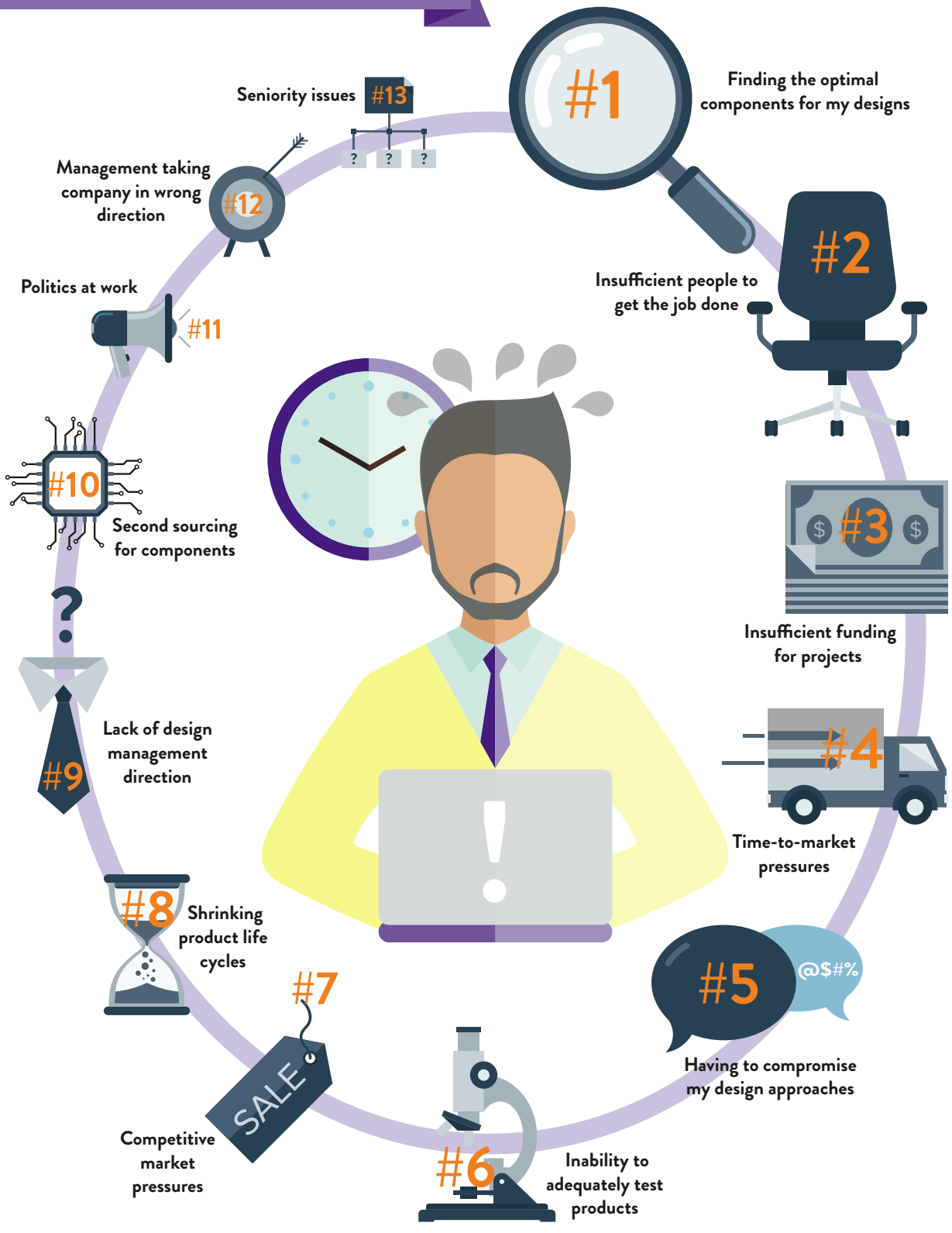
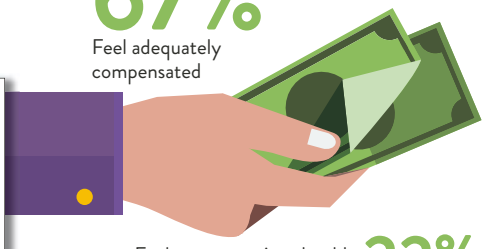
CONCERNS AT WORK



JOB SATISFACTION

The average engineer works **55 hrs/week** at the office and at home and other locations

67% Feel adequately compensated



Feel compensation should increase on average by **22%**

Job satisfaction is generally high in the industry, as only 12% of engineers say they are unsatisfied with their current position. However, some did express other concerns. Among them is a sense of displeasure toward company management. "I feel that engineers are worked hard and paid well, but the magnitude of the effort is never appreciated by upper management and marketing types that never set foot in the lab door," said one respondent.

Reasons engineers would leave the profession	
Curious about other opportunities	30%
Do something more fulfilling	22%
Start a business	22%
Do something less stressful	21%
Ready to retire	17%
No further chance for advancement	16%
Switch to teaching	13%

Job Satisfaction	
Extremely satisfied	21%
Very satisfied	30%
Satisfied	37%
Not very satisfied	10%
Not at all satisfied	2%
Have considered leaving the profession	34%

"The rapid changes to systems and components require new skills and, hence, engineers who are adaptable. Those who can and do keep up with the technology have great, albeit challenging opportunities."

Most important factors in job satisfaction

1. Researching potential design solutions
2. Challenges that accompany the design of new products
3. Opportunity to design products that can benefit society
4. The compensation you receive for the work you do
5. Working in team situations with peers
6. The recognition you get from others for the work you do
7. Working independently of others
8. The pressures associated with solving design problems

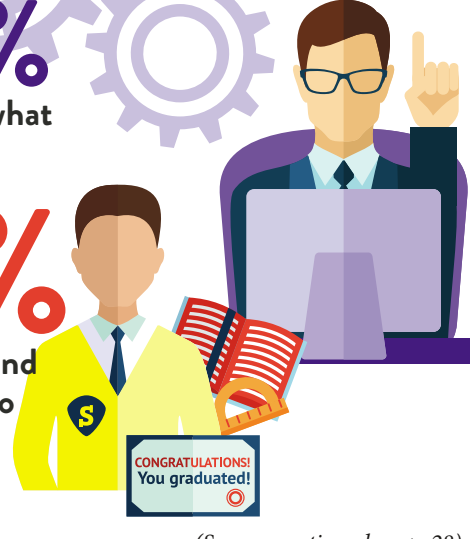
ENGINEERS TALKING FROM THE PULPIT

"Engineering is a stimulating career that offers many opportunities for creativity. It's challenging and always changing. Engineering also develops problem-solving skills that are widely applicable as well as providing great opportunities to work in teams."
"The quantitative skills learned in engineering can be applied to many other areas. It also indicates that someone is able to learn additional skills."

58% feel sufficiently challenged

33% feel somewhat challenged

89% would recommend the profession to a young person



(Survey continued on p. 28)

UNITED MICROWAVE INC.

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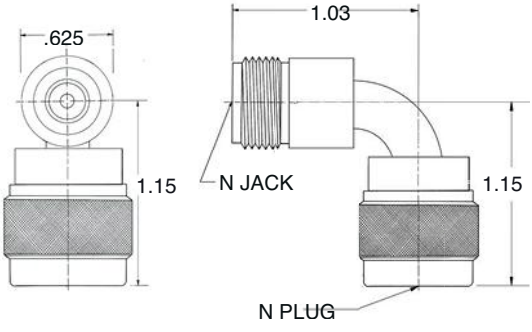
TEL | 310.320.1244
FAX | 310.320.9729

Ed Jacobs | Manager
22129 S. Vermont Ave.
Torrance, CA 90502

COMPANY PROFILE

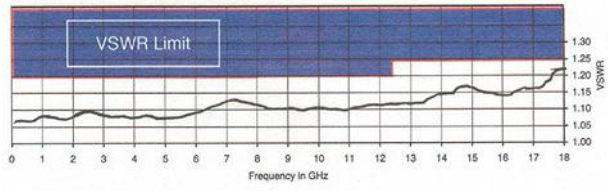
UNITED MICROWAVE PRODUCTS, founded in 1975 and located in Torrance, Calif., is an industry leader in innovative design. We began with the design and manufacture of specialty RF connectors, cable assemblies, and associated microwave products. Being committed to high-quality parts, competitive pricing, and on-time delivery makes us a viable source for RF connectors and cable applications. An assortment of products can be found on our website, unitedmicrowave.com.



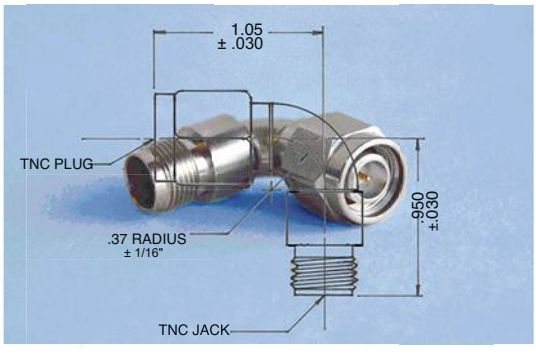
5. VSWR NOT TO EXCEED
   1.20: 1 FROM 8GHz TO 12.4 GHz
   1.25 : 1 FROM 12.4GHz TO 18 GHz
4. ADAPTOR TO MEET OR EXCEED ALL SPECIFICATIONS PER MIL-39012
3. FINISH:
   BODY : PASSIVATE PER QQ-P-35
   CONTACT: GOLD PER MIL-G-45204: TYPE II, CLASS 2, OVER COPPER PER MIL-C-14550, CLASS 4
   COUPLING NUT: PASSIVATE PER QQ-P-35
2. MATERIAL:
   BODY: STAINLESS STL PER QQ-S-763 TYPE 303
   CONTACT: BERYL. COPPER PER QQ-C-530 & BRASS PER QQ-B-626
   COUPLING NUT: STAINLESS STL PER QQ-S-763 TYPE 303
   INSULATOR: TEFLON PER MIL-P-19468A
1. MATING DIMS IN ACCORDANCE WITH MIL-STD-348

NOTES :

1521 N PLUG to N JACK RIGHT ANGLE



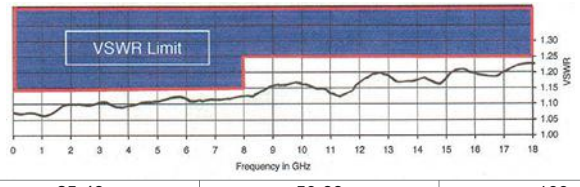
1-9	10-24	25-49	50-99	100+
$152.00	$145.00	$137.00	$123.00	$122.00



6421 TNC PLUG TO TNC JACK RADIUS RIGHT ANGLE

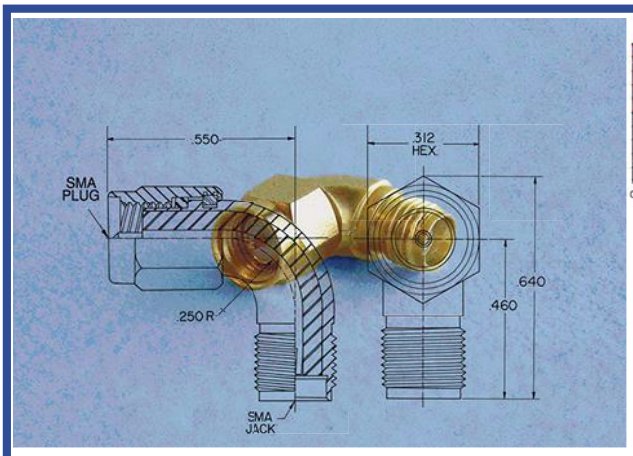
5. VSWR NOT TO EXCEED
   1.15 : 1 DC-8GHz
   1.25 : 1 8-18 GHz
4. ADAPTER TO MEET OR EXCEED ALL SPECIFICATIONS PER MIL-39012
3. FINISH:
   BODY AND COUPLING NUT: PASSIVATE PER QQ-P-35
   CONTACT: GOLD PER MIL-G-45204: TYPE II, CLASS 2, OVER COPPER PER MIL-C-14550, CLASS 4
2. MATERIAL:
   BODY: STAINLESS STL PER QQ-S-764 TYPE 303
   COUPLING NUT STAINLESS STL PER QQ-S-764 TYPE 303
   CONTACT: BERYL. COPPER PER QQ-C-530
   INSULATOR: TEFLON PER MIL-P-19468A
1. MATING DIMS IN ACCORDANCE WITH MIL-STD-348

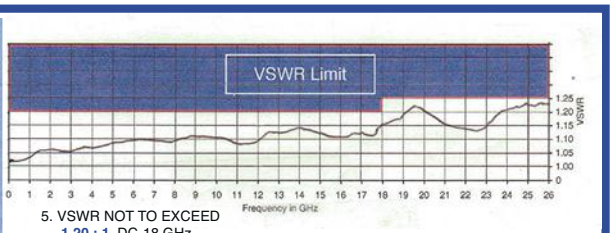
NOTES :



1-9	10-24	25-49	50-99	100+
$132.50	$129.75	$127.25	$124.75	$122.50

Prices listed effective as of 31 October 2015 and subject to change at any time.



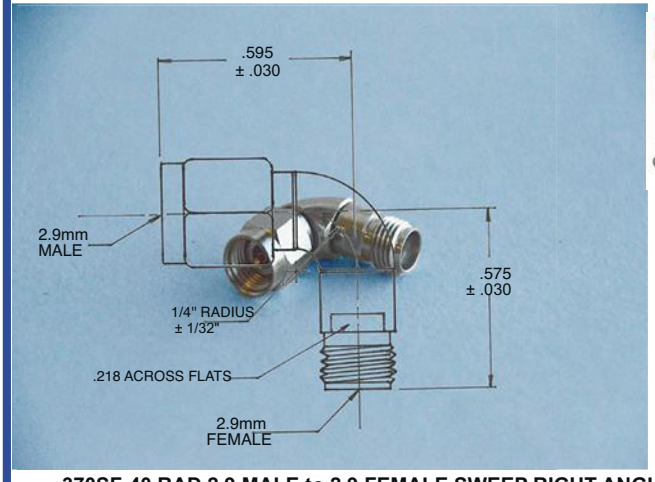


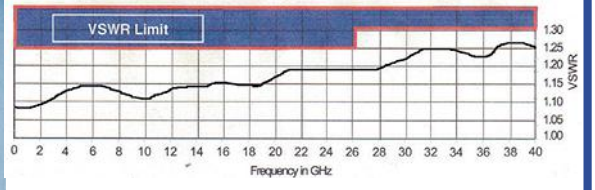
5. VSWR NOT TO EXCEED
   1.20 : 1 DC-18 GHz
   1.25 : 1 18-26 GHz
4. ADAPTER TO MEET OR EXCEED ALL SPECIFICATIONS PER MIL-39012
3. FINISH:
   BODY AND COUPLING NUT: GOLD PER MIL-G-45204:
   OVER NICKEL PER QQ-N-290
   CONTACT: GOLD PER MIL-G-45204: TYPE II,
   CLASS 2, OVER COPPER PER MIL-C-14550, CLASS 4
2. MATERIAL:
   BODY: STAINLESS STL PER PER QQ-S-764 TYPE 303
   COUPLING NUT STAINLESS STL PER QQ-S-764 TYPE 303
   CONTACT: BERYL. COPPER PER QQ-C-530
   INSULATOR: TEFLON PER MIL-P-19468A
1. MATING DIMS IN ACCORDANCE WITH MIL-STD-348

NOTES :

370-26 SMA PLUG to SMA JACK RIGHT ANGLE 26GHz

1-9	10-24	25-49	50-99	100+
$38.50	$37.50	$34.25	$31.50	$29.00



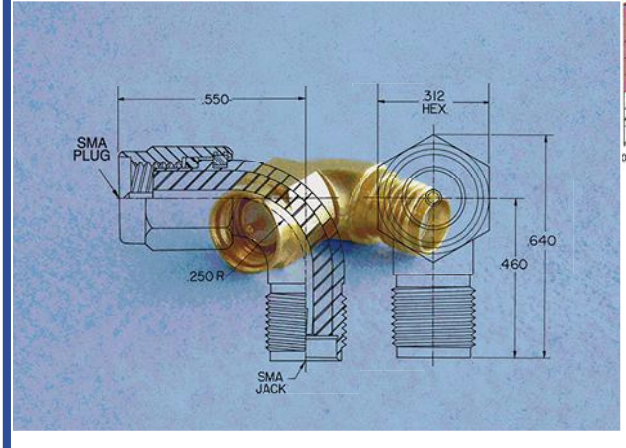


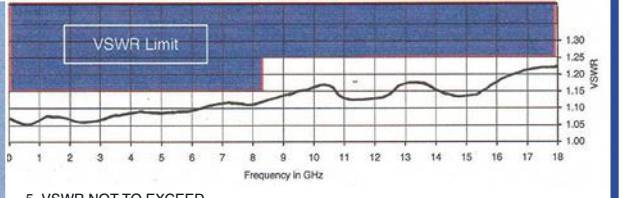
5. VSWR NOT TO EXCEED
   1.25 : 1 DC-26GHz
   1.30 : 1 26-40GHz
4. ADAPTOR TO MEET OR EXCEED ALL SPECIFICATIONS PER MIL-39012
3. FINISH:
   BODY AND COUPLING NUT: PASSIVATE PER QQ-P-35
   CONTACT: GOLD PER MIL-G-45204: TYPE II, CLASS 2
2. MATERIAL:
   BODY: STAINLESS STL PER QQ-S-764 TYPE 303
   COUPLING NUT STAINLESS STL PER QQ-S-764 TYPE 303
   CONTACT: BERYL. COPPER PER QQ-C-530
   INSULATOR: TEFLON PER MIL-P-19468A
1. MATING DIMS IN ACCORDANCE WITH MIL-STD-348

NOTES :

370SF-40 RAD 2.9 MALE to 2.9 FEMALE SWEEP RIGHT ANGLE

1-9	10-24	25-49	50-99	100+
$210.00	$200.00	$195.00	$190.00	$188.00





5. VSWR NOT TO EXCEED
   1.15 :1 DC-8 GHz
   1.25 :1 8-18 GHz
4. ADAPTER TO MEET OR EXCEED ALL SPECIFICATIONS PER MIL-39012
3. FINISH:
   BODY AND COUPLING NUT: GOLD PER MIL-G-45204:
   OVER NICKEL PER QQ-N-290
   CONTACT: GOLD PER MIL-G-45204: TYPE II,
   CLASS 2, OVER COPPER PER MIL-C-14550, CLASS 4
2. MATERIAL:
   BODY: STAINLESS STL PER PER QQ-S-764 TYPE 303
   COUPLING NUT STAINLESS STL PER QQ-S-764 TYPE 303
   CONTACT: BERYL. COPPER PER QQ-C-530
   INSULATOR: TEFLON PER MIL-P-19468A
1. MATING DIMS IN ACCORDANCE WITH MIL-STD-348

NOTES :

370 SMA PLUG to SMA JACK RIGHT ANGLE 18GHz

1-9	10-24	25-49	50-99	100+
$38.50	$37.50	$34.25	$31.50	$29.00

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Direct Sales, Tech Support and Current Order Status
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HOLZWORTH

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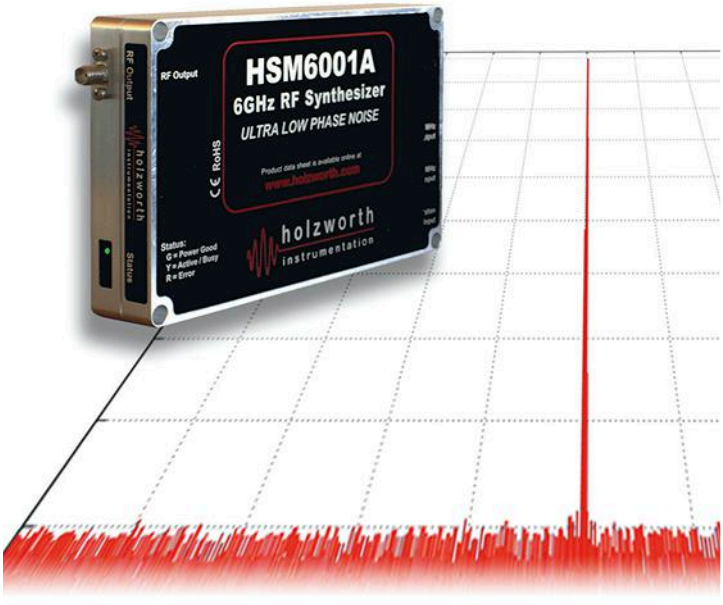
EMAIL | sales@holzworth.com
TEL | 303.325.3473

ULTRA LOW-PHASE NOISE IS OUR BUSINESS

Holzworth Instrumentation was founded in 2004 during a time when making phase noise measurements was still considered to be complicated, slow and expensive. A test requirement that was once best placed in the defense radar industry was spanning into commercial electronics test with the onset of higher speed communications systems. Holzworth emerged with accurate phase noise analyzers that were easy to operate and were cost effective. The demand for phase noise analysis products quickly lent to additional requirements for highly stable, spectrally pure signal sources. One decade later, Holzworth is a well-known global provider of ultra low phase noise RF Synthesizers and Phase Noise Analyzers that can accurately measure to the theoretical limits.

