Vol. 54 • No. 5

May 2011

Microwave Journal

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AMFG-3F-00050100-50-34P	0.5-1	40	1.5	5	1.8:1.8	34	37	750
AMFG-3F-00230025-30-37P	0.23-0.25	50	1	3	1.5:2	37	40	250
AMFG-3F-00700380-60-35P	0.7-3.8	40	2	6	2.5:2.5	35	39	1500
AMFG-3F-00800220-60-35P	0.8-2.2	40	1.5	6	2:2	35	38	900
AMFG-2F-01000300-60-35P	1-3	40	2	6	2:2.2	35	39	1500

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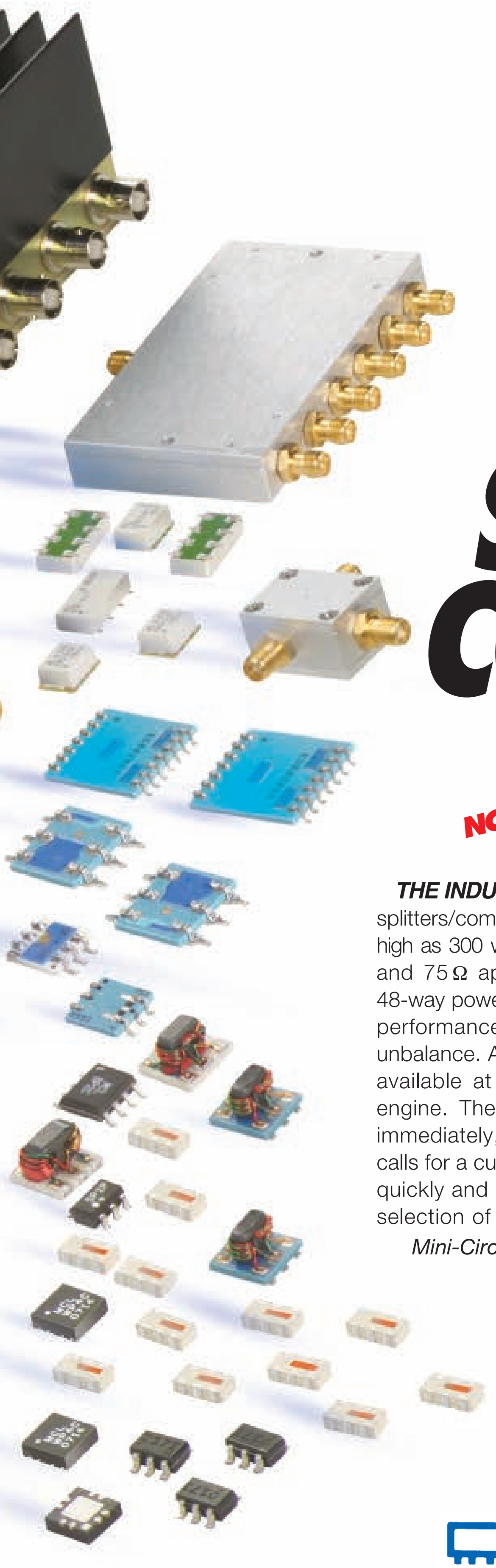


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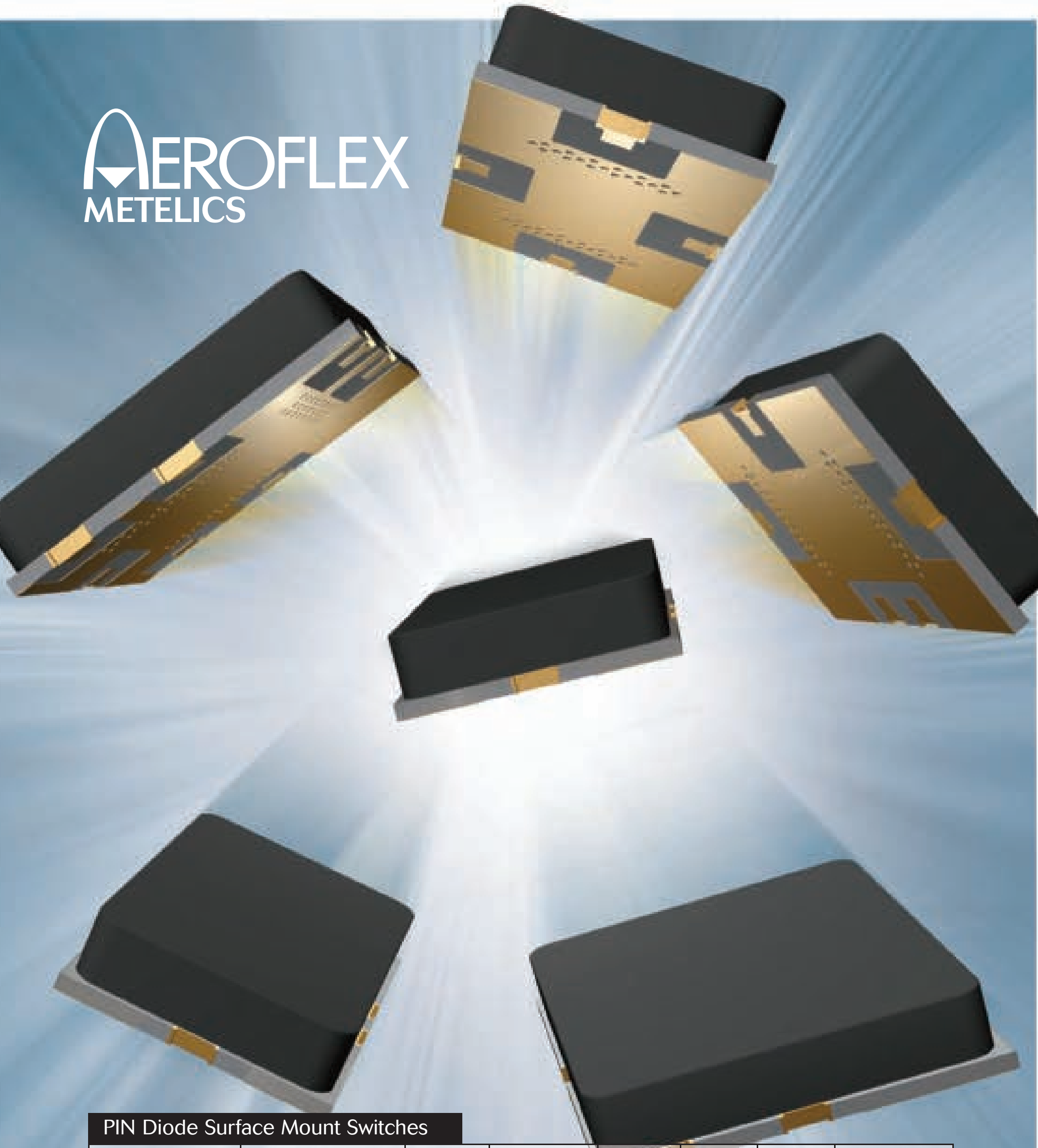

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MSW2001–200	SP2T T-R Switch	+V Only	200–4000	0.3	1.3:1	45	+ 51
MSW2002–200	SP2T T-R Switch	+V Only	2000–6000	0.4	1.5:1	40	+ 51
MSW2022–200	SP2T T-R Switch	+V & -V	10–1000	0.2	1.2:1	52	+ 52
MSW2050–205	SP2T T-R Switch	+V Only	20–1000	0.2	1.2:1	52	+ 52
MSW2051–205	SP2T T-R Switch	+V Only	200–4000	0.3	1.3:1	40	+ 52
MSW2030–203	Symmetrical SP2T	+V Only	20–1000	0.2	1.2:1	55	+ 51
MSW2031–203	Symmetrical SP2T	+V Only	200–4000	0.4	1.3:1	45	+ 51
MSW2032–203	Symmetrical SP2T	+V Only	2000–6000	0.5	1.5:1	40	+ 51
MSW2040–204	Symmetrical SP2T	+V Only	20–1000	0.2	1.2:1	54	+ 52
MSW2041–204	Symmetrical SP2T	+V Only	200–4000	0.3	1.3:1	44	+ 52
MSW2060–206	Symmetrical SP2T	+V & -V	20–1000	0.2	1.2:1	55	+ 51
MSW2061–206	Symmetrical SP2T	+V & -V	400–4000	0.4	1.3:1	45	+ 51
MSW2062–206	Symmetrical SP2T	+V & -V	2000-6000	0.5	1.5:1	40	+ 51
MSW3100–310	Symmetrical SP3T	+V Only	20–1000	0.3	1.2:1	57	+ 51
MSW3101–310	Symmetrical SP3T	+V Only	200–4000	0.5	1.4:1	43	+ 51
MSW3200–310	Symmetrical SP3T	+V & -V	20–1000	0.3	1.2:1	57	+ 51
MSW3201–310	Symmetrical SP3T	+V & -V	400–4000	0.5	1.4:1	43	+ 51

* 20-1,000 MHz specs at 500 MHz, 400 – 4,000 MHz specs at 2000 MHz, 2000 – 6,000 Specs at 4,000 MHz

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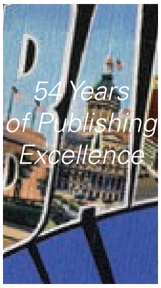

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Executive Editorial Office:
685 Canton Street, Norwood, MA 02062
Tel: (781) 769-9750
FAX: (781) 769-5037
e-mail: mwj@mwjournal.com

European Editorial Office:
16 Sussex Street, London SW1V 4RW, England
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June 8, 2011, 12:00 – 1:30 PM

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To view live webcast online, register at www.mwjournal.com/ims_2011_microapps_experts

Executive Interview

Described as a microwave pioneer, **Professor J. David Rhodes**, Engineering Emeritus Professor at the University of Leeds, UK, explains founding Filtronic plc, being awarded the OBE and CBE by the Queen and his role as 2011 MTT-S IMS plenary speaker.

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Microwave Applicator with Conveyor Belt System
Application Note, Presented by COMSOL

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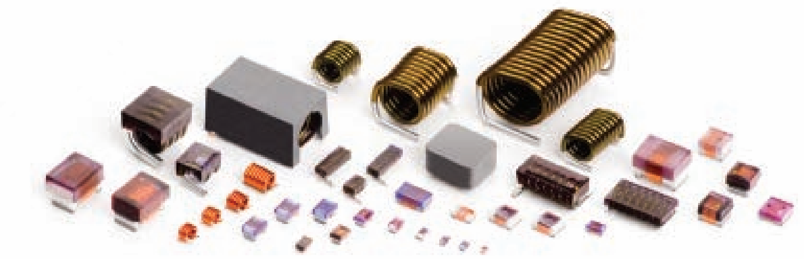

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SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
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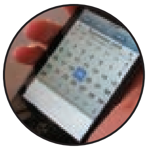

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May 16–19, 2011 • Jeju Island, Korea
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2011 Microwave Industry Exhibition in China
June 1–4, 2011 • Qingdao, Shandong, China
www.cnmw.org

RFIC 2011
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June 5–7, 2011 • Baltimore, MD
www.rfic2011.org

IMS 2011
IEEE MTT-S International Microwave Symposium
June 5–10, 2011 • Baltimore, MD
www.ims2011.org

ARFTG 2011
77TH ARFTG Microwave Measurement Conference
June 10, 2011 • Baltimore, MD
www.arftg.org

JNC 2011
Joint Navigation Conference
June 28–30, 2011 • Colorado Springs, CO
www.jointnavigation.org

JULY

AP-S/USNC/URSI 2011
IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting
July 3–8, 2011 • Spokane, WA
www.apsursi2011.org

AUGUST

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IEEE International Symposium on Electromagnetic Compatibility
August 14–19, 2011 • Long Beach, CA
www.emc2011.org

AUVSI Unmanned Systems N. America 2011
August 16–19, 2011 • Washington DC
http://symposium.auvsi.org/auvsi11/public/enter.aspx

SEPTEMBER

ION GNSS 2011
September 20–23, 2011 • Portland, OR
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OCTOBER

EuMW 2011
European Microwave Week
October 9–14, 2011 • Manchester, UK
www.eumweek.com

7TH Annual COMSOL Conference
October 13–15, 2011 • Boston, MA
www.comsol.com/conference2011/usa/

Microwave Update (MUD) 2011
October 13–16, 2011 • Enfield, CT
www.microwaveupdate.org

AMTA 2011
33RD Annual Symposium of the Antenna Measurement Techniques Association
October 16–21, 2011 • Englewood, CO
www.amta2011.org

4G World 2011
October 24–27, 2011 • Chicago, IL
www.4gworld.com

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International Conference on Radar
October 24–27, 2011 • Chengdu, China
www.radar2011.org

NOVEMBER

COMCAS 2011
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November 7–9, 2011 • Tel Aviv, Israel
www.comcas.org

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DECEMBER

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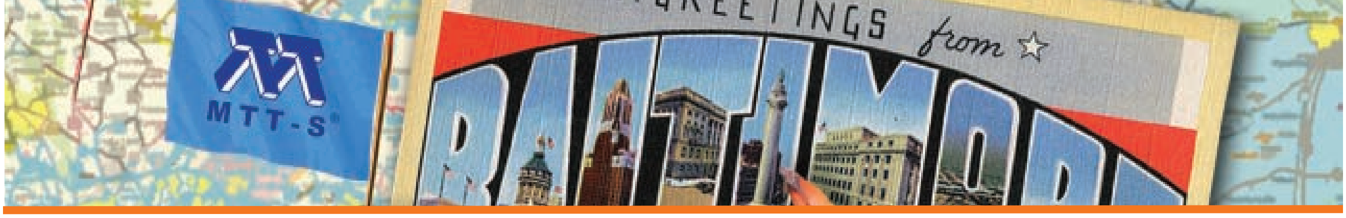


Trending the Conference

Around this time of year, i.e. MTT-S IMS season, I often find myself on one side or the other of the following question – "So, what's new in the industry." In actuality, the big picture does not really change much; communication systems (their devices and supporting infrastructure) are increasingly ubiquitous and defense systems are continually evolving in response to a complex and dangerous world.