PHASE COHERENCY IS KING

HOLZWORTH'S RF SYNTHESIS products are innovative, broadband designs that exhibit industry leading phase noise performance and fast switching speeds in compact form factors. A key characteristic is the phase-coherent relationship that can be maintained across multiple synthesizer modules. The unique phase-coherent nature of the various Holzworth synthesizer architectures supports precise LO-LO, clock-clock, tone-tone, etc. synchronization, which is critical for many high-end applications. Holzworth's synthesizer products are available in modular form for systems integrators as well as a 1U rack mount chassis that is popular with ATE applications.



SPECTRAL PURITY

HSM Series (legacy): Bandwidth: 250kHz to 1, 2, 3, 4, 6.4, 12.5 or 20GHz
1GHz Phase Noise: -134dBc/Hz (10kHz offset)
Spurious: < -70dbc
Output Dynamic Range: -70dBm to +13dBm
Switching Speed: 6µs to 100µs (0s settling time)

HSX Series (next gen): Bandwidth: 10MHz to 6, 12 or 24GHz
1GHz Phase Noise: -144dBc/Hz (10kHz offset)
Spurious: < -85dbc
Output Dynamic Range: -110dBm to +20dBm

Visit Holzworth Instrumentation on the web for more product information, including a broad library of application notes, articles, and product videos.

holzworth instrumentation

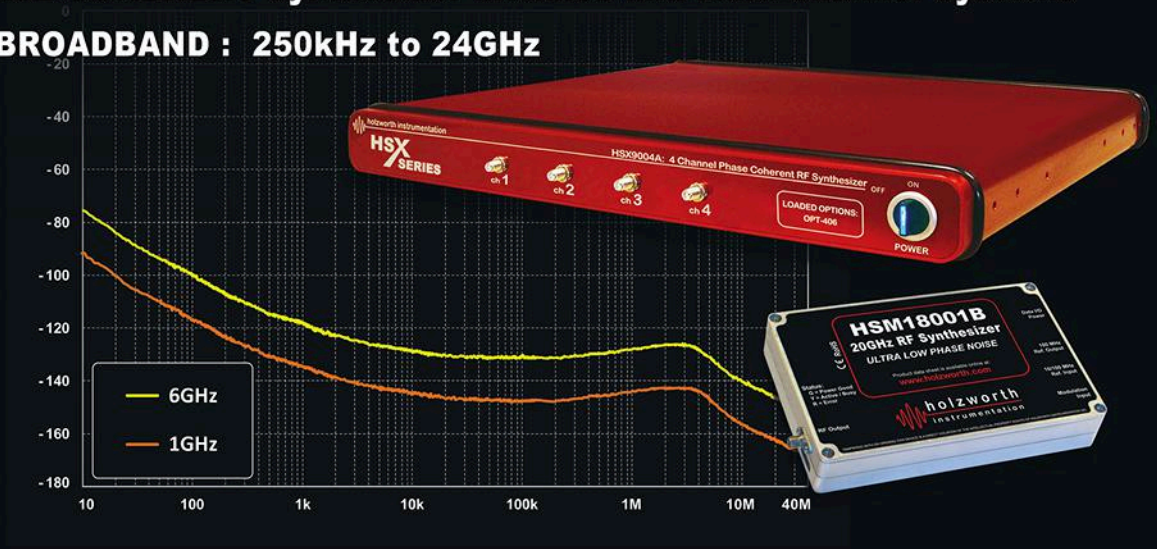
ULTRA LOW PHASE NOISE IS OUR BUSINESS

Holzworth Instrumentation was founded in 2004 to be a leading provider of high performance signal generators and phase noise analyzers that are built on unique platforms. From laboratory brenchtops to radar systems and even the International Space Station... Holzworth's phase coherent RF Synthesizers and NIST traceable Phase Noise Analyzers can be found in both commercial and defense systems, worldwide.

RF SYNTHESIZERS

PHASE COHERENT Synthesizer Modules and Multi-channel Systems

BROADBAND : 250kHz to 24GHz



PHASE NOISE ANALYZERS

ACCURATE : ANSI z540 Calibrated to the Absolute Limits

BLAZING FAST Data Acquisition and HIGH RELIABILITY

holzworth instrumentation

phone: +1.303.325.3473

www.holzworth.com

PASTERNACK

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TEL | 866.PASTERNACK (866.727.8376)
or 949.261.1920
FAX | 949.261.7451

17802 Fitch Irvine, CA 92614

RF SOLUTIONS FROM RF ENGINEERS

Providing Engineers around the world RF solutions since 1972, Pasternack has evolved to become the Engineer's immediate source for anything RF. This includes maintaining the largest single source of RF inventory, including hard-to-find items so that you get exactly what you need—when you need it. All backed by our team of expert RF applications engineers, ready to help troubleshoot your technical issues and ensure you get the right components to address your specific challenges. Our 24/7 sales support by phone, chat, or email gives you instant access, day or night. Online, we provide a host of additional support resources including calculators, conversion tables, selection guides, and continuing education, in partnership with the industry's RF education leader, Besser Associates. Whether your need is products, resources, or education, Pasternack has your solution.

CABLE ASSEMBLIES: YOU DESIGN IT ONLINE TODAY, WE BUILD IT TODAY

DESIGN CABLE ASSEMBLIES to meet your exact requirements online with Pasternak's Cable Creator. Our RF Engineering team developed Pasternak's Cable Creator to provide our customers an efficient and flexible solution to sourcing urgently needed cable assemblies. Users can quickly and easily create and purchase, online, over 250,000 customized RF cable assemblies from any combination of compatible connectors and cables we offer. These unique cables are built and shipped the same day they're ordered.

FROM L-BAND TO W-BAND, our vast offering of in-stock waveguide products makes our portfolio the largest in the industry. Our waveguide lines include large families of gain horns, bandpass filters, bends, sections, couplers, detectors, terminations, attenuators, adapters, antennas and more. A broad spectrum of waveguide sizes from WR-430 to WR-15 and multiple body styles ensure you find the waveguide components you need. All of our waveguide products are in-stock and ready to ship.

PE PASTERNACK®
THE ENGINEER'S RF SOURCE

RF Solutions From RF Engineers

Largest selection ✓

Expert technical support ✓

Same day shipping ✓

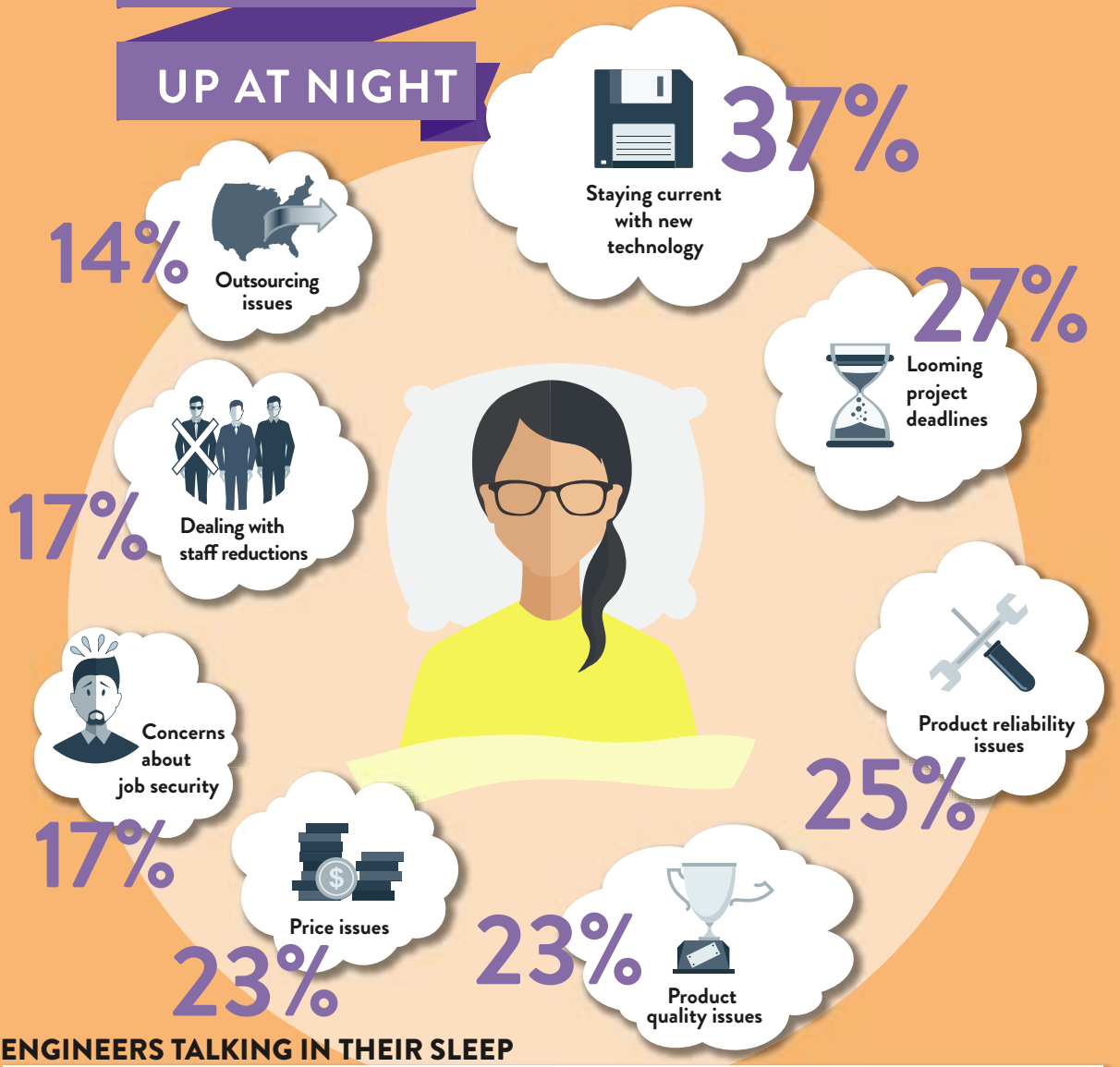
Armed with the world's largest selection of in-stock, ready to ship RF components, and the brains to back them up, Pasternack Applications Engineers stand ready to troubleshoot your technical issues and think creatively to deliver solutions for all your RF project needs. Whether you've hit a design snag, you're looking for a hard to find part or simply need it by tomorrow, our Applications Engineers are at your service. Call or visit us at pasternack.com to learn more.

866.727.8376
www.pasternack.com

PASTERNACK®
THE ENGINEER'S RF SOURCE

ISSUES KEEPING ENGINEERS UP AT NIGHT

Engineers commonly say they have insufficient time to stay current with technology. Many struggle to consume the vast amount of available information.



ENGINEERS TALKING IN THEIR SLEEP

"Discovering new technologies and getting enough information about them to determine if they are relevant to my work is a challenge."

"Useful, instructive information on some areas of design is incredibly hard to find."

"There is never enough time in the day to just read engineering publications that interest me."

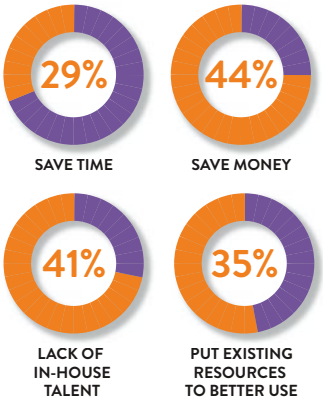
"Greed and the bottom line drive all ethics in development. Business needs to override good design and product development. We are constantly under pressure to 'just ship it.'"

THE NECESSARY EVIL OF OUTSOURCING

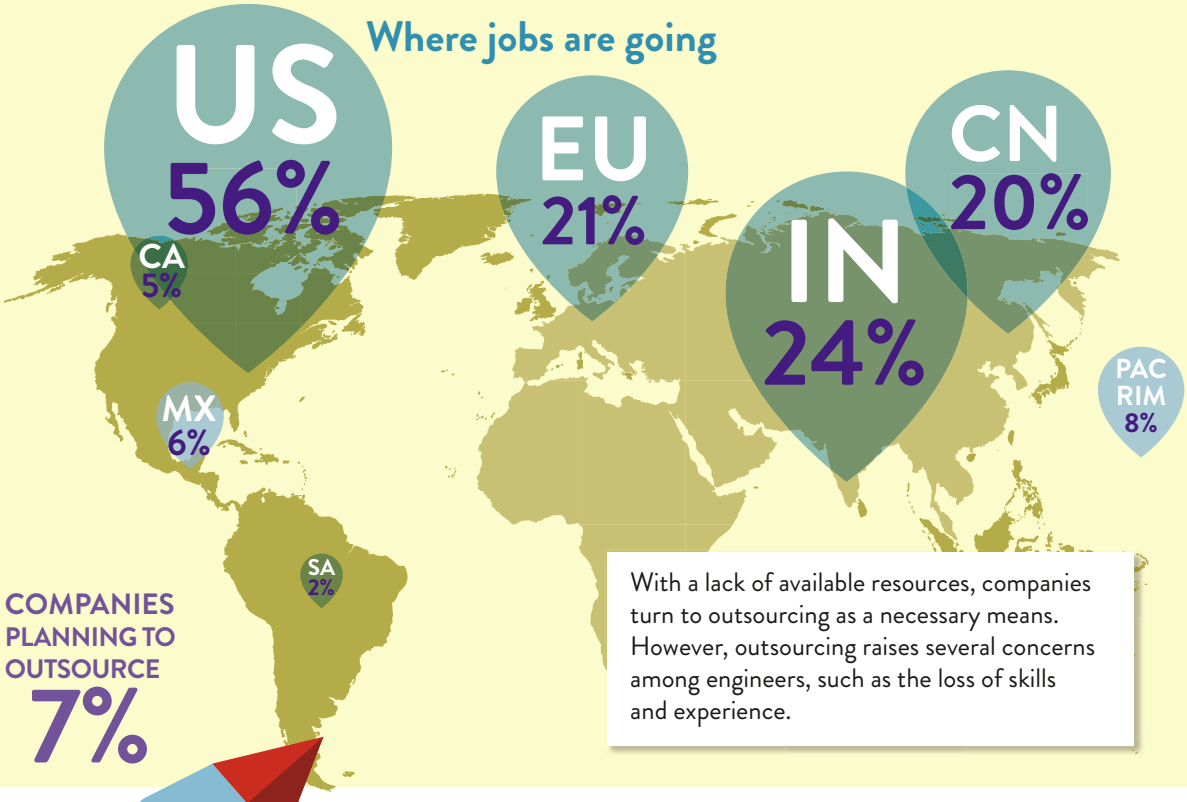
OPINIONS ON OUTSOURCING

FEWER ENGINEERING JOBS AVAILABLE	41%
LOWER EMPLOYEE MORALE	39%
NEW HIRES AT REDUCED SALARIES	36%
FEWER OPPORTUNITIES FOR ADVANCEMENT	34%
SKILLS VALUED LESS	29%
SALARY REDUCTIONS FOR EMPLOYEES	24%
OPPORTUNITY FOR MORE INNOVATIVE PROJECTS	21%
IMPORTANT ASPECT TO BUSINESS GROWTH	15%
SKILLS VALUED MORE	12%
NEW HIRES TO SUPPORT OUTSOURCING EFFORTS	12%

Reasons companies are outsourcing

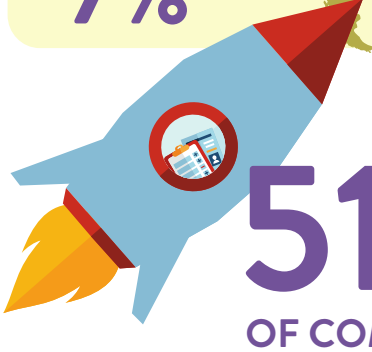


Where jobs are going



With a lack of available resources, companies turn to outsourcing as a necessary means. However, outsourcing raises several concerns among engineers, such as the loss of skills and experience.

COMPANIES PLANNING TO OUTSOURCE
7%



51%
OF COMPANIES OUTSOURCE WORK

JOBS BEING OUTSOURCED

SOFTWARE ENGINEERING/DEVELOPMENT	49%
MANUFACTURING/ASSEMBLY	46%
DESIGN	34%
PCB LAYOUT	33%
R&D	23%
SOFTWARE VERIFICATION/TEST	19%
CAD/CAE	19%
DESIGN VERIFICATION	14%
FINAL TEST	16%
DRAFTING	10%

(Survey continued on p. 34)

NORDEN MILLIMETER INC.

LOOK TO NORDEN FOR INNOVATION IN GOVERNMENT AND MILITARY RF HARDWARE

WEB | www.nordengroup.com
EMAIL | sales@nordengroup.com
TEL | 530.642.9123
FAX | 530.642.9420

5441 Merchant Circle
Placerville, CA 95667

Visit our website for a list of Sales Representatives

Founded in 2001, Norden Millimeter designs and manufactures RF, microwave and millimeter-wave active components and assemblies. Norden's facility is located in the Sierra Nevada foothills of Northern California. Norden is a privately held company with a high level of employee ownership. Norden's staff focus is on speed, agility, execution, and innovation. Norden's management staff consists of specialists in design and application engineering, manufacturing and operations, sales, and marketing.

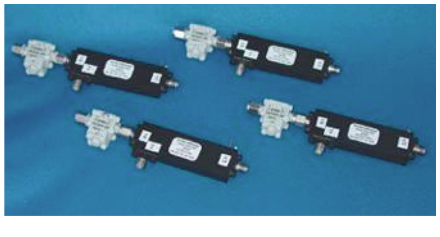
Norden is a customer-oriented company, and we are committed to providing products designed for maximum performance while maintaining cost effectiveness and quick delivery time. Norden uses Monolithic Microwave Integrated Circuit (MMIC) technology extensively throughout our product base. Because of the modular technology, Norden can customize all of our active components and assemblies to support a wide range of unique customer requirements.

Norden product application areas include:

- Military/Commercial/Scientific
- Microwave Test Equipment
- Radar and ECM
- Ultra-Secure Communications Systems
- Radio Astronomy

Norden active products operate in the frequency range of 500 MHz to 110 GHz and include:

- Narrow-Band and Broadband Amplifiers
- Frequency Converters
- Transceivers
- Custom Integrated Assemblies
- Oscillators, VCO'S, DRO's, OCXO
- Frequency Multipliers
- RF Switches and Switched Filters
- RoHs-Compliant Products



Norden offers waveguide in our millimeter-wave products: WR-42, WR-28, WR-22, WR-19, WR-15, WR-12, and WR-10 waveguide connectors or customer-specific waveguides and flanges can be used in all of our standard housings.

Norden's Quality System is ISO 9001:2008 and AS9100C certified. The Workmanship Standards and Visual Inspection Criteria follow the MIL-STD-883 procedure. Norden performs standard electrical and burn-in testing on all our products. However, additional electrical and environmental requirement testing per applicable ISO or Mil Standard can be performed to meet the customer requirement.

NORDEN MILLIMETER

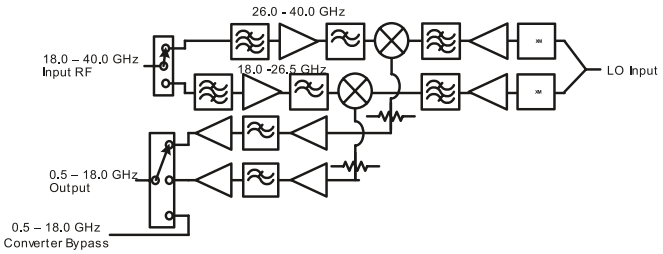
LOOK TO NORDEN FOR INNOVATION IN GOVERNMENT AND MILITARY RF HARDWARE

NORDEN MILLIMETER

Norden Millimeter Down Converters to extend the operating frequency range of EW, EMS, ECM, ELINT Systems to 40 GHz.

18-40 GHz Down Converter with Bypass Type 1

- RF Freq: 18 - 40 GHz
- LO Freq: 14.4 GHz
- Converter Bypass: 0.5 - 18 GHz
- Bypass Loss Max -5.5 dB
- IF Freq: 2.3-16.7 GHz
- LO Drive Typ: +3 dBm
- Conv. Gain Typ: 12 dB
- Gain Flatness Typ: +/-2.5 dB
- Noise Figure Typ: 14 dB
- Input 3rd IP Typ: -10 dBm
- Image Rejection Typ: -65 dBc
- LO Leakage Typ: -70 dBm
- Spurious Typ: -35 dBc
- VSWR IF/LO/RF: 2.5:1
- Supply Voltage: +12 VDC
- Power Dissipation Max: 14 W
- Operating Temp -15 to +70 ºC -70 ºC



Norden Offers Wideband and Narrowband Multipliers for Test Equipment Applications. Custom designs in a variety of multiplication factors.