If you Google 'The more things change, the more they stay the same," you will learn that the phrase is attributed to Jean Baptiste Alphonse Karr (or as he put it 'plus ça change, plus c'est la même chose'). For Karr, turbulent changes did not affect reality on any deeper level other than to reinforce the status quo. So what is our status quo? I would say this year's technology is expected to do more than it did last year… only for less money. And I am sure to be saying the same thing next year.

The meaningful part of the question "what's new" is more about specifics; as in "What will be the improved power added efficiency with that low loss switch?" or "What is the state of the art in dynamic range for a spectrum analyzer?" and are either worth the extra cost. In addition to finding out about the latest research and technical advances, a good number of microwave professionals are equally interested in new products, market trends, applications, mergers and acquisitions, appointments, and who won what contract or got promoted. It is wise to take an interest in such developments. Technology makes our business possible and vice versa.

I have come to believe that one of the most valuable functions of IMS and the exhibition is to provide answers to the "what's new" question, on all fronts. The technical program provides part of the answer in its organized workshops, panels and sessions. The remaining part is found in the exhibition hall, which is more akin to parallel processing or should I say, connecting to 'the cloud.' Information overload is inevitable.

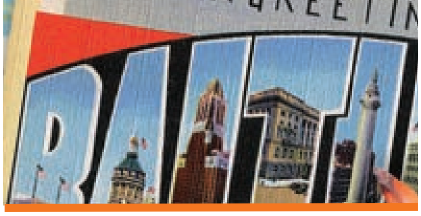
Anticipating a large captive audience and the media spotlight, exhibitors usually schedule their major product releases right around this show. Absorbing all the "what's new" information from over 500 exhibitors, on top of the technical program is a daunting if not impossible task. Our goal for this month's IMS show issue editorial, as well as our series of show related electronic newsletters, exhibitor preview and dedicated IMS online show coverage is to provide readers with enough advance coverage to help them sort through all this information and prioritize that which is most important before heading to Baltimore.

For this issue, my predecessor Harlan Howe used to scribe his annual "Attending the Conference." Playing off that title, we have solicited content that looks at industry trends heading into the conference. Trends are mapped with data points over time. And so we begin with our cover story based on the reflections of two well-known entrepreneurs who launched very successful microwave businesses in Maryland and were largely responsible for developing the region into a hotbed of filter companies.

Our show coverage also includes a welcome from this year's conference chairs (IMS, RFIC and ARFTG) as well as pre-conference perspectives from industry and defense research – Opportunities and Challenges in 2011 by Greg Peters of Agilent and Microwave Technology Development at the Naval Research Lab by Jeff Pond of NRL.

IMS is made up of many events within the event and so we have asked the organizers of this year's MicroApps and the 'Women in Engineering Reception' to provide a preview. Speaking of MicroApps, the *Journal* is pleased to be co-organizing the MicroApps marquee event and keynote, an expert panel on nonlinear device characterization featuring an open forum with presenters from Agilent, Anritsu, Rohde & Schwarz/NMDG and Tektronix/Mesuro. Advances in measurement equipment and nonlinear modeling promise to make this event educational and lively. The *Journal* will cover the action via a live webcast so that even those not attending IMS will be able to watch and participate in the Q&A.

David Vye
Editor, Microwave Journal



For your guide to exhibiting companies and new products, we feature the complete exhibitor listing with an index to their ad location in the issue and the new products section is exclusively dedicated to items you will find at the show. The exhibitor listing, new product section and advertisements placed throughout this issue undoubtedly represent the most comprehensive pre-show snapshot of who's introducing "what's new."

With the IMS technical program available online and printed in the conference guide, it would be redundant to publish the schedule in this issue. The same is true for a guide to tourist spots and restaurants in the host city, where the Internet can provide a more comprehensive list. Removing these items has created space for us to do what we do best—deliver show and industry related content and perspective. I hope you find this month's special editorial insightful, informative and even entertaining (check out the animated MTT-Stories). We began implementing these changes a few years ago, and I am confident that it has been a worthwhile disruption to the status quo.

As engineers, you make your livelihood from being inventive. You should expect no less from your reading material. How we access and absorb information was forever changed by the Internet. We at the *Journal* are constantly thinking of new ways to utilize all forms of media; each has a particular strength. So look for our IMS related newsletters in your e-mail, visit our website for online show coverage and take the next three weeks to leisurely read your show issue, hopefully cover to cover. Then you will be better prepared to discover what is most significant to you from among all the "what's new." As Robert Gallagher said, "Change is inevitable - except from a vending machine." You might as well be ready for it. Safe travels and I will see you in Baltimore. ■

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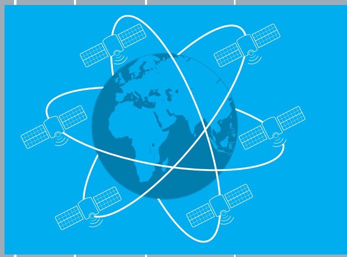

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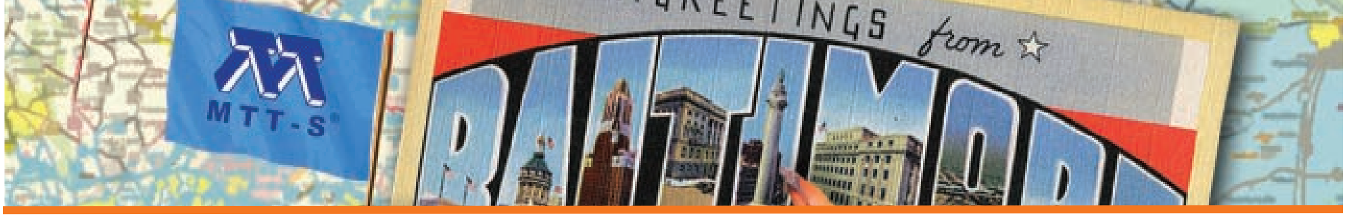


Made in Maryland: Filter Lore from Gaithersburg to the Eastern Shore

Starting in the early 1960s, Maryland has been home to numerous custom microwave filter houses. Originally founded as small, family-oriented companies by hardworking and ambitious entrepreneurs, these start-ups saw opportunity and were hungry to seize it. Possessing the agility and inventiveness that is the hallmark of all fledgling companies that succeed in business, many of these organizations went on to become among the most famous names in the RF/microwave industry.

To get their products designed into the defense and telecommunication systems of the day, they would have to push the state-of-the-art in performance, size and cost. These young filter houses became incubators for creative filter design. Their ability to develop and, most importantly, deliver products on time and on budget surpassed the efforts of the internal filter departments of the large defense contractors that eventually became their customers.

Grooming and retaining engineering talent was critical to these smaller companies in achieving technical prowess and transforming their filter building formulas into a competitive advantage. In contrast, large defense contractors were forced to frequently replenish their expertise with less experienced employees as leading engineers followed career paths that went "up" into management or went "out" to join some promising start-up.

With a sharp and motivated worker and an environment offering the right nurturing and support, the art of filter tuning and design was developed, enhanced and passed down to the next generation. Success required one or more knowledgeable gurus, a tight group of self-motivated learners and a driven business leader with enough 'can-do' attitude to convince customers and his own team that they could achieve new heights in filter technology. These are some of the insights shared during a dinner conversation between *Microwave Journal* and two such entrepreneurs from Maryland's rich filter history and the sons who are carrying on their legacy.

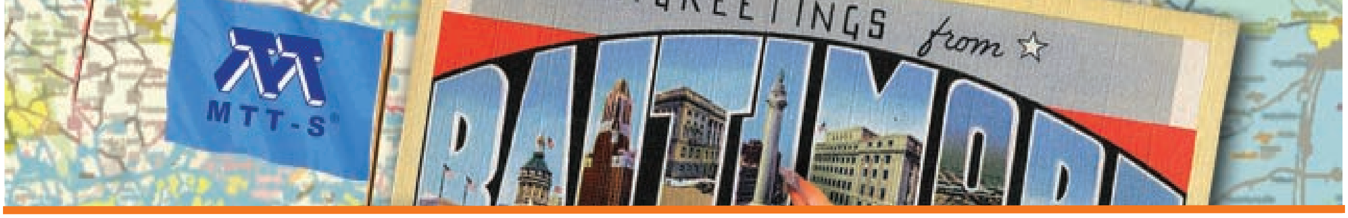
Meet the Bernsteins and the Assurians

Dick Bernstein is the legendary founder of K&L Microwave. Bernstein studied engineering at the Virginia Military Institute and earned his undergraduate degree from Salisbury State University after having gone to work as a Lead Designer for I-Tel, a filters, diplexers and multiplexers shop founded by Richard Wainwright and his wife, Virginia, in Kensington, MD. Within three years, Bernstein outgrew the opportunities available at I-Tel and followed a career path to Texscan in 1967. Texscan was a solid-state sweep generator manufacturer in Indianapolis, IN; a spin-off from a California company called Telonic, founded by two other (un-related) Wainwrights, Claire and his wife, Barbara.


Kevin and Dick Bernstein

In 1970, Bernstein returned to Salisbury, MD to set up his own company, named after his children Kevin and Lisa. At its helm, Bernstein grew K&L into one of the most recognized companies in our industry before selling it to Dover Corp. in 1983. Bernstein stayed on at K&L until 1989. The

David Vye
Editor, Microwave Journal



eternal entrepreneur left to start BAI Aerosystems, acquired Lorch Microwave in 1994 and moved that company up to Maryland. BAI Aerosystems was sold to L-3 Communications in 2004; Lorch was sold to Smiths Interconnect in 2006. His son Kevin Bernstein is the company President.

Manny Assurian has also established a global reputation as a leading businessman among the custom filter manufacturing community and their clients. In 1967, Assurian was fresh out of college from the Capitol Institute of Technology when he joined I-Tel as an engineer shortly after Bernstein's departure. As often happens at small companies, Assurian cut his teeth by doing a little bit of everything (assembly, machine shop, tuning, etc.). In the 1970s, I-Tel changed its name to Cir-Q-Tel (see call-out box for details). During this period, Assurian's responsibilities grew until he was serving as company President and running the business for Wainwright. Leveraging his experience, Assurian left Cir-Q-Tel to launch Reactel in January of 1979 along with former colleague, Don Claycomb.

Assurian grew his two man operation, originally located in less than 1000 square feet of manufacturing space, into a leader in the design and manufacture of high performance custom RF and microwave filters, multiplexers and multifunction assemblies. Today the company operates in a 15,000 square foot state-of-the-art facility located in Gaithersburg. Manny's son Jim Assurian is currently the Director of Business Development at Reactel.


Jim and Manny Assurian

Itel was a San Francisco-based equipment leasing company founded in 1967. Through creative financial arrangements and investments, Itel was able to lease IBM mainframes to customers at costs below what customers would have paid IBM, making them second only to IBM in revenues from IBM mainframe leasing. Unfortunately, the name they chose for their company already belonged to a tiny microwave company in Kensington, MD. This led the much larger Itel of San Francisco to sue I-Tel of Kensington over the use of the company name.

Virginia Wainwright, who handled the business side of I-Tel went to New York and hired the most prestigious lawyers she could find. In court, the judge ruled in her favor. Recognizing the considerable costs associated with re-branding the larger company, Virginia was able to negotiate an attractive financial compensation in exchange for renaming her company. Meanwhile, Dick Wainwright envisioned a future market for drop-in circulators and thus developed such a component. The company's new name, Cir-Q-Tel was chosen to reflect its re-direction in product focus.

STEAK AND SHOP TALK

We met in a Washington, DC restaurant, where everyone had travelled to attend the Satellite 2011 show. The Bernsteins had just returned from Dubai, where they were visiting an armaments show. Dick is currently the CEO of LWRC International, a company that designs and manufactures what the company claims to be 'the finest evolution of the M4/M16 rifles and carbines since the weapon's introduction.' Using the latest technology and materials, Bernstein's new company is able to produce rifles that operate cleaner, cooler and more reliably without sacrificing accuracy. Asked if his experience in the filter business has been applicable to his current endeavor, Bernstein replied, "Everything we've done has been a stepping stone in all our ventures."

MWJ: So, why start a filter company in Salisbury, MD?

Dick Bernstein: I thought I would start the business close to my family and Salisbury had an airport. Then UPS and FedEx came along; so today, location is much less important. I tell people that unless you're in the next town over, it doesn't matter where you are. I'm as close to my customers in France as I would be if I were in Philadelphia or some other place. In my early ads we said, 'just below Baltimore' although it was over 100 miles away.

I grew up on the shore where my parents had a garment factory, so I knew the people in that industry. They were very loyal, fast learners, steady and dependable workers, which leads me to a story about one of the things I brought to the industry.

I had left the shore unable to get a job there after college and took a job [at I-Tel] on the western shore in Kensington [Maryland], followed by a few years at Texscan [Indianapolis, IN]. Texscan was making solid-state sweep generators, competing head on with Telonic, which made the old wobbleator and oscillator type sweep generators. So they needed someone to handle components, and that's how they came to hire me.

Both I-Tel and Texscan made high mix products; those are low volume, very custom parts. In Washington, DC, I was training people that were part of a very transient labor supply. Somebody across the street would offer an employee 25 cents an hour more and they would leave. But in Indianapolis, we didn't have that problem. We were getting very loyal people. They were unskilled, basically off the farm, but very trainable people. They reminded me of the people on the eastern shore. In the early 1970s, defense spending was winding down and engineers were losing jobs and driving taxi cabs. Texscan was cutting back, so I thought it was a good opportunity

to come back to the eastern shore and start a business (Note: I-Tel and Texscan are now part of Trilithic).

So when I came back, I went to Salisbury because I knew the people [garment workers] that were available there. They were also trainable and loyal. Now in Kensington, we had high turnover. I-Tel did not believe in trying to hang on to people. You would learn and you would either get too smart, or need too much money and you were dispensable. But I believed in having continuity.