38-70 GHz X4 Frequency Multiplier

- Input Freq (GHz) 9.5 - 17.5
- Input Power +17 to +22 dBm
- Output Power Min (dBm) +18.5
- Harmonics Typ (dBc) -20
- Spurious Max (dBc) -65
- Input VSWR 2.00:1
- Output VSWR 3.00:1
- 12VDC @ 900mA Typ
- Pout Level Control
- Input 2-20 GHz Switch
- Output Power Control Range 38dB

NORDEN MILLIMETER

LOOK TO NORDEN FOR INNOVATION
IN GOVERNMENT AND MILITARY RF HARDWARE

5441 Merchant Circle, Placerville, CA 95667
WEB: www.nordengroup.com TEL: 530.642.9123 FAX: 530.642.9420

INNOVATION

OMNIYIG, INC

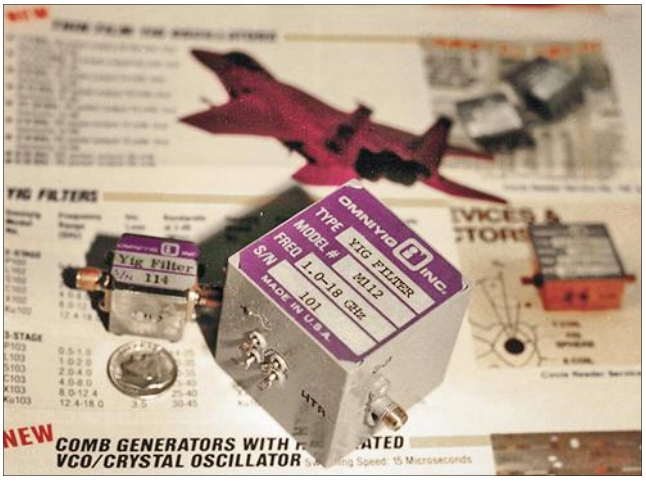
42 YEARS OF SUCCESSFULLY DEPLOYED CUSTOM YIG REQUIREMENTS

WEB | Omniyig.com
TEL | 408.988.0843
EMAIL | omniyig@ix.netcom.com
FAX | 408.727.1373

3350 Scott Blvd., Bldg. #66
Santa Clara, CA 95054

YTTRIUM IRON GARNET

A COMPLETE KNOWLEDGE of Yig theory has been achieved at Omniyig, allowing for the development of thousands of various custom Yig designs. Incorporated in 1973, Omniyig has accepted every job put forth, both easy and difficult. In 40+ years of manufacturing Yig devices, never was said, "No, we can't do it." Always taking the job, putting forth time and effort, has lead to fantastic custom requirements for innovative, forward-seeking clients.



YIG TECH

A broad requirement of electronically tuned microwave components needed for use in numerous systems exists - radar, telecommunication, countermeasure, guidance, microwave receivers and much more. The Yig is the only microwave component element that can be designed for those systems tuned in octave and multi-octave bandwidths.

Omniyig started pursuing the design and manufacture of Yig devices realizing the Yig can replace many microwave components satisfying that broad requirement in a very small, very light footprint. Coupled with a reliable mean time between failure of over 200,000 hours, as well as multi-octave tuned in a single package, a star was born.

With the Yig material, Omniyig can manufacture many microwave components - Band Pass Yig Filters, Band Reject Yig Filters, Yig Multipliers, Yig Oscillators, Phase Lock Yig Oscillators, Phase Lock Yig Filters, Tracking Yig Filters, Front End Tuners as well as many other Yig components and systems – to thousands of custom requirements.

The bulk of Omniyig's sales are Yig components and Yig subsystems built to MIL STD programs with very stringent MIL STD QA guidelines. Some of the programs that Omniyig has manufactured Yig devices for are the ALQ-99, ALQ-117, ALR-172, ALR-56C, ALR-62, ALR-64, ALR-67, ALR-69, WLR-8, EF111, B1 and L-130… and the list goes on.

R&D activities at Omniyig occur continually, with a dedicated R&D team fleshing out any particulars related to novel custom designs or requests on the client's part. They relish continuously developing new and improved Yig products in providing a deliverable product performing under all environmental conditions.

OMNIYIG DELIVERS

OMNIYIG continues to further the design, development and technology of Yig devices, subsystems and more. With unending engineering passion, Omniyig welcomes future uncharted waters in advancing Yig technology even further.

"Delivering the Highest Quality of Technology Since 1973"

OMNIYIG INC.

OMNIYIG INC.

We design to your RF requirements!

FUNDAMENTAL YIG-TUNED OSCILLATOR

Frequency Range	2.0 to 18.5 GHz
Min. RF Power Output	10 dBm
RF Power Output Variation	± 3
Max. 2nd Harmonic (typ)	> 10 dBc
FM Noise @ 100 KHz Away	> 120 dBc

0-10 Volt Analog or 12 Bit Digital Driver Available!

CELEBRATING 42 YEARS IN CUSTOM YIG DESIGN

Omniyig's advanced products are designed into some of the world's most sophisticated systems, including commercial, EW, and ECM programs such as the ALQ-99, ALQ-117, ALR-172, ALR-56C, ALR-62, ALR-64, ALR-67, ALR-69, APR-39, WLR-8, Rapport III and we are on board the F-15, F-16, F-18, EA6B, EF111, B-1, B2 Stealth, L-130 and more.

DUAL CHNL BAND REJECT YIG FILTER

Frequency Range	2.0 to 8.0 GHz
Rejection Bandwidth per Channel	10 MHz
Insertion Loss	1.8 db

0-10 Volt Analog or 12 Bit Digital Driver Available!

Since 1973, **Omniyig** has continued technology improvement with expansions in Yig technology and new microwave products in thousands of designs developed and built for Customers Worldwide. MIL-E-5400 Class II, MIL-STD-883, in frequencies 0.5 GHz to 40.0 GHz, both Octave & Multi-Octave.

Ask Around - **Omniyig** Delivers.

- YIG FILTERS
- YIG OSCILLATORS
- YIG MULTIPLIERS
- LIMITERS
- DETECTORS
- COMB GENERATORS
- FRONT END TUNERS
- SUB SYSTEMS

OMNIYIG INC.
Since 1973

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[t] 408.988.0843 • [f] 408.727.1373
Omniyig@ix.netcom.com • http://www.Omniyig.com

CONTINUING EDUCATION

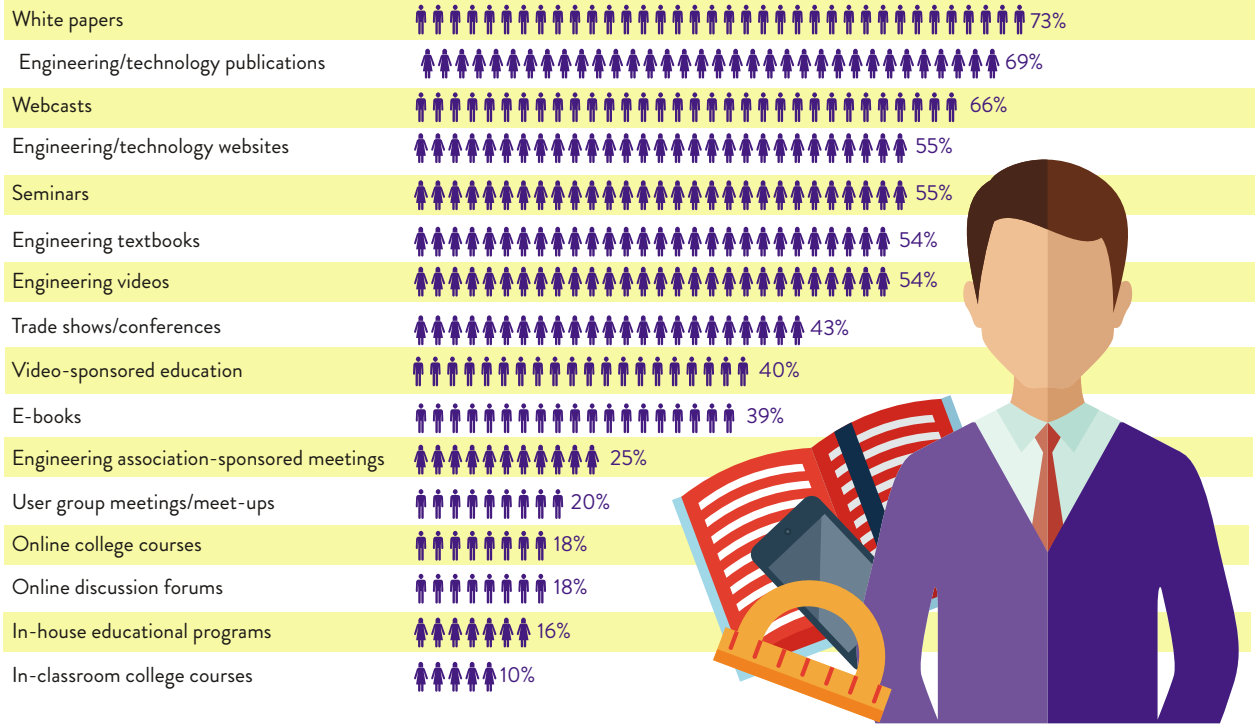
#1 obstacle to staying current with information:

Finding the time.

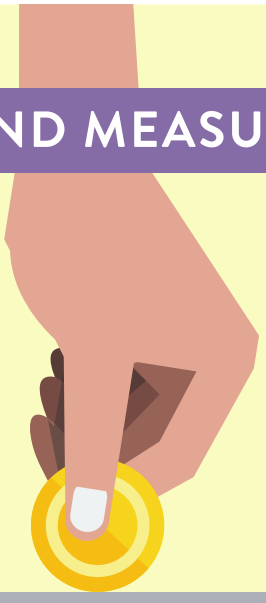
Engineers are required to stay current with the latest technology. However, many say they simply don't have enough time to pursue further education. As one respondent noted, "Because I am so busy with work, it can be pretty challenging finding the time for further education." A large number of additional learning resources are available, ranging from publications, white papers, webcasts, and more.

For which of these forms of education does your company reimburse costs to engineers?	
Trade shows/conferences	56%
Seminars	54%
College tuition	36%
Engineering textbooks	37%
Publication subscriptions	28%
Engineering association dues	26%
Certifications	23%
Online training	21%

How engineers are keeping up

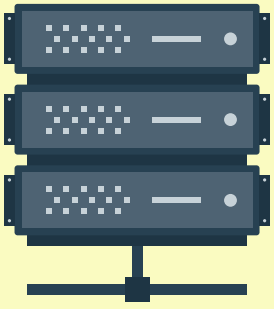


TEST AND MEASUREMENT



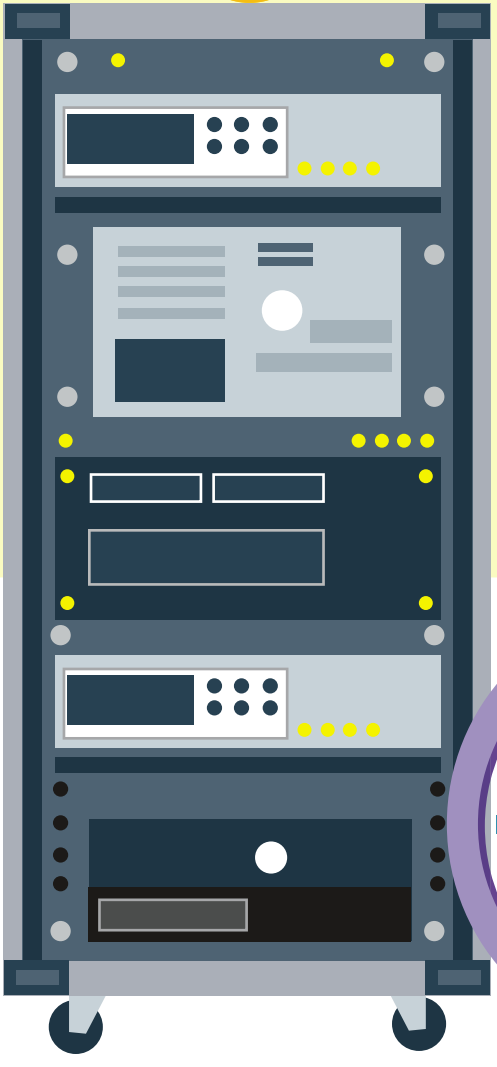
60%

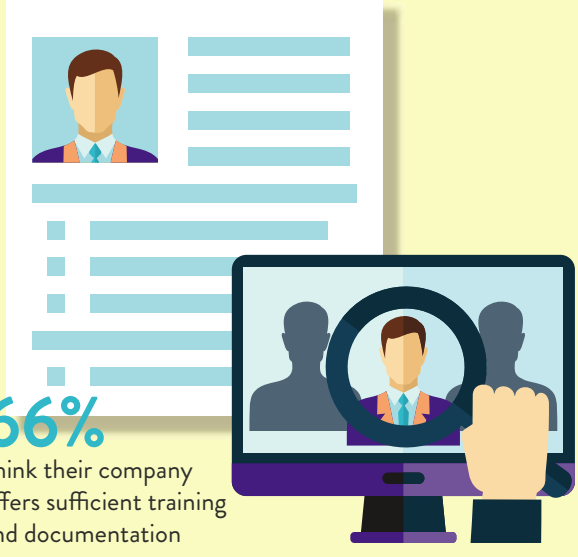
Think their company invests sufficiently in test equipment



21%

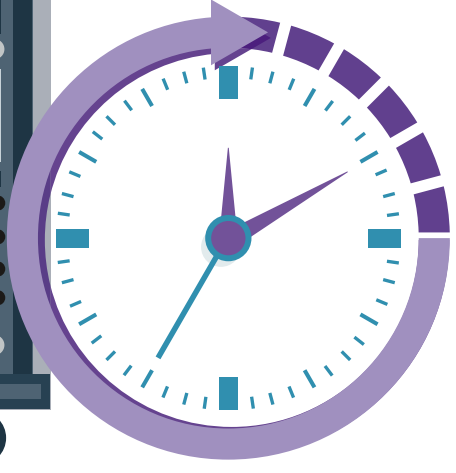
Companies that have replaced box-test instruments with modular solutions





66%

Think their company offers sufficient training and documentation

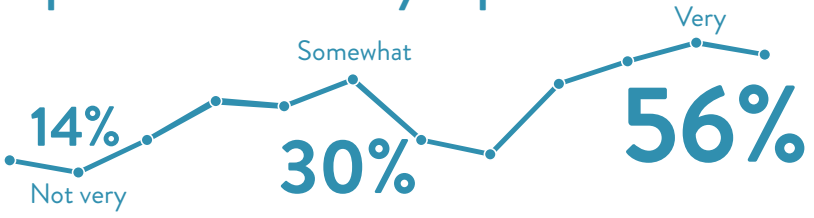


64%

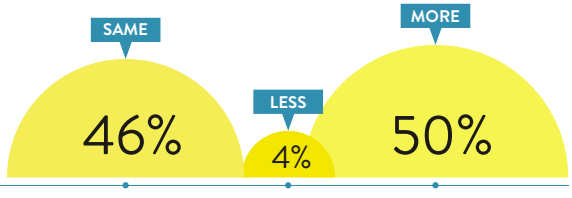
Think testing is a significant challenge in terms of time consumption

PREPARING FOR THE INTERNET OF THINGS

Importance of security in products



How important willsecurity be in future products ?



Companies that will produce connected products

43%

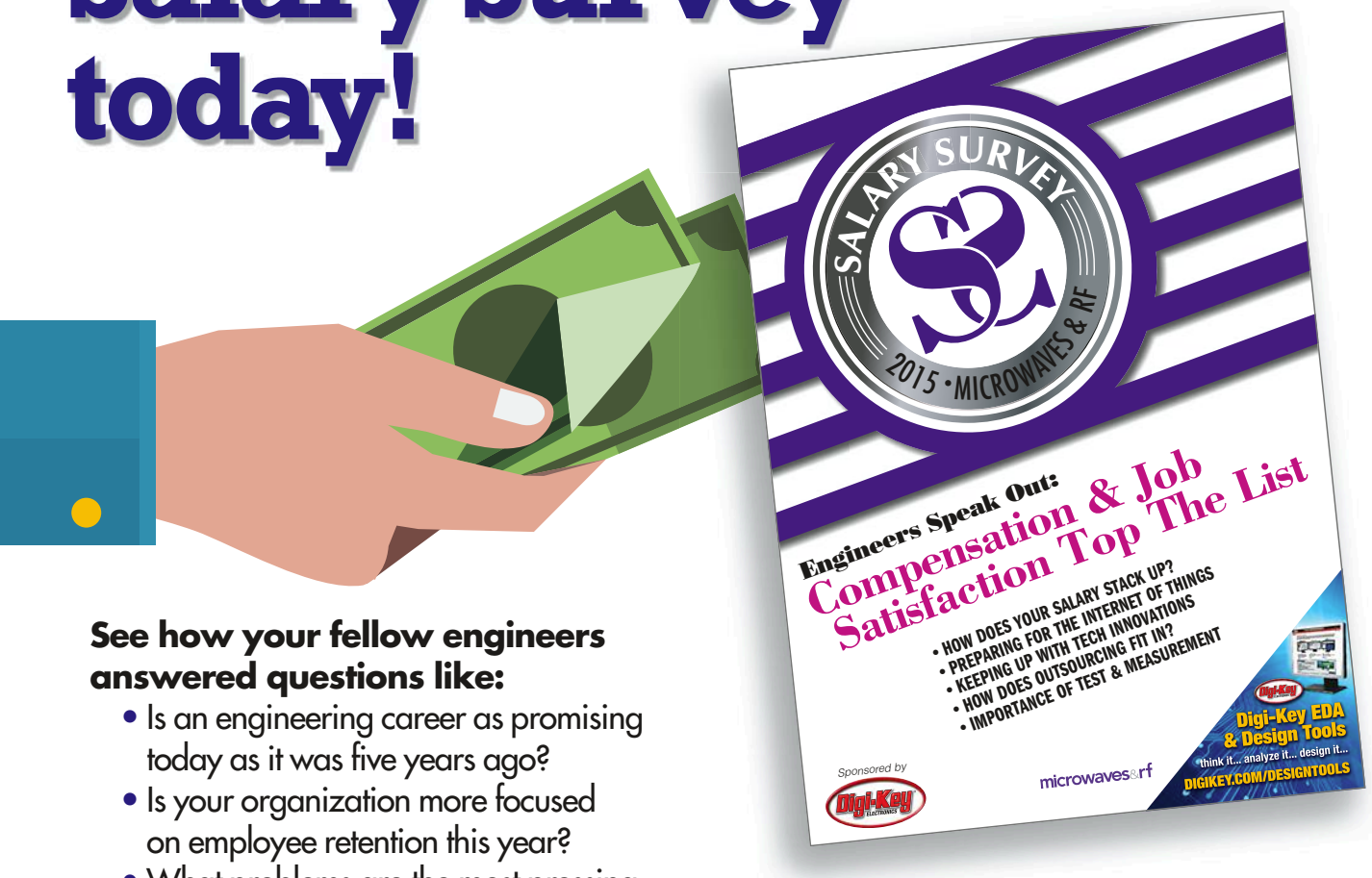
The Internet of Things has the potential to have a huge impact, providing connectivity to countless objects. This also may provide engineers with even more opportunities in the days ahead. Because of both today's and tomorrow's technology, engineers can expect to stay in high demand.

53% of organizations have difficulty finding qualified candidates

Engineering specialties in demand

- 68% RF
- 22% POWER
- 28% SOFTWARE
- EMBEDDED 23%
- 17% MECHANICAL DESIGN
- 38% ANALOG
- 26% DIGITAL
- 33% SYSTEMS ENGINEERING

Download your copy of the Salary Survey today!



See how your fellow engineers answered questions like:

- Is an engineering career as promising today as it was five years ago?
- Is your organization more focused on employee retention this year?
- What problems are the most pressing in your work?

And of course, learn how your salary "stacks up" against others all around the country!

Learn more at

mwrf.com/salarysurvey

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EMAIL | support@dsinstruments.com
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San Luis Obispo, CA 93405

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BBB Accredited
D-U-N-S Number: 079489002
CAGE Code: 76JK0

BRINGING HIGH FREQUENCY AND SIMPLICITY TO ENGINEERS ON A BUDGET

DS Instruments was founded on the idea that by utilizing cutting-edge semiconductors and innovative designs, RF devices and test equipment could be made more compact and affordable, bringing high-frequency research into the hands of a wider audience. We have been designing and manufacturing equipment that provides university laboratories, defense projects, the communications industry, and contractors intuitive, compact solutions for a fraction of the traditional cost. Being an American manufacturer, we stand by our warrantee. From concept to the day of shipment, we are 100% responsible for our devices and proudly outsource nothing. As a young, flexible small business, our engineering cycle is extremely fast-paced, resulting in cutting-edge silicon powering our unique products within months. Device customization and additional features are happily welcomed and refreshingly affordable.

FLEXIBILITY SETS US APART

THE MARKET HAS no match for our dual-use devices at this price. The combination of industry-standard SCPI remote operation requiring no special drivers combined with our simple front-panel control and feedback is unique. DS Instruments currently specializes in developing compact Signal Generators, Programmable Step Attenuators, Tracking Generators, Power Meters, and Frequency Counters, with new products released regularly. Visit us online for updates!

2016 AND THE FUTURE

THE COMING YEAR will be DS Instruments' most exciting yet as we release to market designs in entirely new RF categories, including: a value-line power amplifier, a scaler network analyzer, an integrated wideband mixer-RF-generator, and a new flagship signal generator supporting active harmonic suppression, advanced I&Q modulation, true power-level control, lower phase noise, and a wider frequency range. Call us for a quote!

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DS INSTRUMENTS

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RF Generator & Modulator

- Wideband range of 100MHz - 13.6GHz
- Output power level control (0.5dB steps)
- Active harmonic suppression
- Hardware quadrature modulation to 6GHz
- Front control buttons and display
- ±300ppb internal reference frequency
- Very low phase noise & tiny step size
- Standard SCPI COM port PC interface

Only $1499.00

Wideband Step Attenuator

- Frequency Band: 100MHz - 12GHz
- Up to 63dB attenuation in 0.5dB steps
- USB powered / SCPI command support
- User display and step buttons
- Stress-tested for absolute reliability
- Laser-etched aluminum construction
- Premium SMA connections
- Simple PC control application included

Only $799.00

Entry-level 6GHz Generator

- 25MHz - 6GHz Output
- Internal reference frequency
- USB power and control
- Ultra-micro aluminum enclosure
- Frequency sweeping support
- Extremely cost-efficient

Only $319.00

KU-Band RF Source

- 12GHz - 22GHz Output
- 25MHz - 6GHz Output
- Internal / external reference
- USB powered / automated control
- Bright mini-display and buttons
- High RF power output

Only $1049.00

6GHz Digital Attenuator

- Covers 1MHz - 6GHz
- Input power up to +26dBm
- Low insertion loss
- USB powered / controllable
- Bright mini-display and step buttons
- Tiny, rugged, all-metal design

Only $439.00

Saving Time and Resources from DC - 22GHz

MADE IN U. S. A.

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ENGINEERED IN CALIFORNIA REPUBLIC

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EMAIL | sales@microlambdawireless.com
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46515 Landing Parkway,
Fremont, CA 94538

LEADING THE WAY IN "YTTRIUM IRON GARNET" BASED MICROWAVE COMPONENTS AND SYNTHESIZERS

COMPANY DESCRIPTION:

Micro Lambda Wireless Inc. was founded in June 1990 with the purpose of supplying the microwave community with YIG-based products that provide technically superior performance at competitive prices with the highest regard to customer service and quality. We're a market-driven company continuing to push YIG technology on a consistent basis into new domestic and foreign markets and applications.

Privately held, Micro Lambda Wireless Inc. has been formed from a core of individuals with specialized YIG-based component experience combined with analog, digital, and PLL specialists to yield a strong, dynamic technical staff. High-volume manufacturing techniques have been implemented across all product lines along with standardized mechanical and electrical design, which lend themselves to low-cost and high-volume applications.

We maintain a commitment to Total Quality Management and Just-in-Time concepts throughout the organization. Our integrated manufacturing system combines sales orders, word orders, accounting, inventory, and scheduling. Material planning is supported by an MRP module, which coordinates subcontractor material requirements. Product standardization focusing on a repeatable manufacturing process enables our company to stock material, allowing for very short build cycles.

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Permanent Magnet and Electromagnetic Designs

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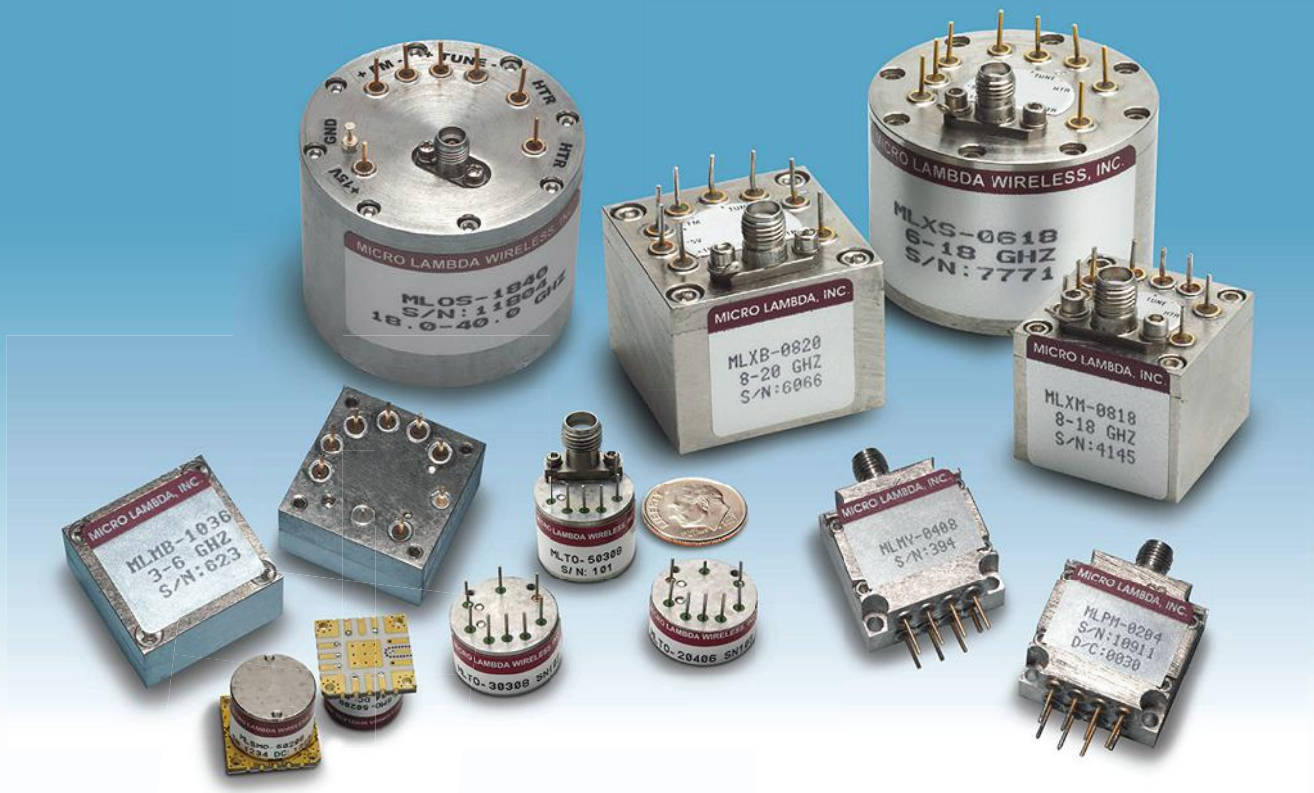

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MLMB/MLMY-Series. Electromagnetic PCB mount and Mini designs are available covering 700 MHz to 12 GHz frequency range. Phase noise of -130 dBc/Hz is provided with output power levels to +16 dBm. Commercial and extended temperature units are available throughout the product line.

MLOS-Series. Units cover 600 MHz to 40 GHz in bands. Standard 1.75" or 2" cylinder packages are provided. Millimeter wave units are available in wide band configurations covering 18 to 26.5 GHz, 18 to 40 GHz and 26.5 to 40 GHz. Commercial and extended temperature units are available throughout the product line.

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JEAN-JACQUES DeLISLE | Technical Editor

4 Major M2M YOU NEED

With the explosion of machine-to-machine and Internet of Things devices and applications, more large technology companies are jumping on board with devices spanning from wearables to beacon modules.

There are so many considerations to take into account when implementing machine-to-machine (M2M) and industrial Internet of Things (IoT) technologies and every aspect must be carefully considered, ranging from cost and power to long-term product-life-cycle challenges and interference.

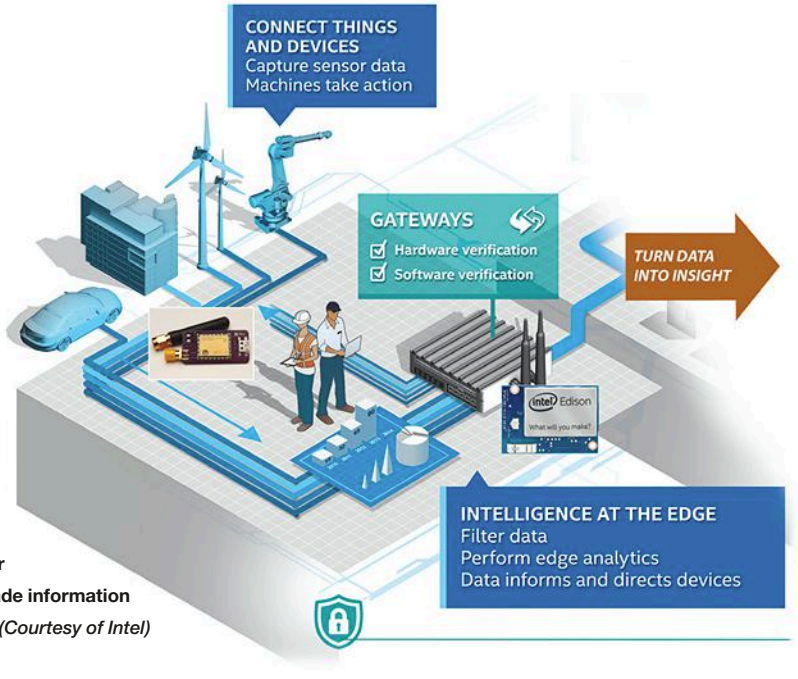
Even those companies armed with a solid standard—one that is efficient and sufficiently versatile for a variety of applications—may find that innate RF and infrastructure challenges continue to plague this emerging industry. Here are four critical areas to watch out for:

LOW POWER OR DATA RATE

The urge to acquire data, control, and intercommunicate throughout a connected-device environment can be quite costly in terms of power. Many wireless-device nodes only need to transmit data in a very limited and infrequent duty cycle. As a result, the power requirements for these types of devices is understandably low. The power requirement will be quite different for devices that are relaying large amounts of data or continuously gathering data from their surroundings.

The tradeoff between power efficiency and data rate extends from the base hardware and wireless protocol used to communicate to the sensors integrated into the platform and the RF environment in which the IoT device is communicating. Generally, a higher data rate and longer range correspond to a higher power requirement. If a device is more sophisticated, in terms of the data it can process and share, it will therefore be more limited in terms of range. It also will be more susceptible to the outside environment.

According to Greg Fyke, marketing director of IoT wireless products for Austin, Texas-based Silicon Labs, "Balancing data rate, range, and battery life are challenges for most low-power IoT platforms. An obvious way to increase the wireless transmitter's range is to boost the transmit output power to



The expansive goal of many IoT platforms is to gather real-time sensor data in order to provide analysis-grade information for the optimization and study of intelligent systems. *(Courtesy of Intel)*

and IoT Challenges TO KNOW

the maximum allowable level, but to realize low power in this scenario you have to architect your application to limit transmitter use and maximize the time spent in standby."

If the competing features of low power, range, and data rate are all critical, more investigation and development are needed for an appropriate wireless standard/protocol.

STANDARDS & INTEROPERABILITY

With an overwhelming number of proprietary and open M2M and IoT solutions available, there is a great deal of confusion over which to choose and under which circumstance it is best to deploy it. Many organizations are actively working to promote solutions that will unite M2M and IoT technologies—among them, m2mGlobal Alliance, Thread, Internet of Things Solution Alliance, AllSeen Alliance, and the Internet Protocol for Smart Objects Alliance. In addition, many competitors and various industrial partners are teaming to create solutions that can provide the necessary range of operation needed for IoT applications. These efforts involve merging a variety of disparate wireless technologies.

In these organizations, arguments are typically centered on the wireless hardware, software, and standards (*see Table at right*). A variety of standards, for example, are better suited to certain aspects of applications. Yet some standards are highly versatile. With many of these wireless standards, there are concerns about the cost of adoption and implementation, as well as the risk of obsolescence. As a result, many of the alliances are focusing on creating solutions that optimize the benefits of various existing wireless standards. In doing so, they hope to create standards and technologies that can coordinate devices operating on different standards.

"Recently, in M2M, we are seeing the development of platform applications that enable users to almost do a point-and-click app solution, such as Apple iOS, Thingworx, and our business," notes Alex Brisbourne, CEO of Kore, Alpharetta, Ga. "These companies are creating downstream libraries of pre-designed applications and solutions based on a variety of technologies. So if customers want a sensor application, they can choose from a variety of sensor providers and quite quickly build those solutions. These uniting platforms are still quite early in gestation. But this approach removes the mystery from having to deal with the numbers of proprietary devices and learning each individual one."

SECURITY & DEVICE SOPHISTICATION

When choosing or developing an M2M/IoT solution,

IoT WIRELESS TECHNOLOGIES

Technologies	Standards & Organizations	Network Type	Frequency (US)	Max Range	Max Data Rate	Max Power	Encryption
WiFi	IEEE 802.11 (a,b,g,n,ac,ad, and etc)	WLAN	2.4,3.6,5,60 GHz	100 m	"6-780 Mb/s 6.75 Gb/s @ 60 GHz"	1 W	WEP, WPA, WPA2
Z-Wave	Z-Wave	Mesh	908.42 MHz	30 m	100 kb/s	1 mW	Triple DES
Bluetooth	Bluetooth (formerly IEEE 802.15.1)	WPAN	2400-2483.5 MHz	100 m	1-3 Mb/s	1 W	56/128-bit
Bluetooth Smart (BLE)	IoT Interconnect	WPAN	2400-2483.5 MHz	100 m	1 Mb/s	10-500 mW	128-bit AES
Zigbee	IEEE 802.15.4	Mesh	2400-2483.5 MHz	10 m	250 kb/s	1 mW	128-bit
THREAD	IEEE 802.15.4 + 6LoWPAN	Mesh	2400-2483.5 MHz	11 m	251 kb/s	2 mW	128-bit AES
RFID	Many	P2P	13.56 MHz, etc.	1 m	423 kb/s	~1 mW	possible
NFC	ISO/IEC 13157 & etc	P2P	13.56 MHz	0.1 m	424 kb/s	1-2 mW	possible
GPRS (2G)	3GPP	GERAN	GSM 850/1900 MHz	25 km / 10 km	171 kb/s	2 W / 1 W	GEA2/GEA3/GEA4
EDGE (2G)	3GPP	GERAN	GSM 850/1900 MHz	26 km / 10 km	384 kb/s	3 W / 1 W	A5/4, A5/3
UMTS (3G) HSDPA/HSUPA	3GPP	UTRAN	850/1700/1900 MHz	27 km / 10 km	0.73-56 Mb/s	4 W / 1 W	USIM
LTE (4G)	3GPP	GERAN/UTRAN	700-2600 MHz	28 km / 10 km	0.1-1 Gb/s	5 W / 1 W	SNOW 3G Stream Cipher
ANT+	ANT+ Alliance	WSN	2.4 GHz	100 m	1 Mb/s	1 mW	AES-128
Cognitive Radio	IEEE 802.22 WG	WRAN	54-862 MHz	100 km	24 Mb/s	1 W	AES-GCM
Weightless-N/W	Weightless SIG	LPWAN	700/900 MHz	5 km	0.001-10 Mb/s	40 mW / 4 W	128-bit

another compromise arises in how secure the device or system needs to be. The level of security usually depends upon the application, which requires anything from maintaining consumer privacy to limiting cyber attacks against utilities. Unfortunately, as we rely more heavily on these systems, more opportunities arise for malicious conduct against them.

The race for IoT system platforms focuses on a radio architecture with the smallest size, lowest power consumption, highest integration, and most versatility. *(Courtesy of Intel)*

As noted by Daniel G. Steele, director of the OEM, Utility, and Energy Market for Freewave Technologies, "M2M, from a security perspective, has probably changed dramatically after 9/11. Some people are more aware from the cyber-attack side of the fence and informed about a lot of the attacks seen by SCADA networks. These issues are on everybody's mind now—especially with smart-grid applications and how they keep their networks secure."

From corporate espionage to denial-of-service (DOS) attacks, many connected systems face regular threats. As a result, Steele says, "Security needs to increase along with all the performance benefits we like to see. The focus shouldn't just be on what we expect with speed and connectivity but also, how secure is everything? We have to make sure no one is eavesdropping on our data packets or conversations."

Generally, adding security features to wireless systems requires more overhead in each packet sent. It also means adding components within the electronics. "There is a cost-analysis side of security features," says Kore's Brisbourne. "For example, if you are putting tens of thousands of devices in a network, how much processing can you have on that device for security? The security sophistication at the device level affects the relative balance of device cost, performance, and power. It is safe to say that there is a specific tension in a design engineer, urging him to look into this."

INTERFERENCE/FAILURES & SPECTRUM

To prevent interference and failure modes in M2M/IoT devices, reconfigurable networks must be created to ensure adequate operation. A variety of new networking standards and updates to old standards include techniques for networks to automatically decide workarounds. These adaptations are designed to work in scenarios ranging from fatal node failure to interference issues.

"Devices can fail so it is important for networks to have built-in resiliency," says Silicon Labs' Fyke. Mesh networks, such as ZigBee and Thread, are designed to self-heal and the network has the ability to intelligently redirect traffic if a device node is no longer available. In the event of a node failure, routes are dynamically updated to realize the most optimal path through the new network configuration. These fail-safe mechanisms in mesh networks ensure that messages can reliably reach their destination. The market won't tolerate an IoT platform where the lights turn on 'most' of the time. When you flip a light switch, the light must turn on every time."

As more wireless devices operate in a frequency swath within the RF environment, the greater the noise and interference will be in those frequencies. Many unintended and non-congestion-related aspects of interference, such as intermodulation and nonlinear effects, lead to other noise-causing issues. These performance-degrading issues exist, regardless if the frequency band is licensed or unlicensed.

Freewave's Steele says, "Another great challenge and the biggest complaint of the operators in the industry is why hasn't the FCC opened up more dedicated spectrum specifically for SCADA and M2M systems. The ISM band is great, along with the uniband and 5-GHz bands. But it is a double-edged sword if you don't have a radio product that can adapt and work around the noise potential."

He adds, "If you don't engineer the system well for noise, it can be your worst enemy. There are licensed systems around. With licensed systems, though, you generally have narrow bandwidths and can't operate at high capacity."

CONCLUSION: DO ENDLESS POSSIBILITIES EQUAL ENDLESS CONFUSION?

As mentioned, several organizations have been looking to create standards and technologies that will serve as the wireless "glue" that joins the various standards and wireless technologies. From a component level all the way to a protocol level, devices will then need to be optimized for flexible operation over common wireless standards. The resulting solutions could range from software-defined operation to highly capable, though specialized devices that are geared toward power optimization using a few critical wireless technologies.

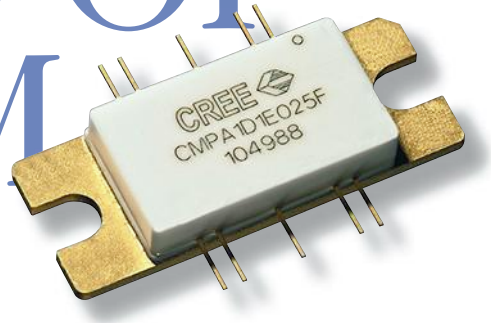
"Traditionally, to enable multi-protocol support, one would need to use multiple radios, which can be expensive," says Fyke. "If you had a radio that was designed to support multiple protocols by time-slicing operation, you could enable multi-protocol support at a much lower cost point and still be able to address some really exciting use cases."

Although there are still many standards and challenges associated with implementing M2M/IoT networked systems, significant progress is being made in uniting current technologies. These approaches may take the form of new wireless standards or even devices that can operate using a variety of wireless standards and frequencies, which will, of course, be based on sophisticated protocols. Whatever solutions end up dominating, they will have to overcome the challenges of security, node failure, and ever-growing interference. mw

Special Report

CHRIS DeMARTINO | Technology Editor

5 Areas Impacting the FUTURE OF SATCOM



1. This MMIC amplifier provides 40 W saturated output power from 13.75 to 14.50 GHz. *(Courtesy of Cree)*

Today's satcom market can be analyzed by examining five focal points: Ka-band products, GaN devices, solid-state power amplifiers (SSPAs), traveling-wave-tube amplifiers (TWTAs), and passive components.

The latest RF/microwave technology is enhancing performance for the satellite-communications (satcom) industry with a wide range of products. Among the products leading this charge are high-power gallium-nitride (GaN) devices, which are empowering the next generation of solid-state power amplifiers (SSPAs). Because GaN technology can achieve performance levels beyond previous-generation technology, SSPA manufacturers can develop their products with better performance in smaller sizes. While GaN technology has certainly received a significant amount of attention, traveling-wave-tube (TWT) technology remains a vital aspect of the satcom industry. Ka-band is another major focus, as the usage of this frequency band has significantly increased in recent years. Many Ka-band products are on the market today, as manufacturers seek to support this frequency band. In addition, manufacturers of passive components are supporting the satcom industry with a wide range of products intended for satcom applications. By taking a closer look at these five areas, it is possible to track the near-term evolution of satcom and discover how RF/microwave technology is enabling the satcom industry.