In the garment industry, what I learned is that the operator used every part of the body, their knee, their elbow, whatever it takes to run the equipment, workers are very efficient. When I went to work at I-Tel, I was amazed by how inefficient the electronic industry really was. After all, the material costs are only a small percentage of the total product and the rest of it is mostly labor. We usually had to rebuild the product two or three times to get it right, so I created some mechanization for the workers, such as hot plates to solder on and automatic wire cutters, and stuff like that. We also moved away from individually made parts and more toward a mass-production type of line with one person working on one aspect of the component and passing it along to the next person, assembly line fashion and that really improved the quality and efficiency right away.

The reason we were able to grow this industry is that we didn't try to teach somebody how to tune and build a microwave filter; we taught them how to do one part of it. They would learn that and then they moved on to something else. We broke up the product assembly so that each aspect of the product's construction became a simple task for entry level people to achieve and feel good about.

My competition at the time advertised in the paper for skilled technicians or specialized microwave machinists and was forced to pay higher wages. In the same paper, Frank Perdue would be advertising for chicken pluckers and gizzard trimmers. The same person who would apply at his [Perdue's] place then would come over to apply at my place. That was the choice people had in those days; they could either pluck chickens or tune filters, and I had a cleaner operation than Perdue.

Charlie Schaub was one of my first employees. By the time I left K&L he became the President. Bob Livingston, who I hired as an accountant in 1982, is now the CEO of Dover Corp., which is now a $7 B company. Bob went to Salisbury University, and he worked for a company in Washington and then he came back, bought a restaurant and was a cook around the time I was looking for somebody to work in accounting. So when I talk about growth in Salisbury, there are lots of people who demonstrate that. Many of them were able to go far beyond what I was able to teach them.

THE 'SHOE BOX' AD

Every entrepreneur knows that launching a company and winning initial business is not necessarily a pretty or clean endeavor. Dick recalled for us the tale of how a clever, yet somewhat over-reaching marketing campaign provided both customer and vendor with the confidence to move forward together on the development of a new filter type, helping to secure a much needed contract in K&L Microwave's early days.

Mike Hallman,* Microwave Journal*: I was at K&L, working for Charlie Schaub as an intern when I heard some folklore of how you went to banks with broom handles cut up and painted black to look like filters. Is that stuff true?

Dick Bernstein: The broom part is not really correct, but I can tell you a story about that. Back in the 1970s, the market needed a tunable notch filter and there were none. Telonic was making these tunable bandpass filters and there were some engineering companies that made some other special filters, but nobody had made anything like what the market was looking for.

I had designed tunable bandpass filters as well, so I knew pretty much what the construction was. Texscan began sending me a requirement for a tunable notch filter that they were going to bid on, but they really didn't have interest in developing it themselves. And so they ran it by me thinking it might be something I'd be interested in. This was for Harris Corp. down in Melbourne, FL, and it was all related to a program in Germany.

At the time, we [US Government] had antennas on the border of West Germany and Czechoslovakia and whatever other borders we were listening in on. In Germany, there were these high power television stations that were interfering with the ability of our listening equipment to find out what was going on over the border. So I got this requirement from Texscan for a notch band filter to block the high power television signal. I responded "no bid" because I didn't really know how to make them.

Well, after being in business for about seven or eight months and nearly starving to death, I decided to run an advertisement in a microwave magazine for a filter based on the same specifications that I was getting from Harris. I created an ad that basically reproduced the requirements for a tunable notch filter with this frequency, performance, etc. I called it the shoe box ad. It was actually a block of wood that I painted black, I took the knob off my TV set and pasted it on as a tuner dial and stuck N-connectors on the side of it with glue and took some fuzzy pictures of it.

Well, I got another requirement from Harris and once again I 'no bid' it, since it was just a marketing gimmick; a way to say 'we do these things' to differentiate ourselves from all the other microwave guys. But the buyer calls me and asks, 'why don't you bid this,' to which I said we don't make that frequency. He replied, 'well it's pretty CLOSE to what you're advertising in this magazine. Do you mind coming down here and making a presentation to our engineers? What we really want is what you've been advertising.'

So on the airplane heading down I literally sketched up how I would design this tunable notch filter on yellow lined paper. I arrived and three or four other engineers were already there to do a presentation. I remember there were guys from TRW and others from Hughes and they all went in and did their presentations. I went in with my yellow pad. There was a blackboard in the room and I drew up how I was going to do this thing. So they called us all back about an hour later to say they made their decision 'and gentleman, we're going to give the award to K&L Microwave.'

I said to the guy, 'well I'm delighted to get this order but I thought these other guys [from TRW and Hughes] would be far more advanced,' and the buyer said, 'well Mr. Bernstein, this is a critical program for Harris Corp. and we can't afford to wait and you've already got it made, we've seen the advertising.' That's the power of advertising!

AN ANGEL VISITS K&L

Dick Bernstein: We were just starting the business when I bid on a requirement from GTE Sylvania in Syracuse. GTE said that I was the only vendor who was fully compliant on the ten or so different items in the proposal. There were some high power stuff and some tiny stuff, but I quoted 100 percent that I could do everything they wanted in the proposal. And they called me up and told me they liked my quote but that they wanted to come out for a pre-award survey [similar to a source inspection]. At the time, I had rented this building for $75 a month; it had no heat, no air conditioning and one door. Today they would put you in jail for trying to operate out of a building like that.

Let me give you an idea of my operations back then. On weekends I would borrow Wavetek test equipment from Herb Weinstein, who was with Eastern Instrumentation, meeting him at the bay

bridge on Saturday mornings, returning it on Sunday nights. This way I was able to tune filters on the weekend and it didn't cost me anything. That's how poor I was.

So the guy [from GTE] came in and I had my family members sitting around at tables [workstations] in the back, looking like they knew what they were doing. And we sat up front and talked. I had made up this control manual that showed how I was going to run the company. He looked through that and said it looked good, and then he said, 'let me see the rest of your factory.' Well the factory was essentially 1200 square feet of empty warehouse. But what I had done was put lines on the floor, marking off different spaces with tape. 'This is where my stock room is going to be and this will be my assembly room—all marked with yellow tape on the floor, and this is my test station, my QC, this is where we're going to do the machining, etc.'

And so we walked across this literally empty space where the floor was marked into these areas. He must have thought I was crazy. That might have taken 20 minutes to walk around and then we went back up to the front desk and he said, 'Mr. Bernstein, this is a very, very big contract and an important contract for GTE. I don't think we can award this contract to you. I don't see much that you're doing here.'

Well, he must have seen my jaw drop, because he then said, 'On the other hand, Mr. Bernstein, I don't see anything that you're doing wrong. So I'm going to recommend that we approve you for this contract, but I'm going to come back in six months and I want to see this machine shop there and that stock room there.' And so I've told people to this day, that everyday I went to the building, I operated as though he was going to come back to make sure that I did what I said I was going to do. And that's been the basic principle behind our success. He never came back, but he didn't need to. And we had many other good breaks.

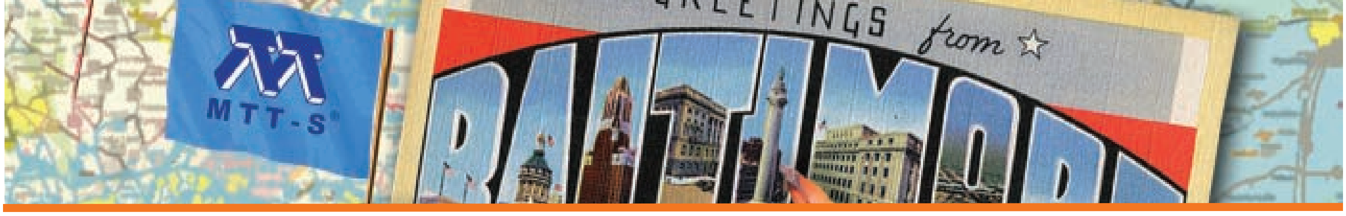
BASEMENT BEGINNINGS

While Bernstein created K&L by leveraging his experience at I-Tel and Texscan with his awareness of an untapped but trainable labor pool in Salisbury and the belief that the electronics industry could operate more efficiently, Manny Assurian leveraged his experience of running a small business with an opportunity to get his hands on the equipment needed to launch his own venture.

Manny Assurian: I had an employment contract with Cir-Q-Tel that prevented me from competing with them directly for one year. Well, I had found this guy who was selling his company. He wanted to retire and he had enough of the necessary equipment in his basement to start a filter company, but this wasn't a filter company. So I went and talked to him and saw that he had lathes, a small mill and some test equipment. I thought—this would be perfect to do filters. So I bought all the equipment in his basement and for one year I started advertising in a local telephone book that I would do any small machining job, build cables, or anything electronic—just to survive until I could get back into the filter business.

Jim Assurian: The business Manny bought was making harnesses and boxes for the weather bureau and this gave Reactel a product to sell while they [Manny and Don] geared up for filters in 1980. I remember moving the equipment and materials from his place to our first windowless warehouse in Rockville. We bought his business because he had the rudimentary equipment that could be used to make filters (some electronic test equipment, some machine shop equipment and some assembly equipment). By no means was it the best, but it would do. Looking back on that equipment, it is laughable, but it got the job done (we do not throw anything out, it is all gathering dust in our current facility).

Manny Assurian: He was building a lot of components for



certain radar markets, but they were older systems like World War II and weather radar vintage. So in 1979, we did those wire harnesses for NOAA – National Weather Service, because the equipment that we now owned and the sample materials he had sold me were for that market. He also introduced me to his contacts there, so there was some existing business, but we basically did whatever work we could find.

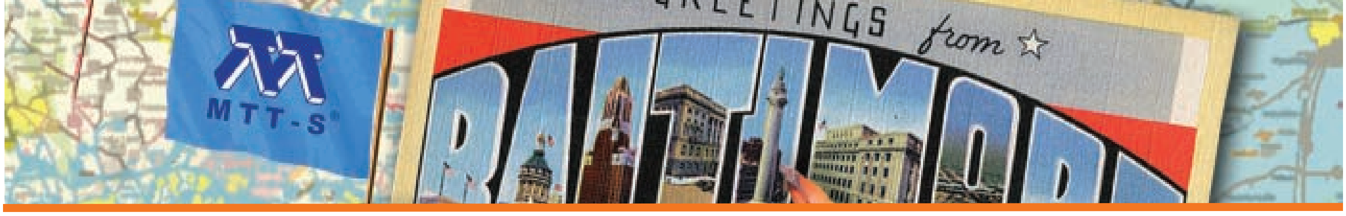
Then as the one year non-compete approached, I started advertising for microwave components such as semi-rigid cables, and I got a call from a company in Virginia. I think it was Atlantic Microwave. They needed a lot of semi-rigid cable and asked if I could make it. So I said 'of course I could, I'm an expert!,' although I had never made a cable in my life.

I went to visit them and they showed me their boards and the drawings for the cables they needed and then I noticed that they were using K&L filters. It's almost one year after leaving I-Tel. I mentioned something about the filters in his design and I told him, 'I can make those.' This guy said, 'nah, nah, nah, you can't make these. These are very sophisticated filters.' So I told him to 'give me the most difficult filter that you have and I'll make you a set.' I went back [to Reactel], and at the time I didn't have any test equipment that went up to that frequency. So I went to a junk house and bought a Texscan sweep generator and made this filter to the spec.

I took it to him and we hooked it up and he was impressed how well it worked. So I told him I could do the rest of them too and I got the job, which included all the K&L filters and all the semi-rigid cables that went with it. And that's how I got back into filters, but this time with my own business. After the year was up, I placed my first advertising in MSN, *Microwave System News* and it said "Manny's back," call this number. Oh boy, and the calls I got. By 1980, we were back in the filter business and what is considered our first "official" job was a nine unit order from COMSAT totaling $1086.00.

K&L GROWS AND IS ACQUIRED

Dick Bernstein: We started our business in 1971, when there was a recession going on. Most companies were cutting back and dropping their advertising dollars. I was running a brand new company, and perhaps I didn't know any better, but I kept advertising and would go out on the road to meet customers. When things eventually turned around, who did these companies remember? It was the last guy they heard from. So K&L was able to get ahead of our competitors. K&L's growth tracked the



industry and general economic ups and downs over the years, but we really outpaced everyone else in our level of growth.

When I started K&L, I was the engineer. But after awhile, I realized I could hire engineers who were a lot smarter than me. I wanted to stay close to the market and so I'd hire the right engineers. That way, I could shift my focus and run the business as a business. To do that, I brought in the people I needed to help me satisfy the customer requirements and that's how we were able to grow.

At K&L, I liked to think of ourselves as being on the leading edge of technology, not the bleeding edge of technology, meaning that we were not trying to create new markets. We were trying to understand new markets and adapt to them. One of the reasons we looked to be part of a bigger company was to have somebody that could help us with the broader vision. And Dover as a parent company made a lot of sense for us.

Dover is a great company. The deal we made with them allowed us to continue with what we were already doing and wanted to accomplish. We were approached by several large microwave companies. The reason I liked Dover is that they weren't in the microwave business. That told me that they needed our people to continue to grow what we had already started. And that made our people feel more secure.

K&L SPROUTS SEVERAL START-UPS: SALISBURY ENGINEERING AND FILTRONIC COMTEK

***MWJ*: Tell us about Wayne Barbely and Salisbury Engineering.**

Dick Bernstein: Wayne Barbely was working at Wallops Island [Command and Data Acquisition Station] out of NOAA. Wayne was a very good engineer. At the time we were building varactor tuned filters and we had hired Wayne and another engineer to work on these. Back then we had to get our production out of the way to meet our payroll and cash flow. So the way I worked the company was to take the first two or three days of the week and have everyone working on achieving that goal. Then after that, engineers could work on new projects and developing stuff. We needed Wayne to get stuff out the door. He didn't like that approach, so eventually he left and started Salisbury Engineering. Wayne wanted to get into what we were doing, but in his own way. So Salisbury Engineering was founded; that was in 1983. We had other people who had left to start businesses in California, but he was the first person to leave K&L to start something new in Maryland.