KA-BAND COMMUNICATIONS

Ka-band is the most recently utilized frequency band to be authorized for commercial satcom. In comparison to other satcom bands, such as Ku-band, Ka-band uses bandwidth more efficiently and is less congested. Thus, Ka-band has become a popular choice for satellite operators in recent years. Although there are some differences worldwide in regards to its exact frequency range, Ka-band is generally considered to span 17.3 to 31.0 GHz. A vast array of RF/microwave products intended for Ka-band satcom applications is available today.

Typical block upconverters (BUCs) used in satellite uplink transmissions convert a band of signals from the L-band frequency range to a higher frequency band, such as C-, Ku-, and Ka-band. The block downconverters (BDCs) that are typically used in satellite downlink transmissions perform the reverse function. They convert a band of signals from a frequency range, such as C-, Ku-, and Ka-band, down to the lower L-band frequency range.

With Ka-band communications becoming more prevalent, high-performance Ka-band BUCs and BDCs are needed to support these requirements. Among companies offering Ka-band BUCs and BDCs are L3 Narda-MITEQ, GeoSync Microwave, Cross Technologies, Jersey Microwave, and WORK Microwave, to name a few. Some suppliers offer the option to purchase these BUCs/BDCs as either an outdoor unit intended for antenna-mounting or as an indoor unit intended for rack-mounting.

HIGH-POWER GaN DEVICES

Today, high-power GaN devices are being used to create the next-generation of GaN-based SSPAs. Prior to the advent of GaN technology, high-power gallium-arsenide (GaAs) devices were widely used to design SSPAs. Thanks to GaN technology's

(continued on p. 48)

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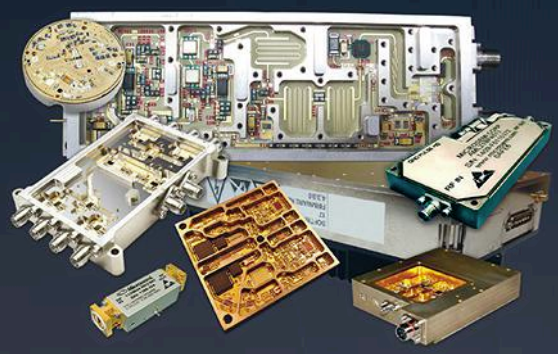

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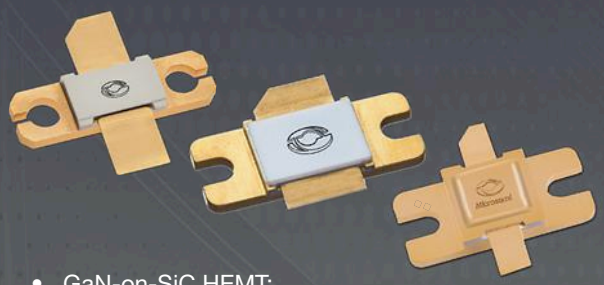

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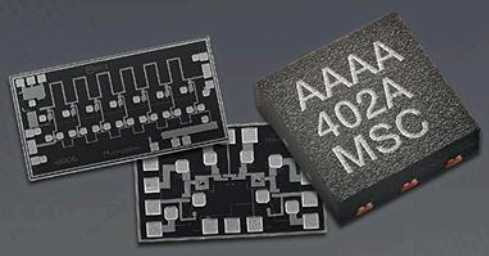

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(continued from p. 45)

continuous improvements, SSPA manufacturers are now building SSPAs with GaN devices. GaN technology offers a number of performance benefits in comparison to the older GaAs technology. A GaN device can deliver significantly more power density than a GaAs device. Thus, GaN-based SSPAs can be designed by power-combining fewer devices, resulting in greater efficiency. This also enables GaN-based SSPAs to be built in smaller package sizes than GaAs-based SSPAs. New high-power GaN devices have recently been released, providing additional high-power solutions to the satcom market.

These SSPAs will soon be available for both Ku- and Ka-band, providing output power levels to 100 W and 50 W, respectively. *(Courtesy of Mission Microwave Technologies)*

With its portfolio of high-power GaN devices, Cree is one company enabling GaN technology to be utilized in satcom applications. The company recently added to its product line with the release of a new high-power monolithic microwave integrated circuit (MMIC) (*Fig. 1*). This GaN MMIC is a two-stage high-power amplifier (HPA) intended for Ku-band applications. It is available in a 10-lead, 25-×-9.9-mm, metal/ceramic flanged package (model CMPA1D1E025F) or as bare die (model CMPA1D1E030D).

"Cree's Ku-band GaN MMIC HPA was specifically designed in response to customer requests for higher-power and higher-efficiency Ku-band amplifier solutions," said Tom Dekker, director of sales and marketing, Cree RF. "By delivering higher power, gain, and efficiency at an affordable price point, this amplifier will set the new standard for Ku-band performance."

Dekker added, "Covering the 13.50-to-14.75-GHz commercial satcom band, the 30-W gallium-nitride-on-silicon-carbide (GaN-on-SiC) MMIC, two-stage high-power amplifier (HPA) enables the satcom industry to achieve higher-power and more efficient Ku-band solutions than the incumbent traveling-wave-tube (TWT) or GaAs solutions used currently. Applications include unmanned intelligence, surveillance, and reconnaissance (ISR), satcom-on-the-move (SOTM) ground vehicles, manned and unmanned aircraft, and maritime vessels."

High-power GaN devices from Cree are also available for other satcom bands. An example is model CGHV96050F1, which is intended for X-band applications. Ka-band products are also currently being developed.

In addition, Qorvo recently released GaN power amplifiers (PAs) intended for commercial very-small-aperture-terminal (VSAT) and military satcom applications. Those PAs include the TGA2239-CP, TGA2595-CP, and TGA2594-HM. The TGA2239-CP is intended for Ku-band applications, while the TGA2595-CP and TGA2594-HM both target Ka-band applications. The TGA2239-CP provides 35 W output power from 13.4 to 15.5 GHz. The TGA-2595-CP is an 8-W PA covering 27.5 to 31.0 GHz, while the TGA2594-HM provides +36.5 dBm of output power from 27 to 31 GHz. These PAs add to the company's existing portfolio of high-power GaN products.

For its part, Toshiba has a line of high-power GaN devices that are suitable for C-, X-, and Ku-band applications. A new Ka-band, high-power GaN MMIC is also scheduled to be released by the end of this year. This MMIC, the TGM2931-15, will provide 15 W output power from 29 to 31 GHz. The company also recently began production of the TGI5867-130LH, which is a C-band, 130-W GaN device.

SOLID-STATE POWER AMPLIFIERS

With high-power GaN devices available on the market, SSPA manufacturers can design their products using the latest GaN technology. Advantech Wireless, for example, has an extensive product line of GaN-based SSPAs. The company offers GaN-based products for C-, X-, DBS-, and Ku-band. As part of the company's SapphireBlu series, C- and X-band SSPAs with output power levels as high as 6.6 kW are available as well as Ku-band SSPAs with output power levels as high as 3 kW.

One newcomer to the scene is Mission Microwave Technologies. Founded in 2014, the company offers SSPAs with integrated BUCs in a cylindrical package (*Fig. 2*). The company utilizes advanced GaN transistors, power-combining technology, and novel full-system designs to create compact SSPAs.

"The amplifiers in the new Javelin and Stinger product lines deliver more than 100 W and 55 W at Ku-band, respectively," said Francis Auricchio, Mission Microwave Technologies' president and CEO. "Unmatched prime power efficiencies of over 20% are achieved in lightweight, compact form factors that include upconverters, linearization, and integrated power supplies. Both the Stinger and the Javelin amplifiers include a standard user-friendly Bluetooth mobile app remote for monitor-and-control, which makes it simple for users to adjust power levels on the fly without a physical connection to the amplifier. Ruggedized for harsh outdoor environments, our Ku-band amplifiers are available now, with 50-W and 25-W Ka-band amplifiers following right behind."

Explaining the innovative packaging of these SSPAs, Auricchio noted, "Our unique packaging was developed as we worked to realize the absolute minimum in amplifier size, weight, and volume, which is difficult to achieve by more traditional methods without sacrificing performance and reliability. Typical rectangular-shaped units tend to have heatsinking across the amplifier that is either uniform and underutilized or inefficient and unbalanced. Our cylindrical package optimizes the heatsinking to where it is needed most and provides airflow

over the complete amplifier body. These aspects together maintain thermal performance—even in a small form factor. Satcom customers continue to request smaller and lighter units, especially for mobile and man portable applications. By optimizing the form factor of our products, we have been able to deliver this without sacrificing performance."

GaN-based SSPAs are also offered by Teledyne Paradise Datacom. Outdoor SSPAs are available for S-, C-, X-, and Ku-band with a wide range of output power levels. The company provides various packaging options for these SSPAs.

The Outdoor PowerMAX, Teledyne Paradise Datacom's new high-power SSPA system, was recently unveiled. Its system architecture is a multi-module amplifier system, which allows PowerMAX systems to be configured with a large variety of output power levels. It also is a scalable amplifier system, as an Outdoor PowerMAX system may be initially configured with four modules and later upgraded to eight modules in the field. The C- and X-band versions of the Outdoor PowerMAX system can generate an output power level as high as 10 kW, while the Ku-band version provides as much as 5.7 kW output power.

3. Ku-, DBS-, and Ka-band TWTAs are now boasting output power levels as high as 1250 W. *(Courtesy of Tango Wave)*

TRAVELING-WAVE-TUBE AMPLIFIERS

With the excitement created by GaN technology, it may seem like traveling-wave-tube amplifiers (TWTAs) have been abandoned. However, TWTAs are still being used today. In fact, the technology has advanced in recent years. TWTA manufacturers continue to release new products, demonstrating that this technology is alive and well.

Yet the debate between SSPAs and TWTAs continues. Manufacturers of SSPAs like to point out the advantages that SSPAs have over TWTAs. The introduction of GaN technology has added fuel to the fire, as GaN-based SSPAs can provide performance improvements over previous-generation GaAs-based SSPAs. While SSPAs do have their benefits, TWTAs can still provide advantages over SSPAs in some applications. Thus, deciding on a preferred amplifier technology is dependent on the specific application.

One company providing TWTAs to the satcom market is Tango Wave. The company offers TWTAs for DBS-, Ku-, and Ka-band with output power levels as high as 1250 W (*Fig. 3*). Those products are designed for direct-to-home (DTH), global up-linking, satellite news gathering (DSNG/SNG), broadcasting, voice/data, mobile up-linking, and maritime applications.

Comtech Xicom Technology recently introduced the Ku- and DBS-band SuperPower Series TWTAs, available in both frequency bands as either outdoor antenna-mount units or as indoor rack-mount units. The XTD-2000KHE model is a Ku-band TWTA that provides 750 W of linear output power while drawing less than 3200 W of prime power. The XTD-1500DBSHE model is a DBS-band TWTA that provides 560 W of linear power while drawing only 2500 W of prime power.

The SuperLinear TWTA product line from Communications & Power Industries ranges in efficiency from 13% for lower-power models to over 22% for 2500-W amplifiers. Life-Extender is its new, patented technology, designed to increase a TWT's lifespan by preserving the active coating on the cathode surface. A TWT reaches the end of its life when its cathode barium reserve is exhausted. The rate of barium evaporation is determined by the cathode temperature, which is in turn determined by the cathode heater voltage setting. With LifeExtender, the cathode heater voltage is adjusted over time to minimize the rate of barium depletion, thereby maximizing the life of the cathode. As a result, a TWT's lifespan can increase by 30% to 50%.

PASSIVE COMPONENTS

Passive components are an integral part of any satcom system. These components include filters, couplers, isolators, and more. Many manufacturers offer a wide range of passive components for satcom applications.

For example, Advanced Technical Materials (ATM) offers an entire product line of components for Ka-band applications. These components cover the uplink frequency range of 27.5 to 31.0 GHz and the downlink frequency range of 18.3 to 20.2 GHz. The company offers both coaxial and waveguide models. The product line includes power dividers, attenuators, phase shifters, couplers, and more.

Another example of a company providing passive components to the satcom market is ETG Canada. The company's SSPA original equipment manufacturer (OEM) product line is intended to allow SSPA OEMs to purchase waveguide components from the same vendor. This product line includes adapters, circulators/isolators, terminations, and couplers.

To summarize, a significant amount of activity is occurring in the RF/microwave industry in support of satcom applications. GaN technology is receiving a significant amount of attention, as it is enabling the next-generation of SSPAs. New high-power GaN devices will continue to be released in the near future. TWT technology also continues to be an important contributor to the satcom industry. And as Ka-band satellites continue to be implemented, suppliers are providing components to support this frequency band. mw

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PCB Materials

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Weighing the Options for

Sorting through different RF/microwave circuit materials educed comparisons of performance improvements and cost hikes, although some materials may save processing expenses.

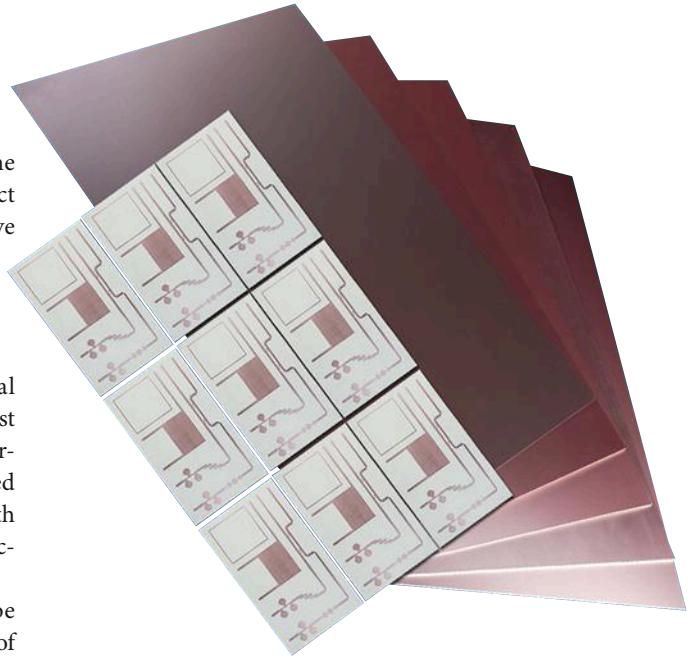
Circuit materials form the foundations for high-frequency designs, from the semiconductor to system levels. These materials tend to be taken for granted, though, in spite of the fact that the choice of a printed-circuit-board (PCB) material can impact the ultimate performance achievable with an RF/microwave circuit design. Hopefully, this quick review of some of these building-block materials used in high-frequency circuits and components can help designers better match a particular material to a design goal, even at the highest frequencies.

Extracting the most performance from a PCB material involves choosing the right material and then applying the best PCB production process with the least errors and tightest tolerances. A PCB manufacturing facility with carefully monitored and controlled processes often delivers better performance with low-cost circuit materials than one with lower-quality manufacturing processes and higher-cost circuit materials.

The choice of a PCB manufacturing facility should not be made casually. Considerations to factor in include the types of circuits to be manufactured, the required circuit tolerances, the number of component and device placements, and even the volume of PCBs to be manufactured.

Before that choice can be made, though, it's necessary to sort through a variety of circuit materials to find a suitable starting point for a PCB. High-frequency PCBs were once mostly single-sided constructions based on rigid, ceramic-based dielectric boards or more flexible, dielectric materials often based on polytetrafluoroethylene (PTFE) materials. Modern circuit-board materials are typically composites, often blending woven glass with a dielectric base material to achieve strength and consistency.

Sorting through current, commercially available PCB materials is a matter of comparing different key material characteristics and how a given material's behavior can be expected to support an application of interest. Frequency range, RF/microwave power levels, and operating-temperature range will help determine which PCB materials are likely candidates from the many materials available on the market.



1. The 4835 circuit material maintains a typical dielectric constant of 3.48 in the z-axis at 10 GHz, with outstanding dielectric constant tolerance of ±0.05. ***(Courtesy of Rogers Corp.)***

Key circuit materials to compare include relative permittivity or dielectric constant (also known by the abbreviation of ε_r), dissipation factor, thermal conductivity, glass transition temperature (Tg), loss tangent, dielectric breakdown voltage, and material thickness and thickness tolerance. Material selection should entail a process of comparing multiple material parameters, since they tend to be inter-related.

For example, a material with a high dielectric constant enables miniaturized circuits; but, in the case of a power amplifier, it may lack the thermal conductivity to effectively dissipate excess heat from the active circuitry. Furthermore, a circuit material with dielectric constant that exhibits a wide frequency variation may serve a narrowband design, but not work all that well for broadband circuitry. In addition, a material with some favorable parameters may fall short in other areas, such

RF/MW Circuit Materials

as the ability to withstand the rigors of lead-free (RoHS) circuit processing. One should consider as many circuit parameters as possible when comparing the various PCB parameters for a particular application.

DIELECTRIC DECISIONS

Circuit designers typically start with dielectric constant when sorting through different PCB materials. The dielectric constant of a PCB will determine the dimensions of the transmission lines fabricated on that PCB for a given frequency or frequency range, with higher dielectric-constant values translating into smaller circuits and transmission-line dimensions. The dielectric constant is a measure of a material's capability to store charge, as in a capacitor fabricated on that material. Higher dielectric constants denote greater charge-storing capacity for a given voltage.

The "relative" dielectric constant of a material is relative to the value of a vacuum (unity) or dry air (close to unity), and can be measured with a proper test fixture and a microwave vector network analyzer (VNA). Dielectric-constant values listed by different manufacturers for their PCB materials derive from these measurements, and the measurement method and particular conditions, including frequency, are usually listed along with the dielectric-constant values.

Some manufacturers will list typical values of dielectric constant while others may list multiple values of dielectric constant for different frequencies. And, as materials specifiers should be aware, the value of a material's dielectric constant does change with frequency as well as with temperature. Also, when choosing a material for an application at a specific frequency, dielectric-constant values should be compared for test conditions as close as possible to that frequency of interest.

It should also be noted that circuit materials are anisotropic in terms of dielectric constant, with different values of dielectric constant in the x, y, and z axes of the material. Comparisons of different materials should match axes for axes. PCB dielectric constant will also vary according to variations in a material's thickness. For applications that require tight control of dielectric constant, such as in impedance matching of transmission lines and other circuit structures, PCB thickness should also feature tight tolerance.

Modern computer-aided-engineering (CAE) software simulation programs *(see p. 60)* may contain models for particular brands and models of PCB materials based on the published values of dielectric constant at particular frequencies. Or, they may allow a user to enter values of dielectric constant at different frequencies when calculating the performance of a designed circuit on a particular PCB material. Some PCB suppliers, such as Rogers Corp. (www.rogerscorp.com), will even supply dielectric-constant values that it terms as "Design Dk" values, which are measured at different frequencies and conditions for use with a commercial CAE program to obtain optimum simulation results.

TAKING THE TEMPERATURE

Thermal conductivity in a PCB is important for higher-power circuits—high thermal conductivity translates into effective heat flow from a power source to a heat sink. It's determined by a number of material factors, including the type of dielectric material, the area of heat flow, the thickness of the copper conductor, any type of plating finish used with the copper conductor, and even the surface roughness of the copper conductor.

Thermal conductivity will be less of a consideration when choosing PCB materials for small-signal, lower-power applications, which typically generate less heat. Still, even in small-signal applications, the high density of modern circuit applications can result in "hotspots" throughout a circuit board, and good thermal conductivity can contribute to the long-term reliability of even a small-signal circuit design.

A PCB material's glass transition temperature (Tg) refers to the temperature at which a dramatic change takes place in the material's coefficient of expansion, or its tendency to expand with increasing temperature. Because a material's expansion is limited in the x and y axes due to the large volume of material in those axes, most of the expansion above Tg will occur in the z axis or thickness of the material. This will cause stress on plated

through holes and viaholes in a PCB material above Tg, since the dielectric material will expand while the plated metal (copper) will not expand.

The Tg of a PCB material is a consideration not only for operational temperatures, but during any manufacturing processes (e.g., soldering operations) that may yield high temperatures and failed circuit boards. Another critical temperature parameter for PCBs is the decomposition temperature (Td), which is essentially the temperature at which the material begins to melt.

A PCB can suffer electromagnetic (EM) signal loss due to both its dielectric and conductor materials. The conductors, for example, can lose energy as a result of propagation reflections that occur at impedance mismatches at circuit interfaces, such as transmission-line junctions.

Signal loss may also occur from absorption of EM energy by the dielectric material, otherwise known as the material's loss tangent. Dielectric breakdown voltage simply refers to the highest short-term voltage that a circuit material can survive without damage. While this circuit parameter is more commonly a concern for designers of digital circuits, it can come into play for any circuits that encounter high voltages.

These are just some of the parameters used to characterize PCB materials. While not a complete picture, they provide a good starting point when comparing different commercial materials for a given application.