Wayne ran a different type of company than I did. I think there

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RF5385/95	2.4 GHz FEM, PA, SP3T SW, and P_{DET}	2.4 to 2.5	27	20	3.0	3.0 to 4.8	190	QFN 2.5 x 2.5	Y

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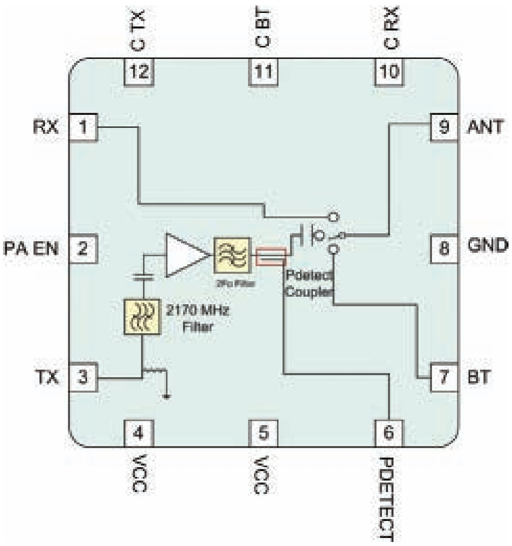

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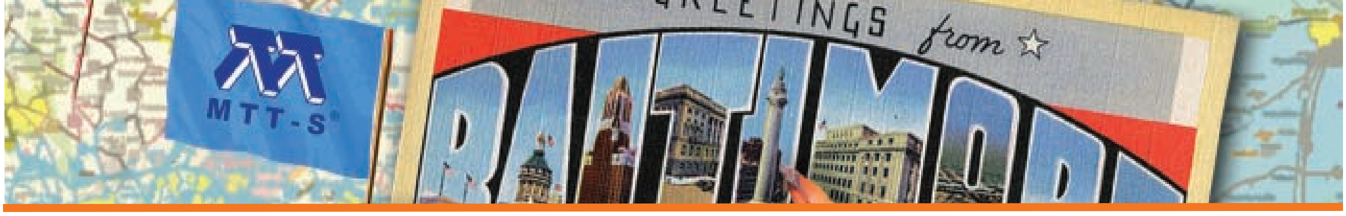

are essentially two types of companies. I try to grow the business and in doing that I bring up other people and eventually they replace me and that's how we grow. This was something I recognized was missing when I worked for Wainwright, which meant I could only go so far at I-Tel. Manny saw that as well, which is why he eventually left. The only way you can grow is to leave, unless you are happy with your position in that company. Likewise, Wayne wasn't happy with our approach at K&L and left to do things his way. Salisbury's approach was for management to maintain strong control of sales and engineering. This worked well for Wayne.

MWJ: Well, there are a lot of companies in our industry that are happy with being a certain size. They make good profit year after year and they don't want to mess up the formula.

Dick Bernstein: That's true, and it works for some people. I prefer to have the challenges that come with trying to grow a business than the challenges of trying to maintain a certain size. In the end, Salisbury's strategy worked for them.

Carl Sheffres,* Microwave Journal: *Wayne told me he never wanted it to get too big. He figured out what he needed to do to make about the same amount of money every year.

According to public record, Salisbury Engineering earned approximately $4 M in 2004, the year they were acquired by Spectrum Control.

MWJ: Spectrum bought two companies with Maryland produced filter roots: Salisbury Engineering in Salisbury and FSY in Columbia. And API Technologies just acquired Spectrum Control for about $270 M. But going back to the topic of K&L spin-offs, how did Comtek come about?

Dick Bernstein: Dr. David Chambers worked for Professor Rhodes of Filtronics in the UK. Rhodes was a pure genius who approached everything from a theoretical perspective, including business. He would visit me at the shows and congratulate me. He would ask 'how do you guys do this stuff.' That is, being so well known in the filter business without many engineers or PhDs. I told him that our approach is based on the belief that ultimately, the low cost producer was going to win. The competition was no longer just across the street or across the state but all over the world, and our job was to take customers orders and deliver the product in the shortest time possible at the lowest possible cost. Well, Professor Rhodes had a different philosophy. He was able to go beyond the filter and integrate these complete systems.


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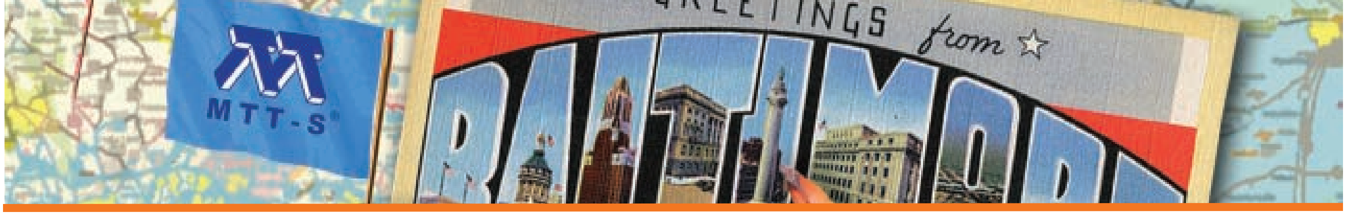

Learn more about
J. David Rhodes,
Engineering Emeritus Professor
University of Leeds, UK
Visit www.mwjournal.com to read this in-depth interview.

ExecutiveInterviews

In the mid-1980s David Chambers joined K&L as our Senior Engineer and helped take us to the next level. He's what I call an engineers' engineer. All of a sudden my other engineers could learn from him. We had been using University of Maryland professors to come in and teach some microwave networks theory, but when he (Chambers) came on board everyone gravitated toward him. He became their mentor.

And Dave used to tell me that it was amazing what we were able to accomplish with so few engineers, which he meant to be a compliment. And I would kid him back by saying that's why we had been so successful. But he understood where I was coming from, and he did help us get to the next level, handling the more sophisticated stuff as our market grew from production oriented to more engineering oriented. And this was from 1983 through the early 1990s. David stayed with me through that period of time, and then when I left the company there was a change in management.

THE COMMERCIAL WIRELESS EXPLOSION

Kevin Bernstein: You have to understand what was happening at the time. K&L was positioned squarely in the defense market and we would see these requirements for ridiculous quantities at ridiculously low prices and our natural reaction was 'impossible.' Rhodes understood what was happening and believed in it. Prices were just dropping. Things we would sell for $800 to $1,000, people were demanding $300 or $400. We would tell them no way, but they would tell us they were getting it from a new type of supplier.

Dick Bernstein: At that time our business was 90 percent defense, small quantity high mix of products. The cellular business represented high quantity, low mix products. And that was something we didn't see coming. It was a more sophisticated kind of product. Filtronics filled that void; they

were focused on that kind of market.

Kevin Bernstein: When you look at how Comtek started in Salisbury, it was really a combination of some personalities, and market changes. Rhodes knew it was time to invest in the commercial business and David lived in Salisbury, and he was a visionary and knew where the business was headed. Rhodes also knew which way it was heading. For practical guys like us, we would say there's no way that's going to happen.

Jim Assurian: I couldn't believe how big they were, they were huge. At the time, we were both using the same silver plater. Reactel would have a hot job and I'd drop off a handful of units when this truck from Filtronic Comtek would back in. They began unloading pallets, while I've got a box of about five cavity filters that I needed right away and I was going to wait for them to be plated. It was a go-go time for those guys.

Kevin Bernstein: Same for us. They would get some parts machined at the same machine shop that we used. I'd go in there and they would have all the machines dedicated to Comtek and they weren't interested in doing our stuff. I was having trouble using our own machine shop. It came about because they had a vision of the market that wasn't understood at the traditional defense businesses.

In 1994, demand for the company's filters used in cellular base stations was booming. Filtronic Comtek, a division of Filtronic Comtek PLC England, had 110 employees on the Eastern Shore and expected to add another 200 after the construction of their 62,500-square-foot, $4 M headquarters and manufacturing center in Salisbury.

Dick Bernstein: Professor Rhodes bought one or two companies, he bought a circulator company, had a company up in Scotland, a foundry that made their integrated circuits, and they were publicly financed in the UK. I remember meeting some of the board members; they didn't have much tolerance for losing money. But they had fantastic growth.

Manny Assurian: At that time [early 1990s] the commercial market really took off. They were selling stuff for much less and we would scratch our heads trying to figure out how they did that. And that's when I came up with the idea to see if I could get my labor costs down since the most money that you spend on a filter is the manual labor for tuning. So I figured if I can get it to the point where anybody could come in here and learn this skill in a week, I could get lower wage earners. So we developed a methodology to tune filters and I was able to reduce my labor costs.

Dick Bernstein: In the defense market the customer pays for the R&D, so you get a higher mark up because your costs are higher. In the commercial business you have to go with the 1000 piece price that is set by the market. So you're taking all the development cost on your chin and you're at risk. And what happens when they do that? Well, take a look at everything that's going on in the commercial business. Where is it being done today? It's being done offshore and they're chasing lower labor dollars constantly. So that's what happened to Comtek. Eventually it went off to China, because that's the big market. And you have to be in China today to satisfy that cellular business.

Manny Assurian: Even K&L went to China [under Motorola's insistence], but they didn't do very well. But then it was all based on Motorola business. Later, I was congratulating K&L at one of the shows and they told me that they had to shut it down. Although they were making the parts there, they needed them at a Chinese price. The price had dropped from $400 a unit down to $150 a piece. And there was no way they could do that, so they had to shut it down.

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Power Amps							
MAAP-008923	2.5 - 5.0	33.0	30.0	44.0	—	+6/-1.0	5 mm PQFN
MAAP-008924	10.0 - 13.3	27.0	31.0	43.0	—	+6/-1.0	5 mm PQFN
XP1039-QJ	5.6 - 7.1	16.5	34.5	49.0	—	+7/-1.0	6 mm PQFN
XP1050-QJ	7.1 - 8.5	15.0	33.5	48.0	—	+6/-1.0	6 mm PQFN
XD1008-BD	0.003 - 40	15	22.5	38.0	3.0	+7/-2.5	Die
Driver Amps							
MAAM-009286	250 - 4000	15.5	27.0	42.0	3.5	+5.0	SOT-89
MAAM-009560	250 - 4000	14.5	28.5	40.0	2.7	+5.0	SOT-89
MAAM-009563	250 - 3000	19.5	31.0	47.0	6.25	+5.0	SOIC-8EP
XB1007-QT	4.0 - 11.0	23.0	19.0	31.0	4.0	+4.0	3 mm QFN
XB1008-QT	10.0 - 21.0	17.0	18.0	32.0	4.5	+4.0	3 mm QFN

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M/A-COM Technology Solutions
THE FIRST NAME IN MICROWAVE

LORCH MICROWAVE

MWJ: So Dick, you mentioned leaving K&L, which eventually got you connected with Lorch. What's the story behind Joe Lorch and Lorch Microwave? What got you interested in purchasing them and returning to the filter business?

Kevin Bernstein: Joe came out of Empire Devices and started Lorch Electronics in the mid 1960s.

Manny Assurian: They didn't make filters; they were doing lots of combiners and loads.

Kevin Bernstein: Well, Joe did whatever was interesting to Joe. What I saw there were lots of mixers and phase shifters, IQ modulators, some filters but transformers as well. Early Lorch catalogs had everything under the sun. Joe sold the company around 1983 or 1984 to Vernitron, who moved it from New Jersey to the St. Petersburg [Florida] area and the company kept getting smaller and smaller and then they eventually sold it to Dad. That's when we moved it back up to Salisbury and we changed its focus to filters.

Dick Bernstein: I left K&L in the early 1990s and at that time my turn-over rate for people was extremely low. And when the new management came in, they began to cut back and replace people, so there were a lot of people on the street that had filter knowledge.

When I left K&L, I actually started a new company called BAI Aerosystems [BAI was later acquired by L-3 Communications in 2004]. We made Unmanned Aerial Vehicles (UAV) or drones. This company that I had just acquired only made airframes. They weren't making autopilots or guidance systems or anything like that. I thought we could make transmitters and receivers for a complete UAV guidance system using people who had knowledge in telemetry. So we started hiring these people who were out on the street. The job market was soft but their background [filter experience] was strong.

Meanwhile, K&L was laying off and people were looking for jobs, and I was approached by a business group to look at Lorch Microwave. They needed someone with knowledge of the products to step in and help them fulfill their contracts.

Lorch Electronics in Florida had taken this product line, and was struggling due to lack of continuity of key personnel from the original company in New Jersey. They tried many manufacturing models, including off-shore manufacturing, but they were unable to consistently maintain the expected quality levels. To this day, in microwaves you can't rely on the last build, because there are always some subtle differences in components. You need that guy (the technician) with the knowledge to figure out what the differences are in order to tweak it properly. I said I could acquire Lorch, but that I would have to move them to Salisbury where we were familiar with the available talent.

I looked at it, they made me a sweetheart deal, and so I acquired the company and moved it to Salisbury. We turned it into a great little company because I needed those products for the airplane business. It was there to support the electronic side of the airplane business. My non-compete with K&L was for five years. Lorch was acquired in 1994 and I had left K&L in 1989, so five years later I was able to acquire them and re-enter the filter business but with a different focus and objective. We relocated Lorch to Salisbury with about 10 employees.

Lorch Microwave is now part of Smiths Interconnect, which designs and manufactures RF components for the wireless telecommunications, aerospace, defense, space, medical, rail, test and industrial markets. From the Bernsteins' perspective, Smiths has been a great parent as the business has been able to maintain its traditional management philosophies, yet has the strength and support of a much larger global organization.