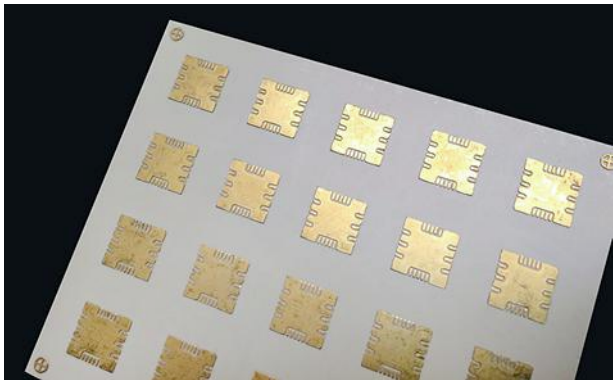
FACTORING IN COST

Cost, of course, is another key parameter, and it may dictate which circuit material will be used for an application. Low-cost FR-4 circuit materials, for example, are often used as a reference to specify circuit materials for RF/microwave applications. However, they tend to be limited in terms of their capabilities when compared to newer (and more expensive) circuit materials developed for higher-frequency applications.

FR-4 circuit materials consist of woven fiberglass covered with epoxy. They exhibit high loss, but are often used for mixed-signal, analog, and digital circuits through about 3 GHz. These rigid materials aren't meant to be flexible, and can handle temps to about +120°C before melting, so manufacturing processes must be maintained at lower temperatures accordingly.

Though FR-4 materials are popular from a cost perspective, they lack the stability and consistency of dielectric constant available from more expensive PCB materials. G10 FR-4 materials are a variant of standard FR-4 materials, developed to handle higher temperatures and higher moisture environments.

More-flexible, though higher-cost, PTFE-based circuit materials often will be used for higher-frequency applications that are less tolerant of loss. Unlike FR-4, PTFE has several special circuit-board processing requirements, including preparation of viaholes through a circuit board to create plated through holes for multilayer circuits. For those in need of additional details on how FR-4 and PTFE materials compare, Isola (www.isola-group.com) provides the white paper "FAQs for Selecting PCB Materials for RF/MW" as a free download from its website (http://www.isola-group.com/news/faqs-of-selecting-pcb-materials-for-rfmw/).



2. The ULTRALAM 3850HT circuit laminate exhibits a typical dielectric constant of 3.14 in the z-axis at 10 GHz. *(Courtesy of Rogers Corp.)*

HOW DO THE LATEST MATERIALS STACK UP?

Some newer, higher-performance circuit materials were evaluated as examples of how parameters might compare for different circuit materials. One of these, Rogers Corp.'s 4835 circuit material *(Fig. 1)*, has a typical dielectric constant of 3.48 in the z-axis at 10 GHz, held to a tolerance of ±0.05 across the board. It features a dissipation factor of 0.0037, also through the z-axis at 10 GHz.

This high-performance material is compatible with lead-free processes, and can be fabricated with standard FR-4 processes, although the material shows some impressive thermal characteristics. It offers a Tg of better than +280°C and a Td of +390°C, with a thermal coefficient of dielectric constant of +50 ppm/°C in the z-axis from –100 to +250°C. Its low thermal conductivity of 0.66 W/m/K makes this material a serious candidate for high-power amplifiers and phased-array radar systems. It suits critical, high-volume applications, such as collision-avoidance millimeter-wave radar systems in the automotive arena.

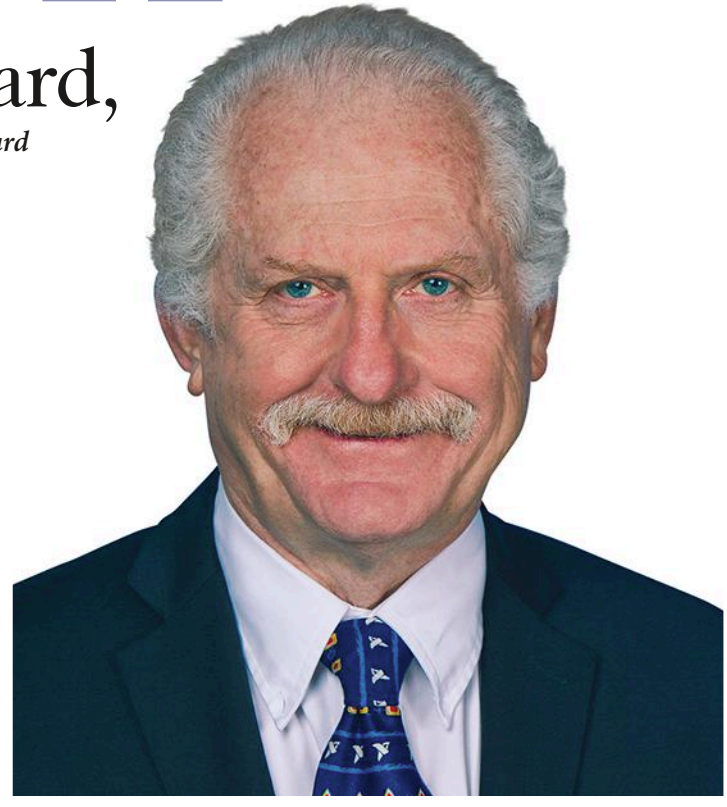
The ULTRALAM 3850HT circuit laminate from Rogers Corp. *(Fig. 2)* also features a low typical dielectric constant of 3.14 in the z-axis at 10 GHz. The material has a dissipation factor of 0.0037, which is once again through the z-axis at 10 GHz. Thermal conductivity is a low 0.2 W/m/K. The ULTRALAM 3850HT is well-suited for mobile applications that require both high flexibility and low moisture absorption.

As noted earlier, cost can be a key parameter when choosing a PCB material for an application. But when also considering performance and achieving higher yields from a production process (especially when higher temperatures are required), the higher initial costs of some circuit-material types may deliver higher yields and lower final costs than materials such as FR-4, which save on cost from the outset. mw

Inside TRACK with Dr. James Truchard,

Winner of* Microwaves & RF*'s Living Legend award

Interview by LOU FRENZEL Contributing Editor



LF: First things first, how does it feel to be a Living Legend?
JT: That's a great question. I think when you graduate from high school, the number of "gold stars" you receive starts to dwindle, so it's a real honor and pleasure to be recognized by *Microwaves & RF*. I truly appreciate receiving this award and it's certainly something that makes you feel like you're doing the right thing with your career.

LF: Your success is National Instruments, but what was the motivation or impetus that led you to founding the company? Give us a little background on the company itself from the beginning.
JT: National Instruments serves the science and engineering community and I view that as a highly leveraged position, because if NI can make these very important people in society more successful, we provide tremendous value to society as well. You'll see NI solutions in a wide variety of industries such as wireless communications, energy, and transportation, and I feel like NI can be more impactful by providing flexible solutions that make those scientists and engineers more productive than if we worked on each of those applications directly. So that is a big fundamental motivation of mine.

At NI, we work on all of the National Academy of Engineering's Grand Challenges through our customers, so having the ability to help these scientists and engineers solve complex problems is very rewarding. In starting the company, my goal was to be aligned with technology and be able to work with the forefront of technology, and we have certainly been able to do that.

Now, I also recognized that we had to be a good business. Because to have autonomy to do the things you want to do, you have to be a good business so that you can get that profit that allows you to have autonomy, instead of somebody else telling you what to do. So that was very much a motivation as well. I saw starting NI as an opportunity to provide good career paths for the very talented engineers and computer scientists that we have, so providing a career path with growth opportunities for both the company and the careers of my employees is very important to me.

LF: When was the company actually founded?
JT: The company was founded in 1976 and we actually moonlighted for three years until we went full time. Then we were able to effectively self-finance the company through that process.

LF: What is the one product that highlights your achievement?
JT: Our software platform with LabVIEW at the core has

(continued on p. 58)

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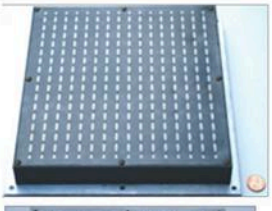

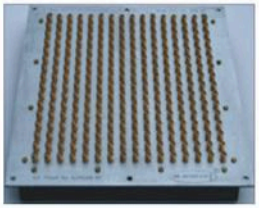

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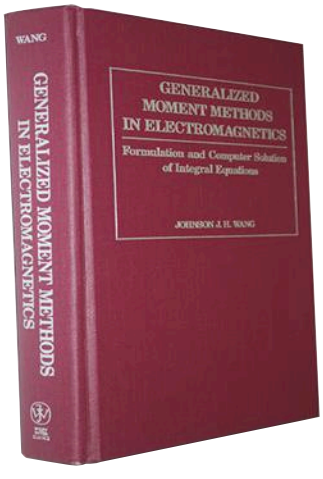

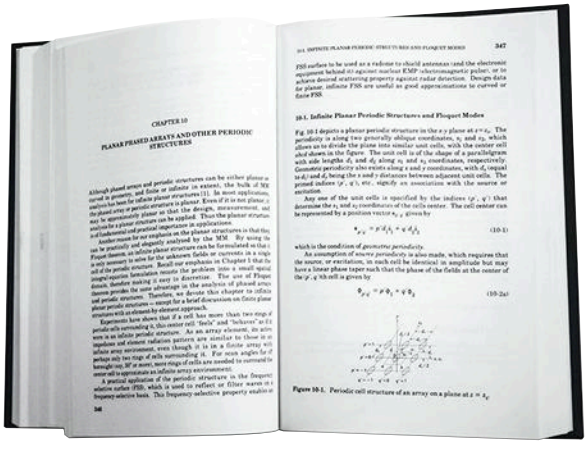

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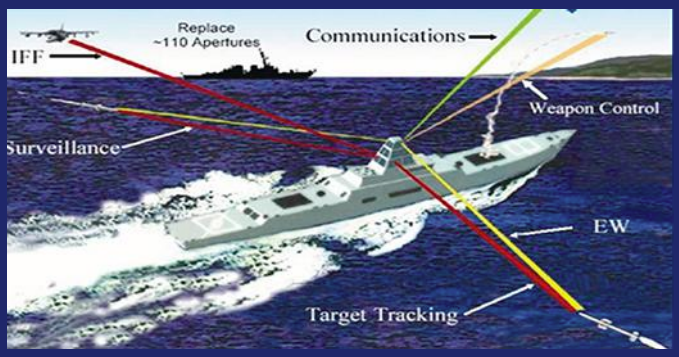
Use of dissipative or exotic materials (e.g., ferrite or metamaterial)	• Not used	• Often needed/used, thus low producibility • Large cost, weight & thickness
Use of substrates/ superstrates of special dielectric property	Not used (minimal use only for structural support); thus lower cost, weight, thickness. Easily air cooled for high power!	Generally necessary; thus large cost, weight, thickness. Difficult to air-cool, thus low power handling!

*Based on Neto & Cavallo, *2015 IEEE Antenna Symp.,* Vancouver, 2015



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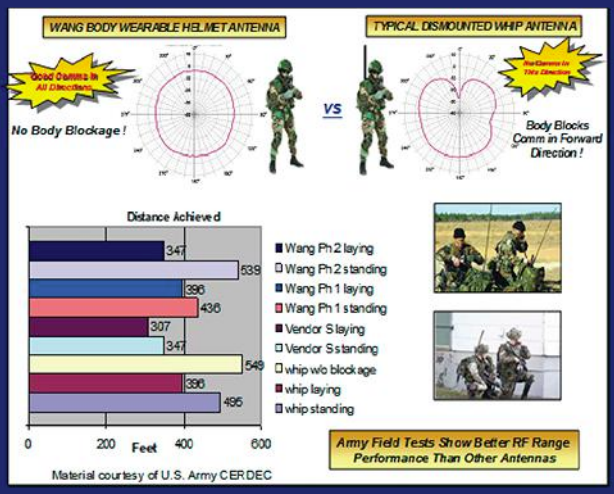

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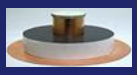

Ultrawideband Miniaturized Omnidirectional Antennas

- Multioctave bandwidth covering many applications (e.g., JTRS)
- Instantaneous bandwidth up to 100:1 or more

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- Broadband & multiband
- Multifunction
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- Low cost

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(continued from p. 55)

really been the most important thing that we have done, and this reaches out and enables our success in many areas. For example, one of our recent product launches, the LabVIEW Communications Systems Design Suite has extended our software platform into the research and prototyping of next-generation wireless communications space. As we saw at recent events like GLOBECOM and the Brooklyn 5G Wireless Summit, NI has enabled engineers to demonstrate algorithms in a fraction of the time that they used to take—In other words, show real working product designs more quickly and efficiently than ever before.

LF: What is the current focus of National Instruments? What are some of the current trends?

JT: So, at several levels—first off, a big focus for us is in the RF and communications space. Both in the design with the tools like LabVIEW Communications System Design Suite and our AWR suite of software for RF hardware design, and also with support from scientists and engineers for data acquisition. Another focus for NI has been embedded systems design, again using LabVIEW extensions in the industrial space. We have been very active in the development work of industrial applications where we have embedded solutions like CompactRIO. We did some very early work in defining what is meant in the industrial space with CompactRIO leading the way over the last decade.

LF: Your focus does seem to be in the RF and communications space. What percentage of the business is that?

JT: Well, it is growing. We don't break it out specifically, but it is one of the fastest-growing areas of opportunities for us. We have introduced breakthrough technology with the vector signal transceiver that is really redefining how measurements are made. It also can be used to prototype new algorithms. It can be used to build radar. The VST is very flexible, yet it primarily serves the test-and-measurement space. LabVIEW Communications System Design Suite is another major development on the software side that creates a highly differentiated tool that helps engineers design new systems, demonstrate algorithms, and the like.

LF: Have you done anything in the field of Internet of Things (IoT)?

JT: Yes. When consumers think of the Internet of Things, they often think about their consumer technologies like wearable devices, home automation, their mobile devices. At NI, we're more involved with the Industrial Internet of Things—developing complex, intelligent engineering systems that impact large-scale infrastructure with our hardware and software platform. NI's involvement in the Industrial Internet of Things spans from smart-grid applications to smart factories in a manufacturing setting.

LF: Somebody told me that you are still selling GPIB (General Purpose Interface Bus).

JT: That's right.

"Receiving this award is certainly something that makes you feel like you're doing the right thing with your career."

LF: It is still out there, isn't it?

JT: Well, the thing is, if you have a group of instruments, until the last one goes away, you still need that interface. And also, GPIB was a very good standard. It was parallel, it was fast, and in the early days, we actually built GPIB extenders so that we could talk to each other. So GPIB was pioneering in terms of performance and you had to go to 100M Ethernet before you got performance that rivaled GPIB. Now, with a large install base and by continuing to support GPIB, we make sure that all those instruments that are out in the field can be used. Can you imagine if nobody was doing that? How many instruments would not be useful because they couldn't be automated because they didn't have the right interface?

LF: Instruments tend to have a long life.

JT: That is exactly right. When I was in university, I was using equipment that was 40 years old. So I tell the story that there was General Radio, then there was Hewlett-Packard. And now there is National Instruments. General Radio had vacuum tubes, Hewlett-Packard had transistors, and NI has software.

LF: What advice about the future can you give readers of *Microwaves & RF*?

JT: I think that there is still a lot left to be discovered and invented, so I'd advise today's engineers to keep that positive view and remember that there is much more to come. As engineers, we will continue to make innovative technological breakthroughs that impact society and improve our quality of life.

For example, over the past decade we've seen how communications has dramatically changed how people work together, how they interact with each other, and has made us more connected than ever.

LF: And if test equipment companies such as yours don't make the test instruments, we will never be able to design the new products. So keep at it.

JT: Exactly. Thank you. mw

JEAN-JACQUES DELISLE | Technical Editor

Strategies for Measuring Common Signal-Corrupting Distortions

To avoid the performance challenges caused by nonlinearities and distortion, modern measurement techniques can help engineers understand the device mechanics that cause them.

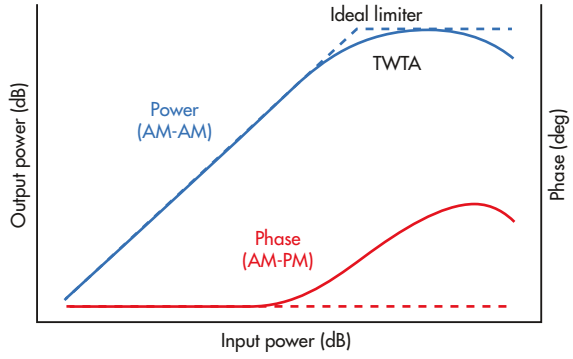
THE INTRINSIC IMPERFECTIONS of devices and the materials that comprise them lead to non-ideal electrical relationships. Nonlinear relationships among power, current, voltage, and phase cause complex responses, which are generally difficult to model. Anything from poorly connected metal structures to internal material properties can induce such relationships.

Ultimately, these nonlinear effects limit component/device performance. Their resultant signals are referred to as distortion products. Engineers must figure out how to effectively measure and mitigate several different categories of distortion products using design or manufacturing techniques. Among the most common distortion challenges are:

HARMONIC DISTORTION

Harmonic implies the development of integer multiples of a series. With harmonic distortion, a distortion product of an input signal appears as the function of a series over an infinite range of frequencies. A nonlinear voltage and current relationship causes harmonic distortion, represented as complex mathematical products. Generally, the first few harmonic products are the most significant—as the power diminishes, the order of the harmonic product rises in parallel. Eventually, these harmonic products fade into the noise floor.

Harmonic-distortion products are generally consistent within a device. Because they are a function of the input signal, careful filtering can often remove the most troublesome harmonic products. Unfortunately, harmonic products may also appear near or within the transmit/receive bands in multi-frequency systems, effectively reducing the dynamic range.



1. Certain materials and active components can induce nonlinear current and voltage relationships, which can cause unwanted signal manipulation.

INTERMODULATION DISTORTION

Intermodulation distortion (IMD) is caused when multiple frequencies are mixed to form sum and difference products of the original signals. These signals occur as integer multiples of the input frequencies (spurs). Often, they impact the operation bands of the devices. Several IMD products can occur within the same receive or transmit band, depending on the input signals and operation bandwidths.

IMD products can be both harmonic and nonharmonic. As a result, predicting and mitigating IMD-generated spurs is both complex and error-prone. If the input signals vary in frequency—in tandem or not—the IMD products will change in both frequency and power. Small component and material imperfections can cause IMD. Examples include dissimilar metal contact, surface corrosion, or intrinsic material properties.

When non-active components cause IMD effects, it's known as passive intermodulation (PIM) distortion. Often, devices and components must be rigorously tested to ensure that they operate with low IMD or low PIM. These non-

(continued on p. 62)

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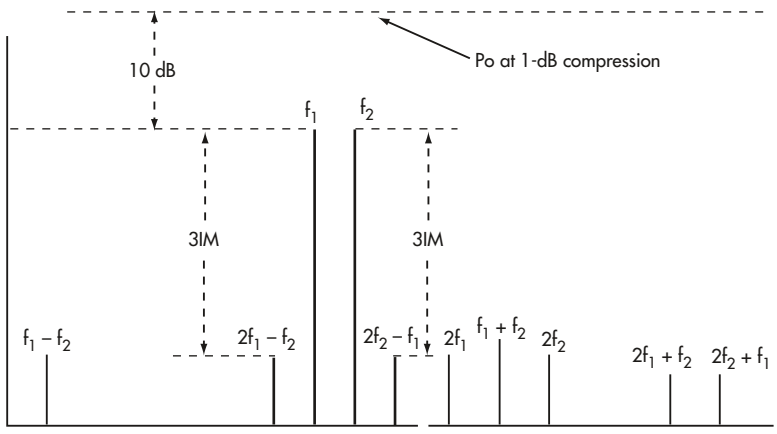
(continued from p. 59)

linear effects tend to increase with cascaded nonlinear component characteristics.

CROSS-MODULATION AND CROSSOVER DISTORTION

Like intermodulation distortion, cross-modulation distortion occurs when two signal characteristics mix together. If two or more input signals are received, the modulation on one signal—caused by nonlinear receiver circuit behavior—can modulate the other input signals. Cross-modulation can dramatically decrease a receiver's dynamic range, especially under high orders of modulation. To limit the effects of this distortion, the receiver front end must be operating linearly.



2. Duplex modulation techniques have a higher-power transmission band and a lower-power reception band. Unfortunately, intermodulation-distortion products can appear in the reception band of the device, impairing signal reception.

When a device changes operating modes (such as a transistor switching or changing bias conditions), its characteristic behavior may be nonlinear during that period. This nonlinear transition period can result in intermittent distortion products, known as crossover distortion. The nonlinear transition characteristics of a device may be inconsistent and depend on difficult-to-model effects. As a result, care must be taken to mitigate the nonlinearity of device operating-mode transitions.

PHASE DISTORTION

Akin to the nonlinear response between current and voltage, a nonlinear response in the device's phase and frequency response often introduces distortions. These phase distortions can induce "echo" responses in the time domain, which may be difficult to interpret for root cause. Moreover, many wireless technologies rely on time-division duplexing, where the differentiating factor between two signal streams is a frame of time. As signal echoes cascading through such systems, they may degrade subsequent signal streams.