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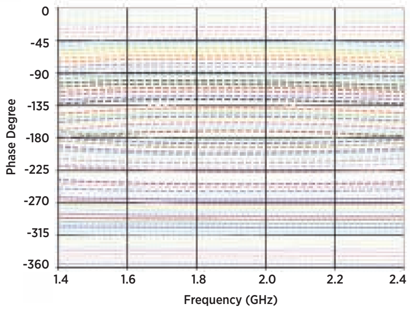
MORE ACCURACY



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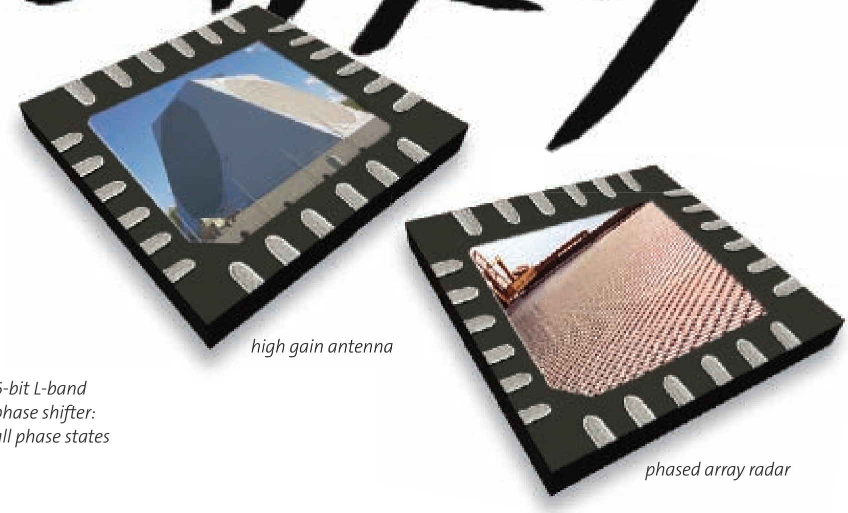

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MAPS-010144	2.3 - 3.8	4-bit	22.5 - 360	3.5	3	± 0.6
MAPS-010145	3.5 - 6.0	4-bit	22.5 - 360	4.5	3	± 0.7
MAPS-010146	8.0 - 12.0	4-bit	22.5 - 360	4.5	3	± 0.8
MAPS-010163	1.4 - 2.4	6-bit	5.625 - 360	5.0	5.2	± 0.8
MAPS-010164	2.3 - 3.8	6-bit	5.625 - 360	5.0	3	± 0.8
MAPS-010165	3.5 - 6.0	6-bit	5.625 - 360	5.5	3	± 0.8
MAPS-010166	8.0 - 12.0	6-bit	5.625 - 360	5.0	3	± 0.8

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THE FIRST NAME IN MICROWAVE

THE MARYLAND FILTER LEGACY

Kevin Bernstein: In Salisbury, the two big spin-offs were Salisbury Engineering and Comtek, but there were all kinds of permutations after that. You had people that were at K&L that went to Comtek, and then we brought Lorch into Salisbury, so people were going from K&L to Lorch. People like Gary Ennis left K&L and Lee Mason left Filtronic and started ClearComm in 1997. ClearComm saw a niche in the market among the 2nd and 3rd tier carriers for orders of less than 1,000 parts that K&L or Comtek weren't interested in supplying. So they started knocking on doors and were able to establish a business there.

There was also RelComm. That's the company that John Tinkler started after he left K&L. In 1993, K&L acquired the switch line from Transco in Camarillo, CA. RelComm Technologies was established in April 1994 in Salisbury. RelComm designs and manufactures custom (design enhanced application specific) RF coaxial relays for telecom infrastructure, MILCOM systems as well as test instruments. In 1996 Dow-Key was acquired by K&L Microwave/Transco under the umbrella of Dover Technologies. Dover felt that Dow-Key had the stronger position in the switch market and all production was moved to Ventura, CA.

There is also Eastern Wireless Telecom (EWT) that was spun off from Lorch in 2000 by my cousins, Kerry and Bryan Bernstein. EWT specializes in custom filters and filter based products for military, commercial, wireless and space applications. All those people worked at K&L at some point. Cir-Q-Tel and Reactel also spawned their share of spin-offs.

Manny Assurian: In 1983, three people (Bill Forrestel, Roland Siushansian and John Yania) who I hired during my time at Cir-Q-Tel (and two of whom worked for us a little at Reactel) left to start FSY Microwave as a company that designed and manufactured filters and multiplexers. Neither Bill, John or Roland were involved in electronics at all when I first hired them at Cir-Q-Tel, but eventually they all moved through the ranks to the point that they decided to go out on their own. FSY eventually got bought by Spectrum Microwave (Siushansian is retired, Yania still works for Spectrum as a Business Development Manager, and Forrestel now works for Aeroflex Weinschel in Frederick, MD as the Director of Subsystems Engineering). While one could debate whether FSY was truly a spin-off from Reactel, our first "official" spin-off was ES Microwave.

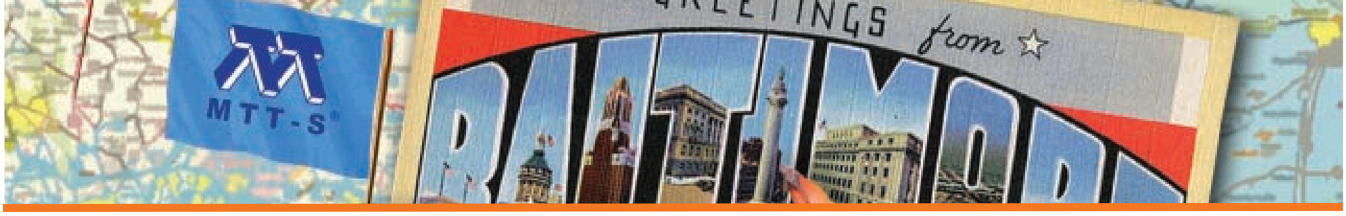
Spectrum Microwave originally evolved under the direction of Spectrum Control's CEO Richard Southworth, leveraging their expertise in RF and microwave ceramic filter and antenna technologies. The division's initial strategic acquisitions in 2002 were FSY Microwave and Salisbury Engineering; both companies were leaders in their own right. In July 2002 Spectrum paid $6.5 M to pick up FSY Microwave Inc. At the time it was purchased the production and R&D facilities in Columbia, MD totaled 45,000 square feet.

My nephew Sargon Assurian and a technician we had at Reactel left to start Eastern Multiplexers in 1991. In 1996, that same nephew left EM and together we started ES Microwave. ES Microwave concentrates mainly on suspended substrate filters, multiplexers and switched filter banks.

MARKET DRIVERS TODAY

***MWJ:* It seems that certain events come along over time and propel the industry forward, such as radar in World War II, the Cold War, Vietnam War, weather radar, NASA, commercial telecom and wireless communications. And that pushes the need for smaller, lighter and less expensive solutions. So looking at where we are today, what do you see pushing the industry forward?**

Dick Bernstein: When this country was building its [telecom-



munications] infrastructure, they were digging trenches and laying cables underneath the ocean. Now anybody in Indonesia or Somalia has a cell phone and they need their own infrastructure. That's where the future market is going to be. That's what Professor Rhodes did so well, and so he set his company up as an integrator and created a new type of filter company. But the cost needs to be so cheap today compared to what it was, and that is where the challenges are. I also think you're going to see the next big opportunity in automotive, where you'll have tracking and cars will be another mobile wireless device and people will get their e-mails on the dashboard and have full access to the Internet.

MWJ: Hopefully the driver is watching the road. But, what you are describing sounds like a high volume, cost driven market. Has Maryland become the center of the universe for custom microwave parts and does chasing that business restrict growth for such companies?

Kevin Bernstein: It doesn't restrict our growth when it comes to the defense market, but it definitely restricts our growth in telecommunications. And the two markets don't really converge; we don't see custom parts working their way into high volume markets.

MWJ: It seemed like years ago, businesses could cycle back and forth between the defense or commercial markets based on whichever one was stronger at a given time. Eventually companies seemed to have settled into serving one or the other markets.

If those markets don't converge, do you ever see custom shops shifting back from defense to commercial markets in the future?

Jim Assurian: You can't put a square peg into a round hole. We may not have a period of phenomenal growth like a high volume, commercial based business would, but few of those guys are making money these days. We have steady growth. We have been around for 32 years and have seen all business cycles and we're still here. People will always need what we provide. We also don't have a problem with a part becoming obsolete. We have buyers come up to us with old catalogs and we're able to supply them with old parts because we have all the old drawings, the bill of materials and the know-how.

People do come up to us and ask, 'what new things are we presenting to the market?' But we're more driven by the market. We respond to market needs, such as making a smaller filter or using a different type of connector. Someone comes to us with a unique requirement and we're going to develop something explicitly for him, but he's going to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*Peak Power: 50 kw
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*Operating Temperature: -35C to +85C ambient
*Average RF Power up to 3 kw
*SC Connectors
Switch Matrices
*Modular Design
*Common Control and Command Protocol
*Flexible system architecture
*Compact physical format
Standard Product Configuration
SPDT
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Transfer
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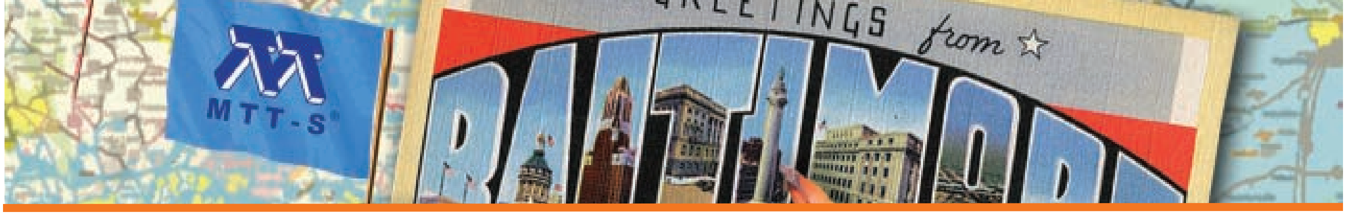

be the only guy who needs that part and he'll be the only guy we sell that part to and he'll come back to us for as long as he needs that part. That's the custom business. Therefore, I think there's always going to be the need for the custom guys.

Manny Assurian: Just the other day I got a call from a buyer. They wanted to know if a certain part was still available. I told him of course it is. I understand why he would ask this question. If you look around, a lot of these companies have disappeared. Maybe because we make these simple boxes, although they are not simple inside, but we are reacting to what our customers tell us they need. So our customers, the system integrators may see larger trends, but it's hard to decipher what direction the market is headed or what the next big thing will be based on our vantage point.

Kevin Bernstein: In the commercial telecom products, every OEM has the same electrical requirements, but people approach the problem in their own way, integrating different parts, optimizing the amplifier or the filter depending on their strengths and expertise. They all have their own formulas and there are infinite ways to address a need. And even with so-called standard parts, there still seems to be the need for a nearly limitless number of components built to infinite configurations, combinations of frequency bandwidths, connector types, etc. So that represents a relatively small but steady market and we're happy to fill that niche.

When customers talk about obsolescence, there's no such thing for us. We can make the same parts that we made 40 years ago. No problem.

YOU CAN'T TUNE A FISH

What Bernstein started in 1971 with K&L Microwave, today represents a community of more than 1,800 workers in Salisbury. In recognition, he has been awarded honorary doctorates from both the University of Maryland and Salisbury State University. Along with Manny Assurian, who extended the state's filter expertise with Reactel and the handful of spin-offs that he has inspired, these entrepreneurs are responsible for some remarkable accomplishments. Thanks to K&L Microwave's impact on the region, the industrial base of Maryland's Eastern Shore now contributes more than $200 M aggregately to the local economy. To mix metaphors – You can give a man a fish and he will eat for a day, but teach him how to tune a filter and he just might be able to buy fish for a lifetime. ■

Best of the...

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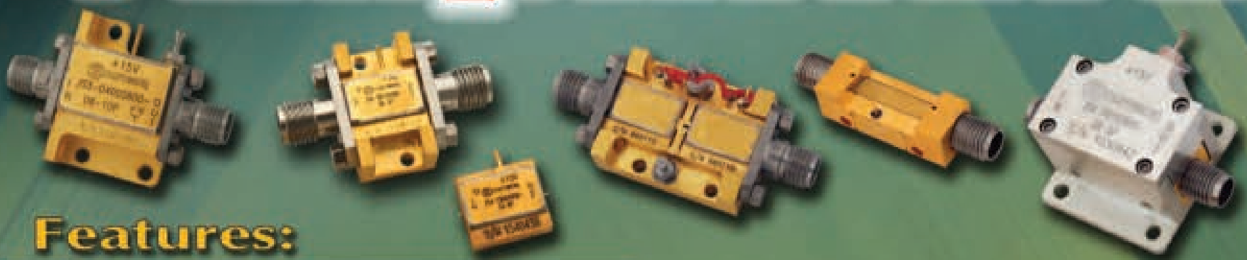

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Model Numbers	Frequency Range (GHz)	Gain (dB, Min.)	Gain Variation (± dB, Max)	Noise Figure (dB, Max.)	VSWR IN/OUT	Power Out @ 1 dB Comp (dBm, Min.)	DC Power @ +15 V (mA, Nom.)
JS2-00100800-13-8P	.1 - 8	23	1.7	1.3*	2.3:1	8	175
JS4-00101000-21-10P	.1 - 10	31	1.6	2.1*	2.5:1	10	200
JS4-00101200-22-10P	.1 - 12	31	1.7	2.2*	2.5:1	10	200
JS4-00101500-23-10P	.1 - 15	30	1.8	2.3*	2.5:1	10	200
JS4-00101800-24-10P	.1 - 18	29	1.8	2.4*	2.5:1	10	200
JS4-00102000-25-10P	.1 - 20	29	2.0	2.5*	2.5:1	10	200
JS4-00102600-30-10P	.1 - 26	28	2.5	3*	2.5:1	10	200
JS4-00104000-54-5P	.1 - 40	30	3.0	5.4*	2.5:1	5	200
JS2-01000200-06-10P	1 - 2	34	1.2	0.65	2.0:1	10	225
JS2-02000400-05-10P	2 - 4	34	1.2	0.55	2.0:1	10	225
JS3-04000800-08-10P	4 - 8	35	1.2	0.8	2.0:1	10	195
JS3-04002000-19-8P	4 - 20	31	1.7	1.9	2.2:1	8	195
JS3-05001000-15-15P	5 - 10	28	1.3	1.5	2.0:1	15	200
JS4-06001800-15-10P	6 - 18	34	1.8	1.55	2.2:1	10	200
JS4-08001800-15-10P	8 - 18	34	1.6	1.55	2.0:1	10	200
JS3-12001800-14-5P	12 - 18	27	1.5	1.4	2.0:1	5	200
JS4-12002600-24-10P	12 - 26	33	2.5	2.4	2.3:1	10	200
JS3-18002200-15-10P	18 - 22	26	1.3	1.5	2.0:1	10	150
JS4-18002600-22-10P	18 - 26	35	1.5	2.2	2.0:1	10	200
JS3-18004000-40-15P	18 - 40	32	2.7	4	2.6:1	15	400**
JS4-18004000-30-5P	18 - 40	23	2.5	3	2.5:1	5	200
JS42-18004000-31-8P	18 - 40	35	3.5	3.1	2.5:1	8	300
JS1-26004000-100-19P	26 - 40	17	2.5	10	2.5:1	19	400**
JS4-26004000-30-8P	26 - 40	23	2.5	3	2.5:1	8	200
JS42-26004000-31-8P	26 - 40	37	3.5	3.1	2.5:1	8	300
JS2-01200140-04-10P	1.2 - 1.4	34	0.7	0.45	1.8:1	10	225
JS3-17901920-14-10P	17.9 - 19.2	27	1.0	1.4	2.0:1	10	150
JS3-19202020-14-10P	19.2 - 20.2	27	1.0	1.4	2.0:1	10	150
JS3-20202120-14-10P	20.2 - 21.2	27	1.0	1.4	2.0:1	10	150
JS3-21002200-14-10P	21 - 22	27	1.0	1.45	2.0:1	10	150

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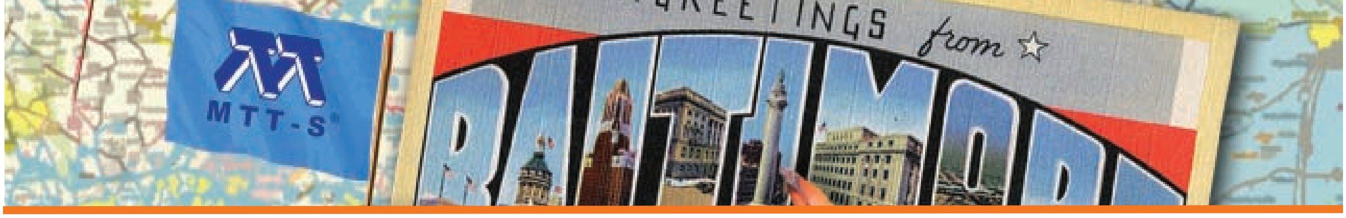

IMS 2011 General Chair's Message

The 2011 IEEE MTT-S International Microwave Symposium is in Baltimore this year with the venue being the Convention Center and hotels surrounding the beautiful Inner Harbor. The theme for IMS 2011 is *Microwaves for the World* with our emphasis on bringing together world experts who will be showcasing how our science, technology and profession have globally benefited mankind.

Since Baltimore last hosted the IMS in 1998, the Inner Harbor area revitalization has continued. The Convention Center is centrally located just a block from the Inner Harbor, assuring attendees of quick and easy pedestrian access to a multitude of restaurants, attractions and official IMS 2011 hotels.

In addition to Microwave Week's technical programs and exhibition, the main IMS events will be Monday evening's Plenary Session and Welcome Reception, Wednesday evening's Awards Banquet, and Thursday evening's Crab Feast. The Crab Feast is a unique feature of IMS when it comes to Baltimore and should not be missed; however, space is limited, so buy your tickets early.

Technical Programs

Microwave Week is June 5th through June 10th this year. In addition to the International Microwave Symposium (www.ims2011.org) you will be able to participate in the Radio Frequency Integrated Circuit Symposium (www.rfic2011.org) and the 77th Automatic Radio Frequency Techniques Group Conference (www.arftg.org).

IMS 2011 is honored to have Professor J. David Rhodes deliver this year's Monday evening IMS Plenary Address, *Migration of 4G LTE into Existing Cellular Networks*, at 5:30 PM June 6th in the fourth floor Ballroom of the Baltimore Convention Center.

The IMS 2011 Technical Program Committee, under the leadership of Ramesh Gupta, Technical Program Chair, has assembled an outstanding international program. This year's Microwave Week combined technical program consists of over 1000 technical presentations. IMS has many Special and Focus Sessions that highlight both the diversity and global reach of our profession. We have something for everyone, from emerging areas like RF Nanotechnologies to applied, life-saving, applications such as high-field-strength MRI. There are Workshops and Short Courses designed to educate and enlighten you in new areas of your profession. IMS is where it is at for continuing education as well as networking with colleagues from around the world. We also think you will be intrigued and fascinated by all of the student activities during Microwave Week. These future leaders of our profession and industry will be in Baltimore for Microwave Week.

Exhibition

The world's largest microwave industry exhibition is collocated

Jeffrey M. Pond
IMS 2011
General Chairman


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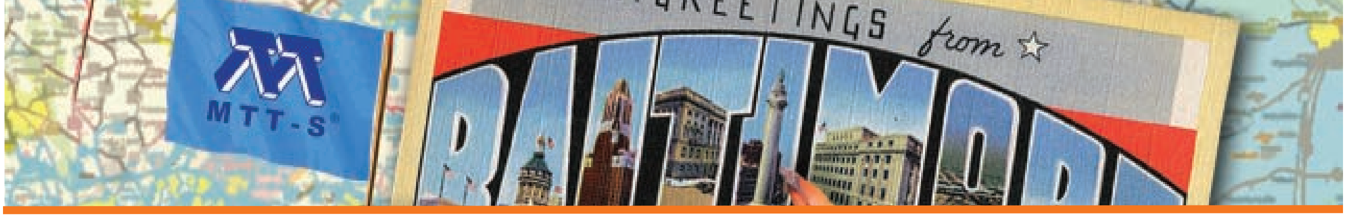


with IMS 2011. As I write this we are nearing 900 booths from nearly 550 exhibitors. Microwave Week is where you can quickly and easily connect with all the leading vendors of hardware, software and services within the microwave industry. In addition, we have an intriguing Historical Exhibit, which showcases both the evolution of our technology and its revolutionary impact on the world.

MicroApps continues to expand and improve with 56 different presentations on readily available state-of-the-art instrumentation, software and services. A new MicroApps feature for 2011 is a Panel Session on nonlinear measurements at noon on Wednesday. Please stop by the MicroApps Theater, prominently located on the exhibit floor, to learn from the experts.

Exhibition hours are Tuesday, June 7th 9:00 AM to 5:00 PM, Wednesday, June 8th 9:00 AM to 6:00 PM, and Thursday, June 9th 9:00 AM to 3:00 PM. On Wednesday, there will be the Industry Hosted Cocktail Reception on the exhibit floor starting at 5:15 PM.

VISITING BALTIMORE

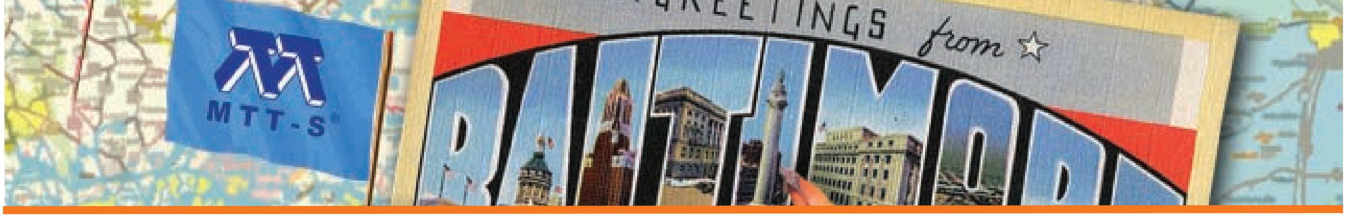
Baltimore-Washington International Airport (BWI) is the most convenient airport for accessing Baltimore. We suggest the Light Rail line, which for less than $2 will take you from BWI to the Convention Center and Hilton in about 20 minutes. Official IMS 2011 hotels are all within a short walk.

Baltimore in early June has an amiable climate and is a wonderful place to bring family and friends. We will have a family friendly hospitality suite in the Hilton and are putting together an innovative guest program featuring self-guided tours with packages of discount tickets, in addition to a few formal tours.

With Baltimore being centrally located on the east coast, you do not have to go far to find the culturally and historically rich cities of Washington, DC, Annapolis, MD, and Philadelphia, PA. Nearby are the beautiful sand beaches of the Mid-Atlantic oceanfront, the vistas and hiking trails of the Appalachian Mountains, the Chesapeake Bay for sailing, world-class golf courses, miles of equestrian trails, and many quaint villages with antique shops and bed-and-breakfast inns.

Now you know why our logo illustrates our slogan: *IMS 2011 in Baltimore: A Perfect Match*. So grab your camera, and with your family and friends, join us at IMS 2011 in Baltimore beginning June 5th to reinvigorate your career, your mind and your life. Heck, you might even bring your supervisor; it would probably do him good to focus on engineering again.

We encourage you to visit the IMS 2011 website (www.ims2011.org) to obtain further information and details that will help you enjoy your visit. On behalf of our Steering Committee, see you soon at IMS 2011! ■



RFIC 2011 General Chair's Message

Welcome to the 2011 IEEE Radio Frequency Integrated Circuits (RFIC) Symposium, which will take place in Baltimore, MD (www.RFIC2011.org), 5-7 June 2011. Our Symposium, held in conjunction with the IEEE MTT-S International Microwave Symposium, opens Microwave Week 2011, the largest worldwide RF/microwave meeting of the year.

The 2011 RFIC Symposium continues to build upon its heritage as one of the foremost IEEE technical conferences, increasing each year its impact and reputation of excellence. By bringing focus to the technical accomplishments in RF circuits, systems and devices, the RFIC Symposium has become essential to both the academic and the industrial communities. This year's exciting technical program will showcase the latest innovations in RF integrated circuit design with sessions that cover a broad spectrum of topics from cellular and wireless-connectivity system ICs, broadband wireless communications, digitally enhanced RF circuits, silicon millimeter-wave ICs, and RF device technology, modeling, and characterization. Applications highlighted by the technology include mobile phones, wireless communication systems, broadband access modems, radar systems and intelligent transport systems.

Running in conjunction with the International Microwave Symposium and Exhibition, RFIC Symposium adds to the excitement of Microwave Week with three days focused exclusively on RFIC technology and innovation.

The 2011 RFIC Symposium will start on Sunday with half-day and full-day workshops covering a wide array of topics. Some of the topics include: New Architectures for Digitized Receivers, RFIC for Bio-Medical Applications, Imaging at mm-Wave and Beyond, Cognitive Radios and Spectrum Sensing, Advancements in Linear Power Amplifiers, Efficiency Enhancement Techniques for Power Amplifiers and Transmitters, Advancements and Challenges Toward Radio-in-package and Radio-on-chip, Re-configurability Requirements for Multi-standard, Low-power Operation, and EMI compliant product design practices.

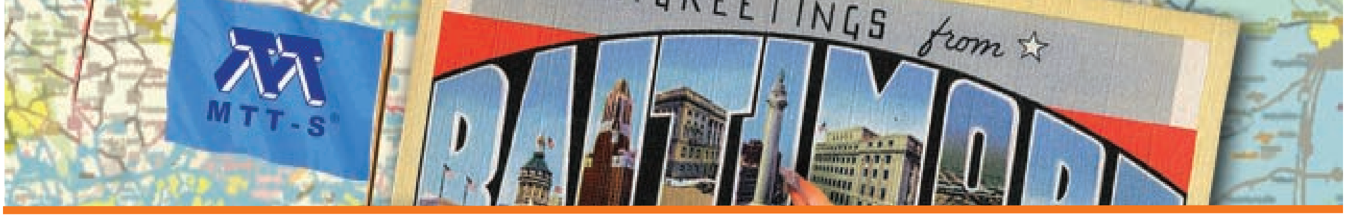
The conference also includes a Plenary Session, which is held on Sunday evening. Keynote addresses will be given by two renowned leaders from the wireless industry. Both of them will share their views and insights on the direction and challenges that the RF IC design community is facing. The first speaker is the Chief Technical Officer and Co-Founder of Telegent Systems, Dr. Samuel Sheng, who will discuss "RF Coexistence—Challenges and Opportunities." The second speaker is Ron Ruebusch, Vice President of R&D of Wireless Semiconductor Division of Avago Technologies. He will discuss "3G to 4G Transition—Challenges and Opportunities." In addition to the keynote addresses, the conference holds a student paper competition to encourage the publication of innovative research from university students. Consequently, best student paper awards are presented in the Plenary Session to acknowledge these contributions. The highly anticipated RFIC Reception will follow immediately after the Plenary Session, providing a relaxing time for all to mingle with old friends and catch up on the latest news.

On Monday and Tuesday, the conference will feature lunchtime panel sessions that traditionally draw strong debate between panel members as well as stimulating interaction between attendees and panelists. The Monday panel session is entitled "Software Defined Radios—Facts and Fantasies," while the Tuesday panel session is entitled "What is the limit of multi-radio integration… or rather, is it 'disintegration'?" Please be sure to attend these lively and entertaining forums.

Technical papers will be presented during oral sessions throughout Monday and Tuesday. There will be a total of 130 papers presented in 23 technical focused sessions. The technical program will conclude with the Interactive Forum session on Tuesday afternoon, which will feature 31 poster papers and the chance to speak directly with authors regarding their work.