DISTORTION MEMORY AND MEMORY EFFECTS

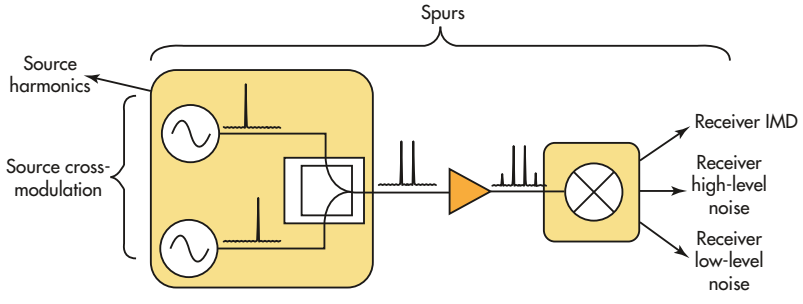
Some component materials will store small amounts of energy. Over time, this energy may be released at varying frequencies and power levels. These "memory" effects are not always consistent. Occasionally, they will cause distortions or increase the difficulty in modeling a device's distortion-generating characteristics. Memory effects are particularly concerning for power amplifiers, which employ predistortion and envelope-tracking techniques. These techniques rely on data tables based on consistent device behavior that's degraded by memory effects.

MEASURING DISTORTION AND DISTORTION METRICS

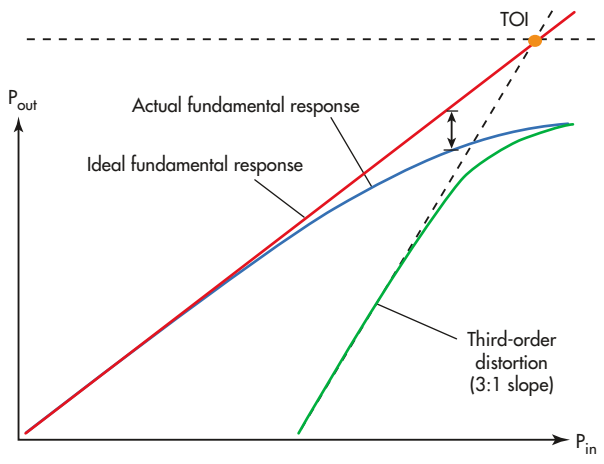
To make design or manufacturing changes that mitigate distortion effects, engineers need detailed knowledge of the different root causes of distortion products. Such information is derived from measurements, simulations, and analysis. Because different effects produce the different types of distortion, a battery of tests is needed to effectively detail each distortion contributors: Two-Tone Distortion Measurement (IP3/IPN)

By using two precisely defined and highly linear tones, a signal/spectrum analyzer will be able to measure a device's distortion products. If the total power of the two tones is well known, it's possible to compare the power of the distortion products. Then a relationship can be developed between frequency and power. This two-tone distortion measurement is often performed with two synchronized and symmetrical sources set to a precise difference in frequencies.

An extremely high-isolation power combiner is used to merge the input signals from the sources into the device's input. Next, the device output is input to a signal/spectrum analyzer. Depending on the power levels, an attenuator may be



3. A common method of intermodulation-distortion measurement is to stimulate with two equal power tones at different frequencies and measure the power level of the products.



4. The third-order intercept is a measure of the depth of distortion created by intermodulation products.

used to lower the input signal's strength to prevent distortion or damage from the analyzer.

Consistent criteria for defining a device's harmonic/intermodulation quality can be beneficial for amplifiers and mixers at various power levels. Typically, employing a power-in/power-out ratio plot with the ideal fundamental response and third-order distortion product can aid an objective comparison. The third order intercept (TOI) is the imaginary point at which the linear slopes of the ideal fundamental response and third-order distortion slope connect. If the TOI is read from the input, it's known as the input intercept point (IIP, IIP3, or IP3). If read from the output, it's defined as the output intercept point (OIP or OIP3). Using the OIP may provide additional insight into the compression effects of a device over multiple measurements.

NOISE POWER RATIO

Using noise as a stimulus to measure a system's nonlinear effects is a broadband measurement approach that can be performed rapidly over large frequency swaths. In multichannel telecommunications systems, channels can be populated with noise via a broadband noise generator. Comparing the noise in populated channels to an unpopulated channel provides a ratio of the contribution of broadband distortion products to that specific channel (known as noise power ratio, or NPR).

Generally, an arbitrary waveform generator (AWG), synthesizer, and signal/spectrum analyzer perform NPR measurements. The AWG is set to create the noise signal with the desired characteristics. The synthesizer ensures that the noise power is upconverted and placed in the selected channels. And the signal/spectrum analyzer detects the difference in the noise-populated channels and unpopulated channel to deliver the NPR measurement iteratively for various channels.

For telecommunications systems, the NPR can be used to measure the total effects from distortions—possibly replacing IP3 in some cases. After all, the NPR may provide a path to a much faster and more easily automated test.

1-dB COMPRESSION POINT (P1dB)

At some input power level, intrinsic device and material properties will eventually develop a nonlinear power-in/power-out response. To avoid significant nonlinear behavior, such as a power amplifier, receiver, or mixer, most devices are run below a point of significant linearity degradation. This point, the 1-dB compression point, is described as the input power level at which the output power drops 1 dB below the ideal linear response. Generally, a single adjustable power source is swept through a range of input powers to a device. The output of the device is directed to a signal/spectrum analyzer, where the device output is measured. Often, the analyzer has an attenuator at the front end of its receiver to prevent receiver compression, which degrades the measurement accuracy.

ADJACENT-CHANNEL POWER RATIO (ACPR)

Adjacent-channel power ratio best describes highly modulated signals over two-tone sinusoidal measurements. It measures the power at an adjacent channel compared to the primary channel. Such a measurement enables a modulated signal source. It replicates the device's intended use more accurately, since it represents real-world distortion characteristics. Also, alternate-channel power ratio is used to describe the power ratios between the primary channel and the bandwidths spaced two channel distances away from the primary.

ERROR VECTOR MAGNITUDE (EVM)

Error vector magnitude, also referred to as receive constellation error (RCE), is a relatively comprehensive measure of the non-ideal effects of a digitally modulated transmitter or receiver. Thus, distortion products are also embedded within the measurement. Coupling EVM with other distortion-analysis measurements can reveal additional information regarding how the distortion effects impact overall system performance.

EVM is determined by measuring either the power error or percent error difference between the ideal constellation point and the received/transmitted constellation point. The error vector is a vector drawn in the I-Q plane between the ideal and actual constellation point. Generally, the average power of the error vector normalized to the signal power is taken as the power EVM (the root-mean-square, or RMS, average for percentage EVM). Many signal analyzers automatically provide EVM measurements for known forms of modulation, though this type of analysis may require additional software packages. With wireless technologies, understanding and mitigating distortions is critical to reducing signal degradation. mw

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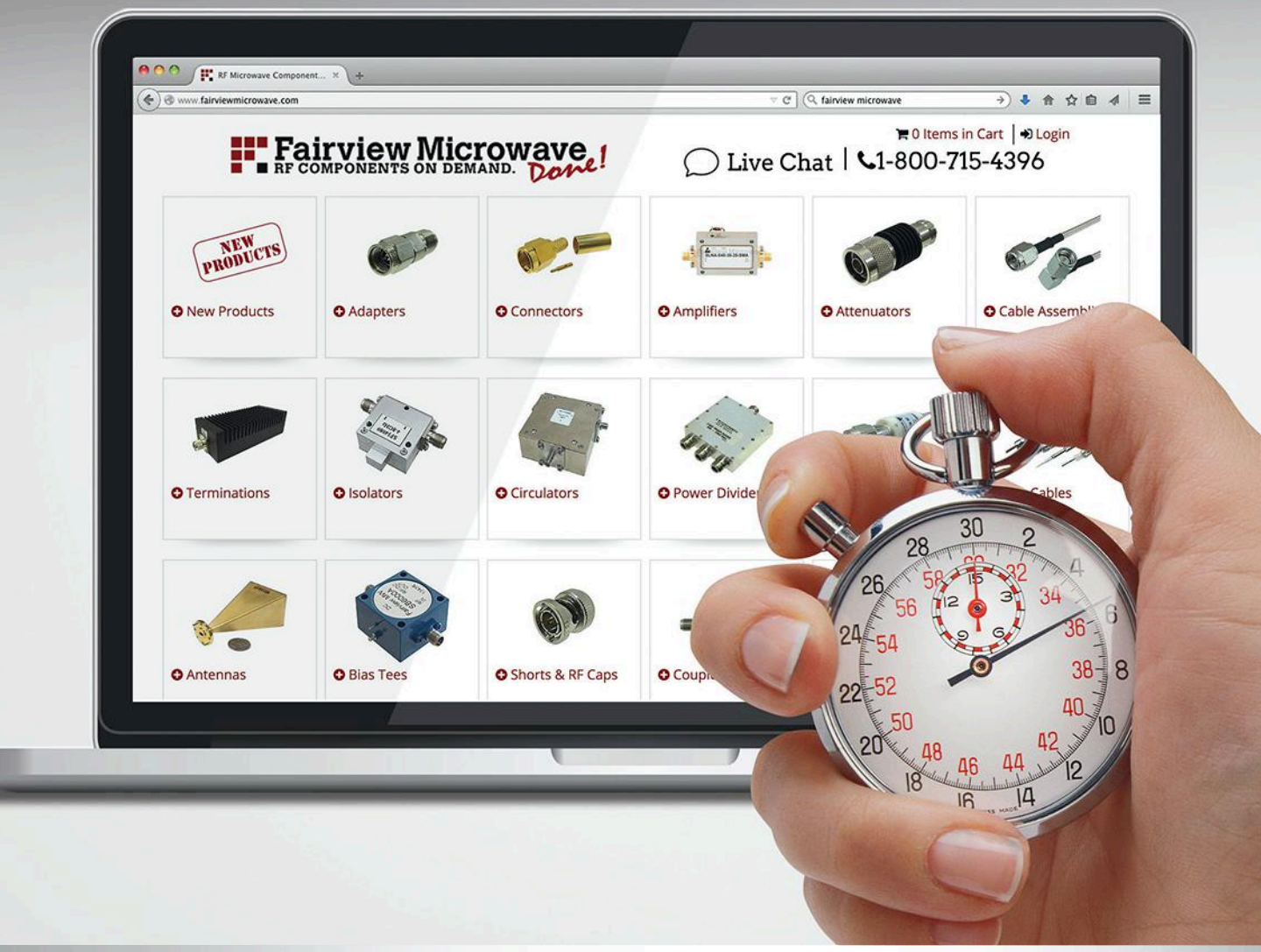

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Industry Trends

PAUL PICKERING | Contributing Editor

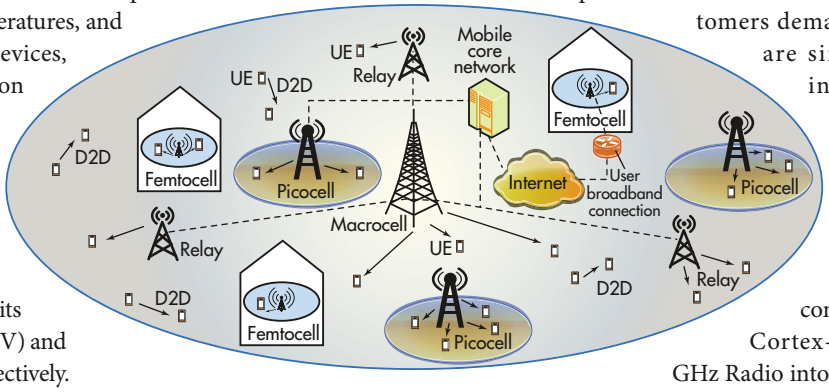
6 Trends Driving Transceiver Design and Development

New technologies, along with innovations and enhancements to existing abilities, lead the list of trends to watch for over the next five years or so.

WHEN IT COMES TO TRANSCEIVERS, the RF communications landscape is always changing, ranging from the seemingly constant turmoil in the commercial cellular market to the somewhat more sedate—yet accelerating—rate of change in the military world. Here are six trends projected to drive changes in transceiver design and development over the next five years.

1. Is the writing on the wall for the power FET? Early predictions of widespread dominance were somewhat premature, but over the next several years, wide-bandgap devices using gallium nitride on silicon (GaN) and silicon carbide (SiC) process technology are expected to gradually replace traditional Si MOSFETs in RF power amplifier applications except for low-end, highly cost-sensitive applications.

Why? GaN and SiC devices operate at higher voltages, temperatures, and frequencies than Si devices, resulting in a reduction in power losses of up to 90%, down to the 1% range. Other competitors, such as super-junction MOSFETs and IGBTs, have technological limits at high voltages (>900 V) and high frequencies, respectively.



Here is a comparison of key parameters for three power-device technologies. *(Source: EEWordsmith)*

A comparison of some key metrics is shown to the right. Johnson's Figure of Merit is a measure of suitability of a semiconductor material for high-frequency power transistor applications and requirements. It's a function of two intrinsic device properties—the electron saturation velocity and the electric breakdown field.

Before you rush out and replace all your MOSFETs, though, be aware that both technologies still have problems to be overcome: GaN has low thermal conductivity and defect issues, while SiC has high wafer costs and low electron mobility.

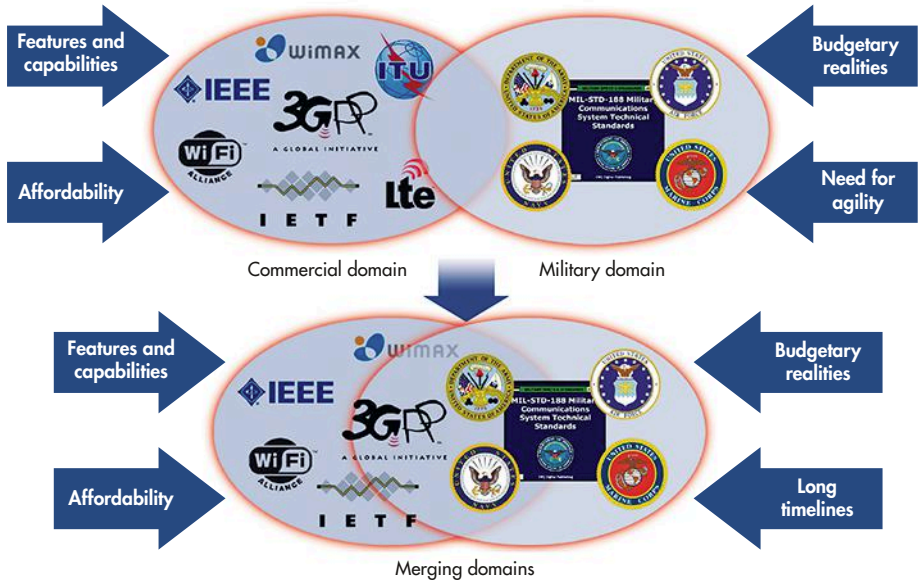
Expectations are that for mid- and high-end designs, GaN will dominate in lower-power or lower-voltage (200 V) applications, and SiC at higher voltages and powers. Traditional Si devices will still hold sway in low-end designs. Of course, the predicted GaN-SiC switchover point depends on whether your company manufactures GaN or SiC devices.

2. IoT drives reduced power consumption, feature integration. As we've all seen, the Internet of Things (IoT) is ubiquitous these days, and it's leading to a slew of products aimed at space-constrained power-sensitive applications such as fitness and medical monitoring. Improvements in battery technology have been slow in coming, and short battery life continues to be one of the main complaints of consumers. To mitigate the problem while still adding the functions customers demand, manufacturers are simultaneously up-integrating features and reducing power consumption.

For example, Silicon Labs' EZR-32WG230 Wireless MCU family combines a 32-bit ARM Cortex-M4 CPU and sub-GHz Radio into a small, form-factor QFN64 package. The features include up to 256kB of Flash, 32kB RAM, and multiple analog peripherals such as a 12-bit 1Msps ADC, a 12-bit 500ksps DAC, 3 op amps, and an on-chip temperature sensor. The RF section is IEEE 802.15.4g compliant, and features a frequency range from 142-1050 MHz, receiver sensitivity of –133dBm, up to +20dBm max output power, a data rate of up to 1Mbps, and a range of modulation schemes. To minimize power consumption, the EZR32WG230 features a flexible energy management system with run, stop, and shutoff modes;

shutoff mode consumes only 40nA at 3V.

For Bluetooth LE applications in the sports/fitness and human interface areas, NXP's QN902X is an ultra-low power system-on-chip (SoC) combining a 2.4GHz transceiver with a Cortex-M0 microcontroller in QFN48 or QFN32 packages. It includes 64kB system memory, a four-channel 10-bit ADC, up to 31 general purpose I/O pins, and user-controllable code protection. The RF section features –95dBm RX sensitivity, TX output power from –24dBm to 4dBm, and up to eight simultaneous links in master mode.



Various factors are leading to the convergence of military and commercial communications. *(Source: Johns Hopkins University)*

3. The connected vehicle considers V2I and V2V communication. Vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communications are moving closer to reality after a long gestation period. In 1999, the FCC allocated 75MHz of spectrum in the 5.9GHz band (5.850-5.925 GHz) for intelligent transportation systems (ITSs); ETSI followed suit with a 30-MHz allocation in 2008.

Many readers will be familiar with communication from a vehicle to a fixed ground station: GM's OnStar has been around since 1995, utilizing CDMA mobile phone technology for voice and data communication. But dedicated short-range communication (DSRC) systems for V2V/V2I use differ from conventional mobile communication systems in several ways: Users (vehicles) may communicate with each other without relying on a dedicated base station or access point; both source and destination stations are mobile. and they can move at high vehicular speeds (>120 km/h); communications between users take place at ground level, so that the effects of three-dimensional scattering become significant; and the system's range is small, typically about 400 meters.These differences call for the design of novel transceivers for V2V DRSC systems that achieve a high spectral efficiency under harsh propagation conditions.

IEEE 802.11p defines enhancements to 802.11 (Wi-Fi standard) to support ITS, using 10MHz channels. This is half the bandwidth, or double the transmission time for a specific data symbol, than specified in 802.11a. This allows the receiver to better cope with the characteristics of the radio channel in vehicular communications environments.

Due to the potentially very brief time available for communications, the authentication and data confidentiality mechanisms provided by the IEEE 802.11 cannot be used, so they must be provided by higher network layers. Accordingly, the IEEE 1609 family of standards for Wireless Access in Vehicular Environments (WAVE) standards defines an architecture and a complementary, standardized set of protocols, services, and interfaces that collectively enable secure V2V and vehicle-to-infrastructure V2I wireless communications.

IC manufacturers are already developing transceivers to meet the anticipated need. For example, Austrian manufacturer Kapsch's 5.9 GHz transceiver MTX-9450 supports both the 802.11p WAVE standard and IEEE 1609.2 security protocols. Key features include: +33dBm EIRP maximum radiated power; 6 x 10 MHz channels (172, 174, 178, 180, 182,184) and 6 × 20 MHz channels (173, 175, 177, 179, 181, 183); 24V or 48V supply voltage; 3DES, AES, and optional ECC encryption; external or built-in directional antenna; and GPS, 10/100 Ethernet, and RS422 interfaces.

Lest you think that all of this is pie-in-the sky, GM CEO Mary Barra announced at the Intelligent Transport System World Congress in Detroit last September that V2V technology would be included in the 2017 Cadillac CTS. The system will be provided by Delphi using application software from Cohda Wireless and NXP's wireless chipset. And this month, U.S. Transportation Secretary Anthony Foxx announced an accelerated schedule for NHTSA's proposal to require V2V equipment on new vehicles.

4. 5G on the horizon. At IMS 2015 in Phoenix last month, "5G" was on everyone's lips. Even though it's five years away from implementation, some key concepts are emerging that promise to drive changes in transceiver design:

Millimeter-wave communications. Given the full utilization of the spectrum currently allocated for cellular communications (as noted elsewhere in this article) and since 5G single-user peak data rates will be in the 10Gbps range, it's anticipated that expansion into millimeter-wave frequency bands (e.g., the 28-GHz, 60-GHz, or 71-GHz bands) will be needed, since it allows wider bandwidth transmission than the 20MHz used for 4G systems. There are hardware problems to be solved, though, including the high power consumption of mixed-signal components such as ADCs and DACs.

Massive MIMO. This is a type of MIMO where the number of BS antennas is much larger than the number of devices. Its implementation involves replacing the expensive, high-performance BS RF amplifier with hundreds or thousands of low-cost amplifiers with much lower power levels. This approach renders the channels to the different devices quasi-orthogonal, giving large gains in spectral efficiency. Studies have shown that a 4 × 4 MIMO array gives 100% improvement in gain for a single user over a 50MHz bandwidth channel versus a single antenna. An 8192-antenna array serving 1,000 users randomly in a 6-km radius cell gives a 7,000% improvement compared to the 4 × 4 baseline. The downside is increased complexity of the transceiver hardware and the complexity and energy consumption of the signal processing at both ends.