On behalf of the RFIC Steering Committee, I look forward to seeing you at the 2011 RFIC Symposium in Baltimore. ■

David Ngo
RFIC 2011 General Chairman



77th ARFTG Microwave Measurement Conference

The 77th Automatic RF Techniques Group (ARFTG) Microwave Measurement Conference is being held at the Baltimore Hilton on Friday, June 10th, 2011. The conference will include technical presentations, an interactive forum and an exhibition; all to give you ample opportunity to interact with your colleagues in the RF and microwave measurement and test community. The conference theme is "Design and Measurement of Microwave Systems" with papers focusing on linear and nonlinear measurement systems, on-wafer methods and uncertainty analysis, and broadband and mm-wave techniques.

The conference will open with an invited talk on modular measurement systems by Jin Bains, R&D HW Director of RF Products at National Instruments. This talk will consider the increasing adoption of chassis-based instrumentation (PXI, LXI, and, to a certain extent USB) with an integrated software platform. While that structure is discussed most often in the sense of manufacturing applications, it may also apply to more flexibility-oriented R&D environments. The audience is intended to be those interested in an area of recent change/development in the RF/microwave measurement area.

One of the major progressions in RF/microwave test recently has been the ability to make fast, flexible and accurate measurements using SW-based modular test products. This is a trend that has gained momentum and is continuing to accelerate. It can be very difficult to solve the ever-changing needs of the wireless industry with traditional test products that are often expensive, fairly large and usually rigid. Advances in RF technologies and processes have enabled the development of smaller form-factor, lower cost modular products to match the performance and features of more traditional test products. Modular systems can take full advantage of multi-core processors and leverage the latest FPGA technologies to allow for the greatest measurement flexibility and timing control. The expandability of modular systems allows for synchronized, phase-coherent measurements on systems comprising multiple sources or receivers.

The Nonlinear Vector Network Analyzer (NVNA) Users' Forum, an informal discussion group devoted to sharing information and issues related to instrumentation utilized in vector large-signal analysis of microwave circuits and systems that contain nonlinear elements, will be meeting Thursday evening. Attendees of the conference are invited to attend.

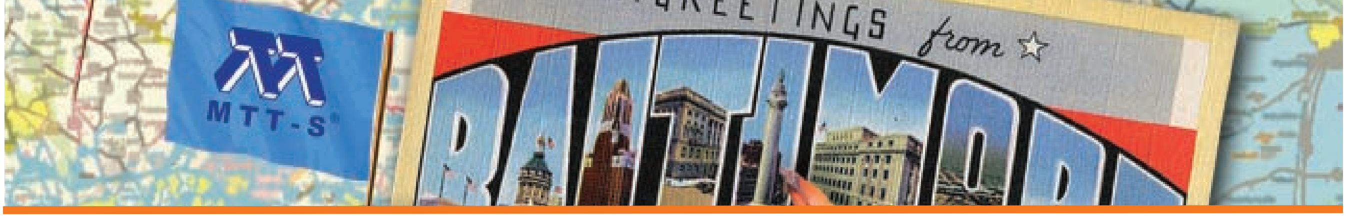
Also, be sure to check out the three joint ARFTG/IMS workshops: "WMC: Practical Compression, IMD, Load Pull and Behavioral Modeling Measurements"; "WMD: Laboratory Class: Wafer-level S-parameter Calibration Techniques"; and "WFC: The Design Flow of Microwave Power Amplifiers: Challenges and Future Trends."

An important part of all ARFTG conferences is the opportunity to interact with colleagues, experts and vendors in the RF and microwave test and measurement community. Starting with the continental breakfast in the exhibition area, continuing through the two interactive forum sessions, the exhibition and luncheon, there will be ample opportunity for discussion with others facing similar challenges.

Full details of the technical program are available at: www.arftg.org/conferences/arftg77/77th_ARFTG_Technical_Agenda.pdf.

ARFTG Conference registration is available through the IMS website at: www.ims2011.org. ■

Mohamed Sayed
ARFTG Conference Chair



IMS 2011 MicroApps: A Perfect Match

The Microwave Application & Product Seminars (MicroApps) portion of IMS 2011 is a series of brief technical presentations featuring new technologies and special capabilities of exhibiting organizations. The talks will be approximately 20 minutes in length and open to all conference and exhibit attendees without additional charge. MicroApps is distinct from the IEEE technical sessions, but complementary in its application-centric treatment of a variety of engineering topics of interest to the microwave community. The seminar series will be held in Booth #413 from June 7 to 9, starting at 9:30 AM on Tuesday and Wednesday and at 9:10 AM on Thursday. Attendees will receive a free CD-ROM collection of all three days of presentations.

The MicroApps program serves as a forum for exhibitors to describe state-of-the-art products and processes, including noteworthy components, emerging technologies, and novel techniques for manufacturing and design. Organizationally, presentations have been divided into seven topic categories:

- 3G/4G
- CAD
- Calibration, Testing and Measurements
- Manufacturing and Processes
- Materials and Components
- Semiconductors and Modeling
- Terahertz Devices

The 2011 program offers 55 presentations on recent hardware and software developments from roughly 25 organizations around the globe. Along with North America, Europe is particularly well represented this year. Multiple first-time presenters help substantiate that Baltimore is fulfilling the hope and promise expressed by "A Perfect Match" as theme.

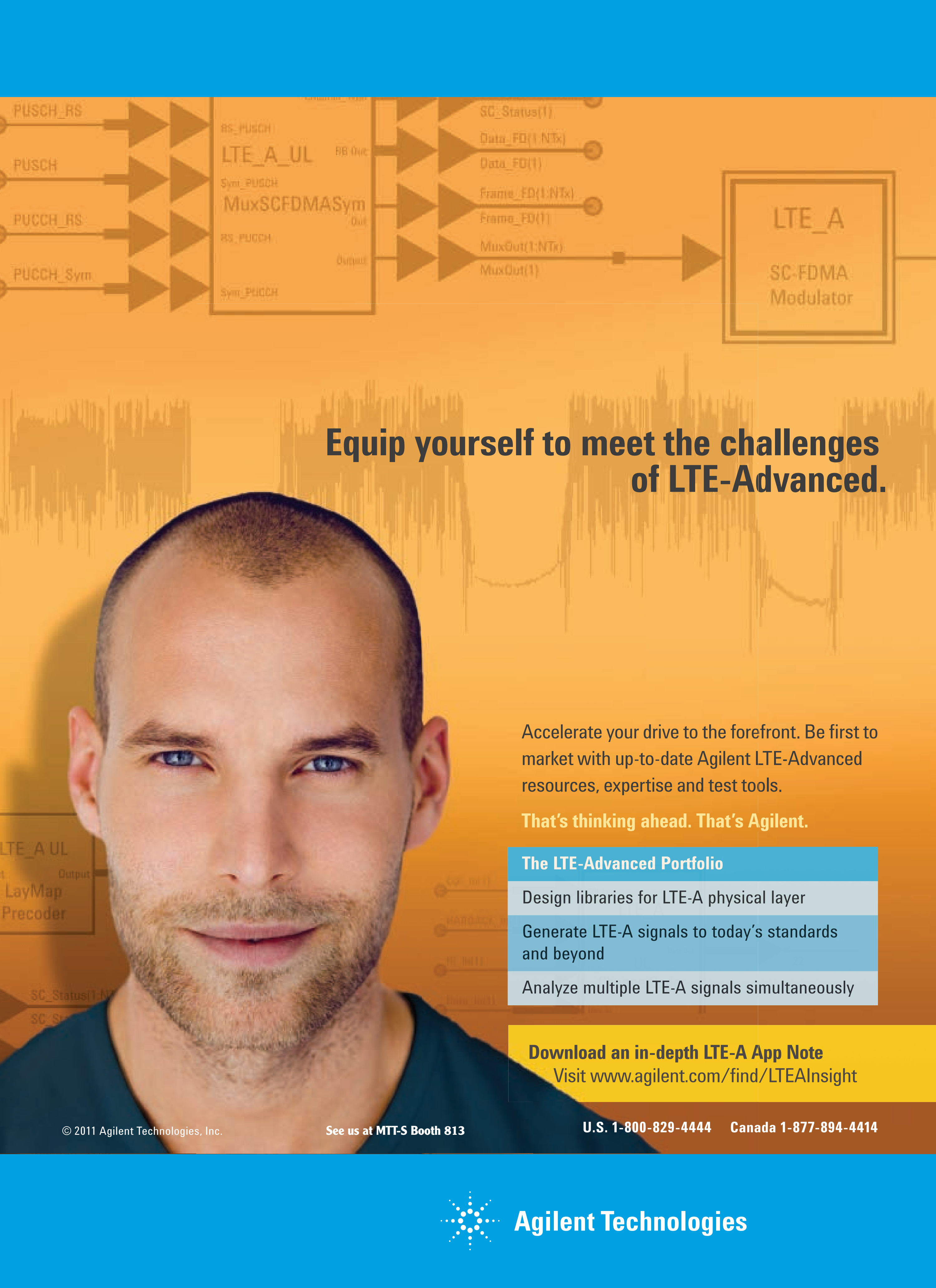
This year's highlights include an emerging technology panel session and a keynote presentation by industry leader John Ocampo, both on Wednesday.

- **Expert Panel – Nonlinear Characterization:** This panel discussion of nonlinear measurements will cover the latest advances in device characterization and simulation. The session will be held on Wednesday from 12:00 until 1:30 PM during the technical session lunch break. This session is organized by *Microwave Journal* and will be featured in a simultaneous webcast for audiences not attending IMS. Both live and web-based audiences will be able to participate in the Q&A following the invited speaker presentations. The event will also be video recorded by IEEE.TV. The session will be available for viewing on both the MWJ and IEEE.TV websites. This event is sponsored by the leaders in RF/microwave nonlinear test equipment—Agilent, Anritsu, Rohde & Schwarz/NMDG and Tektronix/Mesuro.
- **Industry Keynote Address – "What Makes Successful Mergers?":** This year's keynote speaker will be John Ocampo, Chairman of the Board of M/A-COM Technology Solutions. The talk begins on Wednesday at 5:00 PM during the "open exhibition" reception hour. The session will be videotaped by IEEE.TV and available on the IEEE.TV website for future viewing.

Agilent Technologies is this year's MicroApps sponsor, and the presentation CD will be available for free, thanks to the sponsorship of AWR. MicroApps will be conveniently located in the midst of the exhibits at Booth #413. The complete and up-to-date MicroApps session schedule can be found in the IMS 2011 program book or online.

Join us for MicroApps at Booth #413. We look forward to seeing you there! ■

Rafi Hershtig and Tim Dolan
2011 MicroApps Co-Chairmen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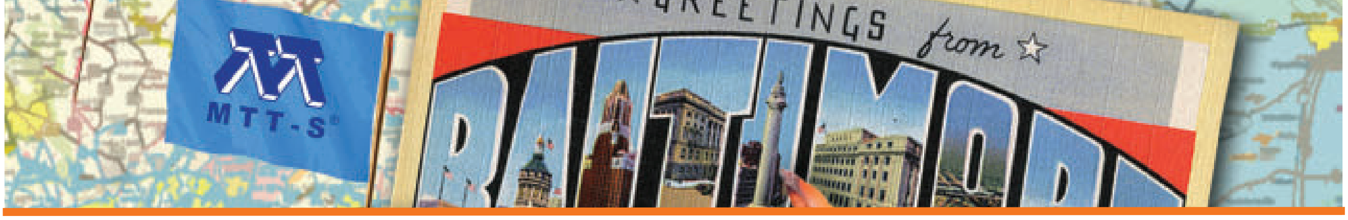
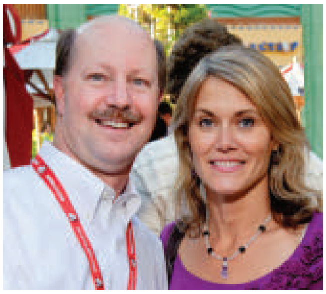


Women in Microwaves (WIM) Reception



IMS 2011 will mark my second year organizing the WIM Reception, and the second time I actually attend this event. Now, I have been going to IMS since the mid-1990s, but I had not heard of this event prior to last year. Why is that? Well, for starters the "technical" side of the show and the "exhibition" side are like magnets with the same polarization. They repel each other. Perhaps I am exaggerating a little with this analogy, but there seems to be some truth in the statement. The technical/committee side of IMS organizes the conference, and many believe the focus should largely be on the conference attendees and not the many thousands of exhibitors who also attend IMS. Let's take a closer look.

Given that I hold a BSEE degree from Carnegie Mellon University—one of only eight women who graduated in a class of 150 in 1988—why would I not have been previously invited to attend the "women in microwave engineering" or WIM Reception? Why had I not heard of it? Certainly, since such a small percentage of engineers in the RF and microwave realm are women to begin with, it appears even more difficult to get the word out about this reception.

After learning about this event, I quickly spoke up and got to work making sure more and more women, regardless of their IMS registration, became aware of the WIM Reception. I knew we had to be aggressive with our outreach in order to increase awareness of our group and to fully promote the many benefits and opportunities that the RF and microwave industry offers women.

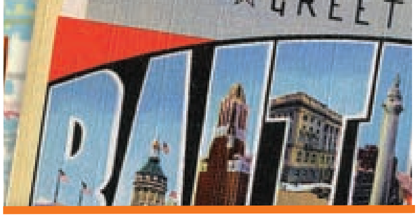
Last year, I am happy to share, we had women from all facets of IMS, regardless of their registration status, attend the event:

- Technologists like Kiki Ikossi of DTRA and Amanda Hereida of Aethercomm
- Exhibitors like Jeannette Wilson of Freescale and Katherine Van Diepen of Anritsu
- Editors like Kate Remley from *IEEE Microwave* and Christina Nickolas of *Electronic Products*
- Educators like Zoya Popovic of UC Boulder and Rashaunda Henderson of UT Dallas
- And *Microwave Journal*'s staff of women too: Jenn DiMarco, newly promoted Managing Editor of *Microwave Journal* and Kristen Anderson, Marketing and Event Coordinator for *Microwave Journal*

Overall, we had more than 75 people (men and women) attend the WIM Reception during IMS 2010, which was more than double the year prior participation. For WIM 2011, I hope to exceed last year's attendance and surpass 100 as there are easily a few hundred women who attend some aspect of IMS.