Heterogeneous networks (HetNets). 5G network proposals envision a wide range of communication channels—a combination of femo, pico, and macrocells, and direct device-to-device (D2D) communications including other channels such as Bluetooth and Wi-Fi Direct. It's also likely that Downlink/Uplink Decoupling (DUDe) will be employed to maximize network throughput and reduce power consumption.

5. LTE spectrum wars lead to transceiver design complexity. The Long Term Evolution (LTE) standard provides significantly increased peak data rates, with the potential for 300 Mbps downstream and 75 Mbps upstream, reduced latency, scalable bandwidth capacity, and backwards compatibility with existing GSM and UMTS technology. Following the initial proposal in 2004 by NTT DoCoMo in Japan, implementation plans are proceeding across the globe with South Korea, Japan, and Australia leading the way, followed closely by the United States.

Finally! A common international standard. Worldwide roaming is just around the corner, right? Not so fast. The allocation of radio spectrum for LTE usage varies widely from country to country, even within countries. With the demise of UHF TV and the auctioning off of its spectrum, it was hoped that 700MHz would become an international roaming standard for LTE. Currently, though, spectrum used for LTE ranges from 700MHz to 2.6GHz with 700MHz coming in at No. 3.

Even in the U.S., the 700MHz band is divided into a lower band at 698-746MHz and an upper band at 746-806MHz. The large nationwide suppliers use slightly different paired blocks, but can afford to have transceivers developed specifically for their phones.

These varying LTE bands, plus the need to accommodate differing legacy systems, are driving increased complexity in transceiver design. Current transceivers must support multiband operation, both TDD and FDD technologies, and legacy systems such as GSM, EVDO, and CDMA.

6. Military communications leverage commercial applications. Certain elements seem to be common to military systems, whether wireless or not: They're designed to meet a rigorous set of performance requirements; they have to operate in harsh environmental conditions; and they must include extreme levels of security and resistance against being compromised, including the likelihood that they will fall into the hands of an enemy. To that list the cynic might add that they usually take many years to come to fruition, are often massively over-budget, and trail behind the commercial sector in performance.

Perhaps no longer. The military is increasingly adapting commercial wireless technology for its own use. There are many reasons for this trend, including:

Cost. In an era of budget constraints, there is heightened awareness in both the military and the government of the need to make better use of taxpayer dollars.

Life cycle. Military operations have changed significantly over the past decade. Today's soldiers must confront a range of small-scale opponents who adapt and change continually.

Features. With their compressed development cycles, commercial technologies are often far superior to military equipment first proposed 10 or 20 years ago.

Recognizing that military equipment has unique security and environmental requirements that cannot be met by purely commercial solutions, military and government communications systems are taking the best commercial devices and embedding them within a secure framework. To help in this effort, the National Security Agency (NSA) established NSA Commercial Solutions for Classified Communications (CSFC) guidelines to enable commercial products to be used in layered solutions.

For example, the Motorola Solutions Assured Mobile Environment (AME) 2000 Secure Mobile Solution combines a commercial-off-the shelf (COTS) device based on the Android OS with hardware and software to provide end-to-end encrypted voice and data communications through private or public wireless networks to support the missions of federal agencies.

And in another project, investigations are underway to use commercial frequency agile transceivers for multi-GNSS (Global Navigation Satellite System) military applications while still meeting military anti-jamming and anti-spoofing requirements.

The bright side to this varied list of trends? Continued employment for transceiver design engineers. mw

WHY DOES THE INTERNET OF THINGS NEED DIFFERENT WIRELESS STANDARDS?

THE EXPLODING GLOBAL market for wirelessly interconnected devices has RF/microwave companies working diligently to develop technologies and create solutions for an Internet of Things (IoT) world. Key to the process is choosing the right wireless protocols and wireless networking technology when implementing IoT solutions. In an application note from Texas Instruments, titled "Wireless Connectivity for the Internet of Things," the author provides an overview of the wireless technologies connecting commercial and industrial devices.

Among the critical factors cited are an IoT solution's network range and topology. In terms of network ranges, choices include personal-area networks (PANs), local-area networks (LANs), neighborhood-area networks (NANs), and wide-area networks (WANs). Different technologies better suit the key features of each network range, though. For example, Bluetooth is a common solution for PAN systems, but isn't as well equipped for LAN systems (unlike Wi-Fi).

Power and noise are the main limiting factors for throughput and range. As a result, each wireless technology leverages a variety of techniques to balance throughput and range with respect to its application. Generally, a network with a wider range will require more transmit power. Also, the maximum transmission data rate of will be lower.

Texas Instruments,
12500 TI Boulevard
Dallas, Texas 75265,
+1 972-995-2011
www.ti.com

A mesh network topology can be created to increase a network's range without boosting the power and coverage area of a single node. A mesh network differs from a star network in that all of the nodes of a mesh network can exchange data to each other. They can even hop data from one node through another, and then onto the third node.

Many IoT and wireless-networking companies lack the resources or justification for producing their own proprietary wireless-networking standard. As a result, they must choose from already existing common standards. From sub-1-GHz to ZigBee/Bluetooth, the various wireless-networking standards each have strengths in different application spaces. They also operate with different network topologies in mind. The latest device concepts, for example, have configurable RF front-ends capable of multiple wireless standards, high-security systems, and ease of integration.

KNOW WHETHER TO MOUNT, REFLOW, OR BOLT DOWN RF TRANSISTORS

RF POWER TRANSISTORS channel significant amounts of RF energy. As a result, substantial considerations must be given to thermal flow, RF isolation, structural integrity, and electrical-connection reliability when inserting these components into an assembly. Over the years, various techniques have been developed to mitigate the design and manufacturing concerns over mounting and soldering RF power transistors. In an application note titled "Mounting and Soldering RF Transistors," NXP Semiconductors elaborates on good practices and manufacturing techniques for electrical, mechanical, and thermal considerations.

NXP Semiconductors,
411 E. Plumeria Drive,
San Jose, CA 95134,
www.nxp.com

When attaching air-cavity packages, a common practice is to use thermal compound as well as solder to attach the RF transistor to the printed-circuit-board (PCB) copper and substrate. Many of these methods depend on the manufacturing process used for PCBs. For example, when using a solder-mask-defined (SMD) pad process, a layer of the solder mask is left to create a ridge and a gap between the flange of the transistor and the PCB pad. In addition, the SMD pad process may not ensure adequate PCB aperture for transistor insertion, which includes providing enough curved radius at the aperture corners of the insertion rectangle. Conversely, the non-solder-mask-defined (NSMD) pad method does not exhibit the mask layer riding over the copper, leading to a more flush metallic contact.

NXP's note explains that a good contact connection is essential for effective heatsinking. Other key aspects include PCB thickness, interface thickness, solder thickness, heatsink dimensions, thermal-compound thickness, and Q dimensions. Furthermore, the surface finish of the heatsink material and transistor package affects the thermal transfer to the heatsink. Surface imperfections, such as burrs, grooves, and particulates, can degrade the thermal transfer. They also may create hot spots between the metallic, plastic, or ceramic materials.

While detailing the thermal considerations of solder joints and transistor placement, the note explains how to determine the effective lower and upper thresholds for the solder joints to form reliable connections. Because the PCB board assembly will not face equal distribution of heat across the board, hot and cold spots will form on the board. When the coldest spot sits above the lower-end threshold and the hottest spot is above the upper threshold, a reliable soldering process can be performed.

SPACEK LABS

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PROVIDING MILLIMETER-WAVE SOLUTIONS

Spacek Labs Inc. is an ISO 9001:2008 certified, ITAR registered, women-owned small business. We manufacture both active and passive millimeter-wave and microwave components and systems operating from 10 to 110 GHz.

Located in Santa Barbara, Calif., Spacek Labs occupies two adjacent industrial buildings covering 10,000 square feet. Our facilities include our millimeter-wave design, development, and assembly laboratory, 30 separate assembly/test benches ranging from 10 MHz to 110 GHz with additional equipment and benches for project specific work stations as required. Our testing facilities include vector network analyzers with the ability to directly test up to 65 GHz and a 60-square-foot screen room (Faraday cage) for low-noise testing. We have the environmental equipment to temperature-test our devices from -55°C to +165°C as well as in-house cryogenic test facilities capable of temperatures as low as 15° Kelvin. Our design capabilities include 2D and 3D CAD and EM simulation.

PRODUCT FOCUS: MM-WAVE TRANSCEIVERS

Spacek Labs' transceiver designs are available in any frequency band between 18 to 110 GHz. Our engineers will design the exact solution for your transceiver requirement with single or multiple channels. Transmit channels offer a high 1 dB compression point output power. Receive channels have a low noise figure with 20 dB typical gain and 60 dB rejection of the unwanted sideband. Cross-channel isolation is greater than 60 dB.

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We are dedicated to providing our customers with the highest quality millimeter-wave and microwave components and assemblies for commercial, military, and space applications. Customers include government, universities, research institutions, and private industry. Our No. 1 priority is fast, reliable delivery with the highest performance possible, whether the order is large or small.

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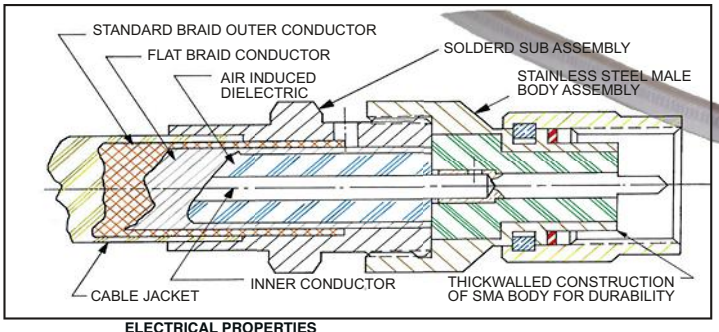
LOW LOSS TEST CABLES

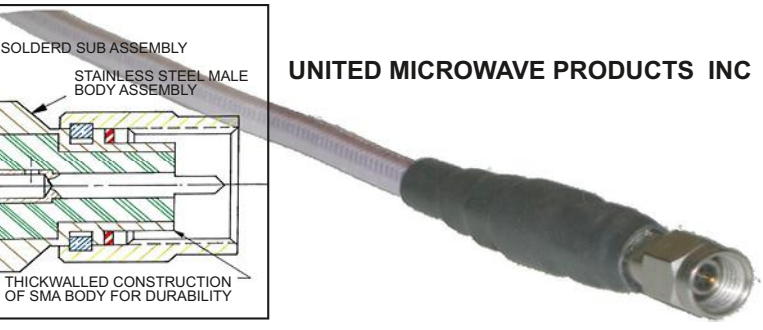
MICROPORE 190

Operating Frequency DC-26.0 GHz

MICROPORE 19O is a new inexpensive high performance super low loss cable. For applications requlrlng flexibility and the lowest possible loss at an economical price MICROPORE I90 Is the cable of choice. The cable is nonmagnetlc, has a double barrier outer conductor for improved shielding and features an air induced dielectric for low loss at hIgh frequency.



UNITED MICROWAVE PRODUCTS INC



ELECTRICAL PROPERTIES

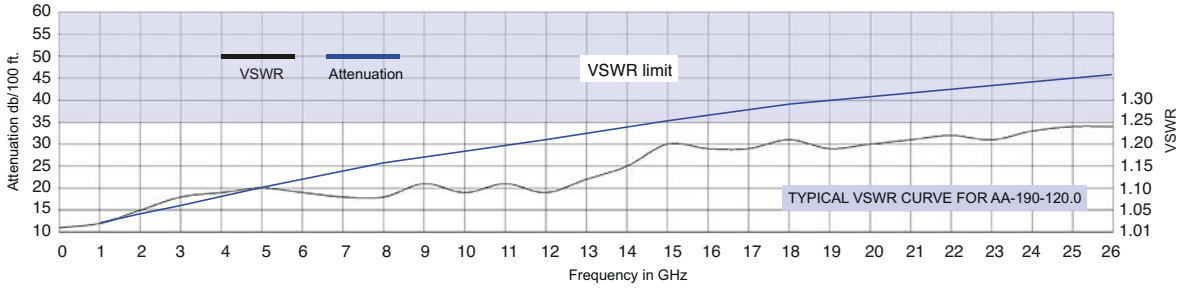
Impedance 50 ± 2 OHMs
Cut off Frequency 26.5 GHz
Nominal Capacitance 25 pf/f
Velocity of Propagation 76%
Max Operating Voltage 1700 Volts RMS
RF Shielding greater than 90db

MATERIALS

Inner Conductor SIL PLT Solid Cu .051in /1.29mm Dia.
Outer Conductor Stripbraid Composite .184in /4.67mm Dia.
Dielectric Air Expanded PTFE .152in /3.86mm Dia.
Jacket FEP Teflon .195in /4.95mm Dia.

MECHANICAL PROPERTIES

Bend Radius Minimum 1.0in /25.4mm
Temp Range -55ºF/-48.3C +400ºF/+204.4C
Weight .6 oz/ft 53.86g/m



SMA MALE TO SMA MALE

PART NO.	LENGTH	1-9	10-24	25-49
AA-190-24.0	2.00 Ft.	$90.00	$88.00	$86.00
AA-190-36.0	3.00 Ft.	$101.00	$99.00	$97.00
AA-190-48.0	4.00 Ft.	$112.00	$110.00	$108.00
AA-190-60.0	5.00 Ft.	$123.00	$121.00	$119.00
AA-190-72.0	6.00 Ft.	$134.00	$132.00	$130.00
AA-190-120.0	10.00 Ft.	$178.00	$176.00	$174.00

SMA MALE TO SMA MALE RIGHT ANGLE

PART NO.	LENGTH	1-9	10-24	25-49
AB-190-24.0	2.00 Ft.	$125.00	$123.00	$121.00
AB-190-36.0	3.00 Ft.	$136.00	$134.00	$132.00
AB-190-48.0	4.00 Ft.	$147.00	$145.00	$143.00
AB-190-60.0	5.00 Ft.	$158.00	$156.00	$154.00
AB-190-72.0	6.00 Ft.	$169.00	$167.00	$165.00
AB-190-120.0	10.00 Ft.	$213.00	$211.00	$209.00

SMA MALE TO TYPE N MALE

PART NO.	LENGTH	1-9	10-24	25-49
AO-190-24.0	2.00 Ft.	$105.00	$103.00	$101.00
AO-190-36.0	3.00 Ft.	$116.00	$114.00	$112.00
AO-190-48.0	4.00 Ft.	$127.00	$125.00	$123.00
AO-190-60.0	5.00 Ft.	$138.00	$136.00	$134.00
AO-190-72.0	6.00 Ft.	$149.00	$147.00	$145.00
AO-190-120.0	10.00 Ft.	$193.00	$191.00	$189.00

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Phone (310) 320-1244 Fax (310) 320-9729
Email umpinc@pacbell.net
Internet http://www.unitedmicrowave.com

TYPE N MALE TO TYPE N MALE

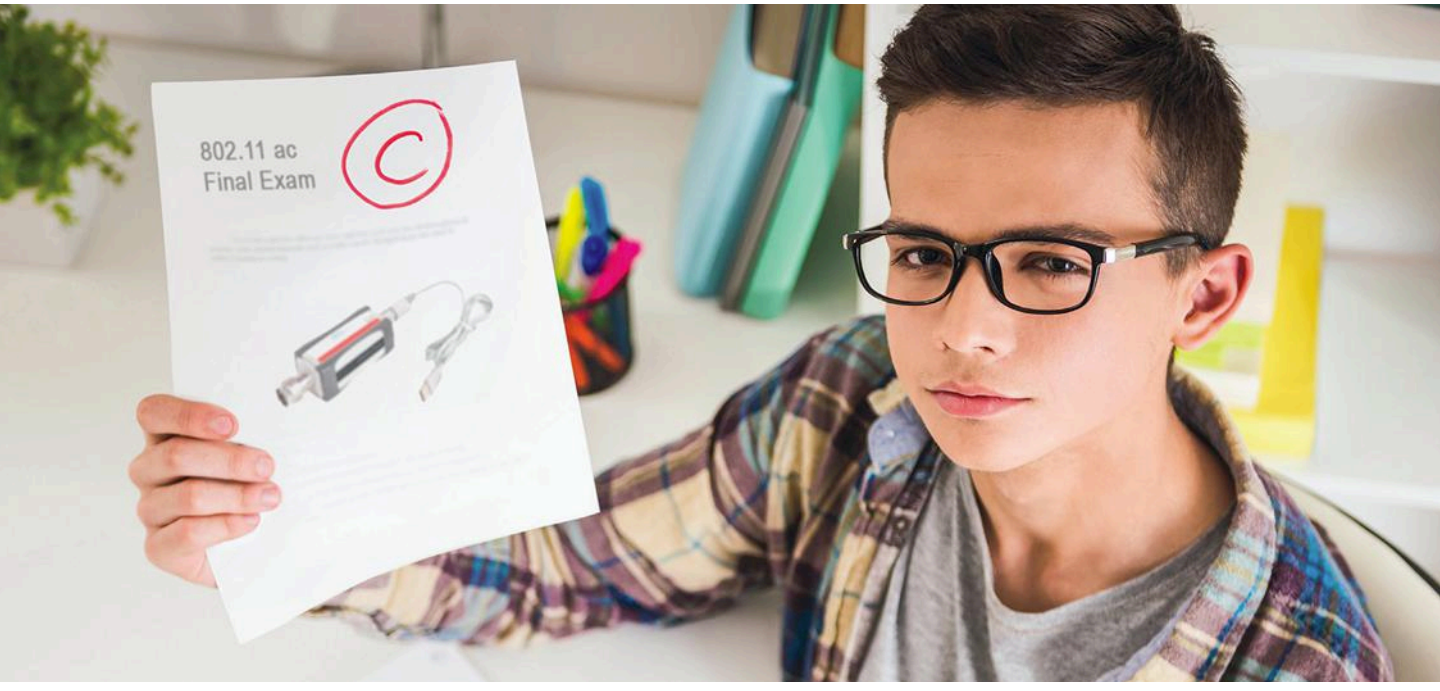
PART NO.	LENGTH	1-9	10-24	25-49
OO-190-24.0	2.00 Ft.	$125.00	$123.00	$121.00
OO-190-36.0	3.00 Ft.	$136.00	$134.00	$132.00
OO-190-48.0	4.00 Ft.	$147.00	$145.00	$143.00
OO-190-60.0	5.00 Ft.	$158.00	$156.00	$154.00
OO-190-72.0	6.00 Ft.	$169.00	$167.00	$165.00
OO-190-120.0	10.00 Ft.	$213.00	$211.00	$209.00

TYPE N MALE TO TYPE N MALE RIGHT ANGLE

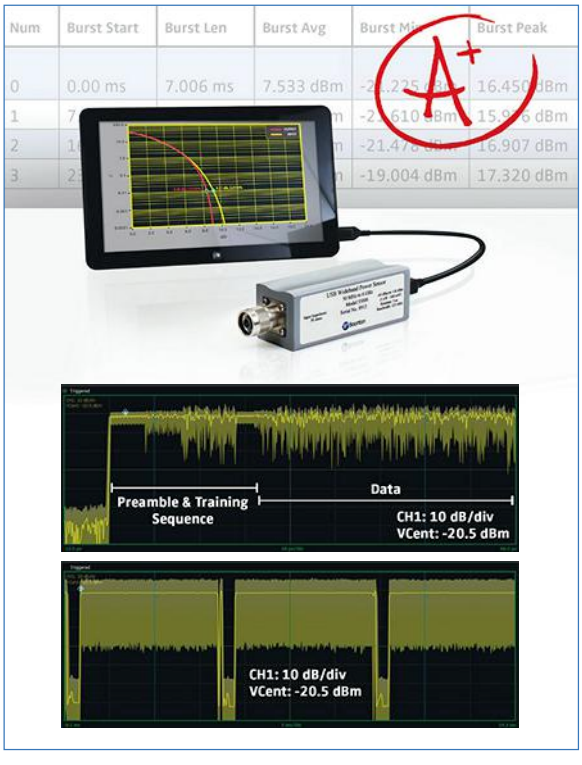
PART NO.	LENGTH	1-9	10-24	25-49
OP-190-24.0	2.00 Ft.	$205.00	$203.00	$201.00
OP-190-36.0	3.00 Ft.	$216.00	$214.00	$212.00
OP-190-48.0	4.00 Ft.	$227.00	$225.00	$223.00
OP-190-60.0	5.00 Ft.	$238.00	$236.00	$234.00
OP-190-72.0	6.00 Ft.	$249.00	$247.00	$245.00
OP-190-120.0	10.00 Ft.	$293.00	$291.00	$289.00

For Connectors or Lengths not listed contact Factory.

Don’t Settle for Average.



Demand Peak Performance.



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Others claim to have fast average measurements, but only the 55 Series measures continuous and burst average power faster than anyone in the industry. It adds wide-band peak and crest factor measurements, allowing you to see all aspects of your device’s performance. This USB Sensor delivers results 100 times faster than conventional meters and with its *Real-Time Power Processing*™ technology captures all glitches with 100ps resolution.

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