With such a small percentage of women pursuing engineering even today, we have to find novel

Sherry Hess
WIM Organizer



ways to stay connected to the ones who have already chosen "RF and microwave" as their path, and work together to uncover ways to bring even more females into this domain of engineering.

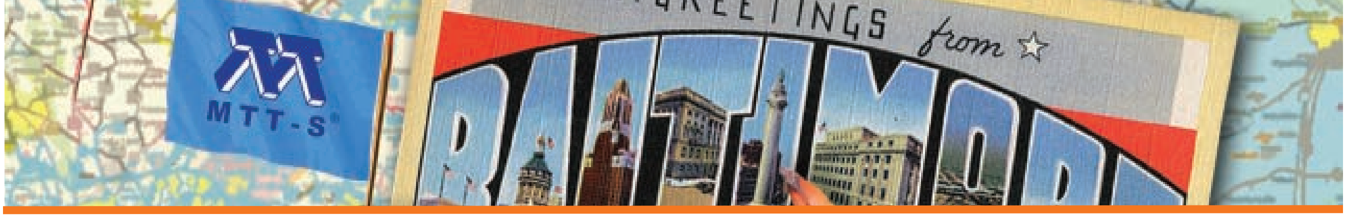
It is definitely a struggle to make engineering appear more inspiring for either gender, whether male or female, but it cannot hurt for all of us—as engineers—to stretch a little bit outside of our comfort zone and talk about our profession. Our field of RF and microwave literally brought us the wireless revolution. I mean the 24/7 access to everything, anywhere and in any way.

Naturally, with so much content and information out there fighting for our attention, we have to raise our collective voice and cut through the information clutter with our message about how great the RF and microwave engineering discipline is. As a simple tip, the next time someone asks, "How does my smartphone know which way I'm holding it and self-adjust?" Maybe we should answer it with an "oh, if you were an engineer, you would know." Or when someone says, "What did we do before GPS?," maybe we should answer, "we spent hours driving around, wasting gas, lost in the car; but now thanks to engineers, we always know exactly where we are."

Remember this and spread the word:

- WIM (Women in Microwave Engineering) Reception - IMS 2011
- Tuesday evening, June 7, 2011, 6-8 PM
- Hilton Lobby Bar, Hilton Convention Center Hotel, Baltimore, MD

Reserve your spot at the reception, e-mail RSVP to wim@ims2011.org or for all of you out there using a GPS on your smartphone, enter 401 W Pratt Street, Baltimore, MD 21201 then touch "go." And remember to say "thanks" to our collective group of engineers who made it possible to do so in the first place! ■



Opportunities and Challenges: RF Industry in 2011

Based on the indicators we have been watching, the RF industry seems to have completed another economic cycle. When the cycle hit bottom in Spring 2009, no one would have dared to predict a rapid recovery that equaled or exceeded 2008 business levels.

Today, the industry faces new questions about additional capacity expansion and the impact of Long Term Evolution (LTE). It is also battling challenges with defense budgets in mature economies. Against that backdrop, let us examine a few important industry drivers and see if we can detect patterns and opportunities:

Wireless: Wireless communications in all forms is now being driven by "edge of the network" opportunities. These include the increasing penetration of mobile communications around the world, especially in emerging economies and in applications that rely on wireless networks coupled to sensor networks to measure the real world. The number of edge-of-the-network devices of all types is increasing at a geometric rate and will soon exceed 10 billion devices.

Aerospace/Defense: This is a tale of two worlds, one emerging and one maturing. Emerging economies are rapidly growing their defense spending while mature economies are struggling to maintain their existing force, components and infrastructure. Even with these differences, both worlds share a common theme: achieve lower costs across the board.

Research: With government budgets under pressure, research funding will become a target of cuts. Overall growth in research spending is centered on life sciences, food safety and medical applications. One consequence: Spending on electronics research is increasingly focused on supporting these initiatives.

The Cloud: While "the cloud" seems to be drifting through the hype phase, this infrastructure approach has the potential to deliver many useful benefits. The path from here to there contains both opportunities and challenges. The key challenges include security and availability, both of which will require large cycles of investment and deployment.

Going Green: This multi-decade trend will transform energy supply and demand. However, the same issues that apply to the trends above also apply here—lower costs, security—and those challenges are compounded by the need to control the grid remotely.

Looking at these trends through the lens of test and measurement (T&M), five conclusions come into focus:

Edge devices become smarter and cheaper. Increasingly, edge-of-the-network devices are a blend of electronics and a real-world sensor (e.g., gas detection, separations, pressure, etc.). The electronics are in service to the sensor and network as well as the analysis that turns data into insight. Electronics must be low-cost, reliable and generally invisible. RF design, characterization, test and maintenance of these solutions must be appropriate to the role electronics plays.

It is all about cost of test. Whether in high-volume wireless manufacturing or in high-mix/low-volume applications, total cost of test will be the key driver. That cost includes much more than in-

Greg Peters
Agilent Technologies Inc.
Santa Clara, CA

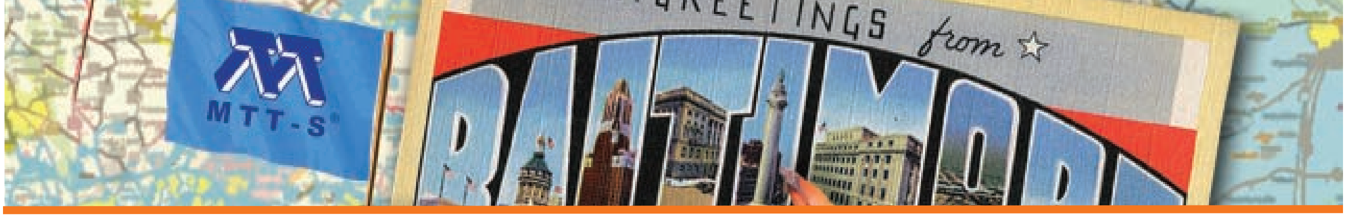
strumentation: the costs of fixturing, software, service cycles and repair must all be added to the total cost envelope.

"Multi-discipline" is the key concept. Today's leading researchers are applying electronics to solve a wider variety of problems than ever before—and all facets of electronics will be used. As with edge-of-the-network devices, researchers are experts in their own domain and use electronics as a means to an end. Software, bench tools and measurement accessories must be designed to enable the researcher to modify the equipment to their specialized purposes. RF/MW plays a key role here in both communications/control as well as stimulus/response in certain applications.

The Cloud = Performance. Here is where the electronics industry really shines. Continuing contributions from semiconductors, channel designs—copper, optical or wireless—between subsystems and software will improve the performance, reliability and security of the core of the Internet. High speed digital is all about excellent microwave design at the physical level. Understanding surface roughness of copper traces is an excellent example of this trend.

Green = Green, as in money. The electronic industry is again at the core of the green revolution and will play a major role in reducing costs and improving performance. Smart meters are just the start of this revolution and RF again plays a key role in enabling distributed energy generation, utilization and management.

Is this a bright and rosy future? No—growth in any of these areas can be dampened by uncertainty in the global economy—and the certainty of more shocks and future downturns. Even so, today's trends offer significant opportunities for T&M vendors to add value to a wide variety of companies around the world. For our industry, the key to success is not just watching or pursuing these trends but harnessing them to our advantage. ■



Microwave Technology at the NRL

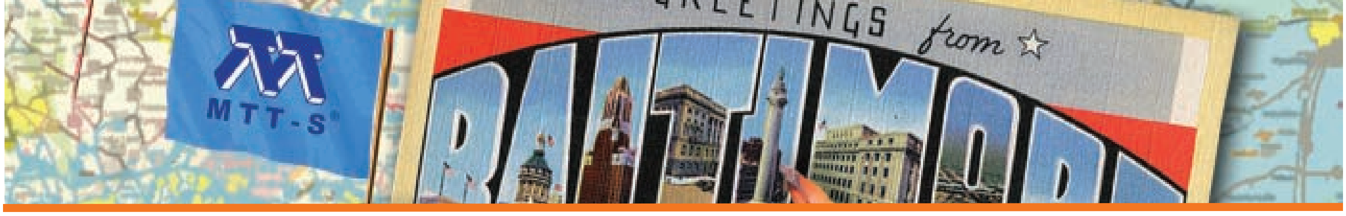
The Naval Research Laboratory (NRL) has a long and distinguished history of making important contributions to the development of microwave technology. The inspiration for NRL originally came from Thomas Edison, who, in 1915, stated, "The Government should maintain a great research laboratory… in this could be developed… all the technique of military and naval progression without any vast expense." War delayed construction of NRL until 1920; it was completed in 1923. Although NRL has long maintained extensive research programs in all areas of the physical sciences, its significant contributions in the microwave area began almost immediately with the development of radar. First came the ability to determine range and bearing of ships in 1922 and aircraft in 1930. Subsequent important radar inventions included the duplexer, the plan positions indicator and the monopulse receiver.

Other NRL microwave-related contributions include the TIMATION satellites (the subject of a talk at Tuesday's IMS 2011 session "Historical Perspectives on Microwave Development in the Baltimore-Washington Area") and atomic clocks that led to our current GPS satellites, as well as numerous communications, electronic warfare and radar systems.

While the above examples highlight the system level R&D that NRL is well known for, basic materials research has also played a significant role. For example, at NRL in the 1970s, a focused effort resulted in a method of growing high-purity single crystals of semi-insulating gallium arsenide, the basis for the revolution in microwave semiconductor devices that followed. NRL began making GaN microwave transistors back in the early to mid 1990s and has continued its own in-house R&D program while also being at the forefront in helping to establish the reliability of this technology by working closely with industry. High-power, high-frequency vacuum electronics has been greatly advanced by NRL developments including: rare-earth-iron-boron permanent magnet materials, the Controlled Porosity Dispenser cathode, and gyro-based devices that culminated in 1999's WARLOC 10 kW average power 94 GHz gyro-klystron.

While NRL has made and continues to make important contributions to the development of microwave materials, devices, components and systems, it is extremely difficult to look ahead and predict which of the many on-going programs may be looked back upon in the future with the same game changing recognition. One of my colleagues keeps Albert Einstein's quote "If we knew what we were doing, it wouldn't be called research, would it?" prominently at his desk. And while many of us can extrapolate today's technology to faster, higher frequency, lower power consumption, etc., I think that quote does summarize the difficulty of predicting breakthroughs. Nevertheless, there is a lot of ongoing microwave materials and device research at NRL that is likely to result in next generation capabilities. In particular, new atomic layer deposition techniques, in conjunction with both wide band-gap and narrow band-gap materials, will lead to complementary circuit capabilities in both of these semiconductor

Jeffrey M. Pond
Naval Research Laboratory and IMS General Chair, Washington, DC



systems. This will push the digital realm much closer to the antenna at higher frequencies on both the transmitter and receiver side. For the narrow band-gap semiconductors one of the big challenges in realizing complementary circuitry will be to raise the hole mobility.

The last few years have seen tremendous interest and investment in carbon-based electronics in the form of both carbon nanotubes as well as graphene. While the electronic properties of these materials are intriguing for microwave applications, there is still much research to be done before conventional semiconductor materials are likely, if ever, to be replaced. Not only do these materials have unique electronic properties, they possess mechanical properties that may prove very useful in future microwave devices and components. This could involve everything from packaging to acoustic wave resonators for high-Q micro-miniature filters. At NRL we have several programs that are developing the electronic and mechanical properties of carbon-based materials for microwave applications.

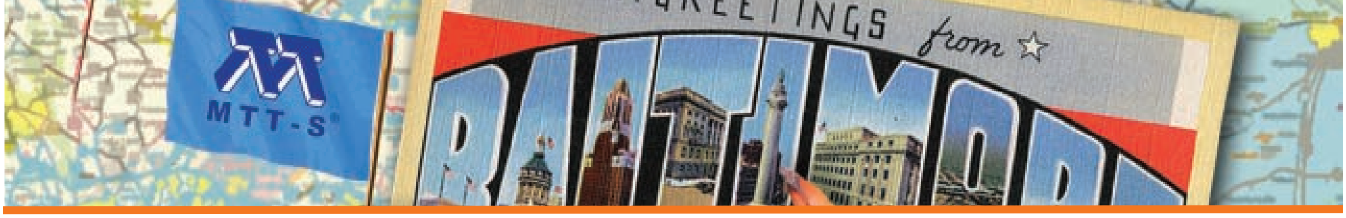
Another area where NRL has been advancing microwave component technology has been in the area of tunable and reconfigurable filters. While the world in general is beginning to understand how crowded the spectrum is becoming, the Navy has been facing this problem much longer since almost all Navy platforms, ship or airplane, are very compact structures considering all of the equipment they carry that involves transmitting and receiving. Co-site interference is a problem the Navy has been dealing with for a long time and has led to a push to develop new filter architectures that address these concerns. These technologies are likely to be recognized, appreciated and adopted by the commercial providers as these spectrum issues become prevalent in their domain.

NRL is the government center of excellence in vacuum electronics and continues to lead in developing the design tools that enable higher frequency and higher power vacuum electronics oscillators and amplifiers for millimeter-wave frequencies. NRL CAD software is commonly used by industry to design current and next generation vacuum electronics. In addition, NRL has R&D efforts in multiple and sheet beam technologies and advanced cathodes that should result in much greater powers and frequencies in the next few years.

Of course there continue to be active programs in next generation radar, electronic warfare, and communications systems within NRL's Radar, Tactical Electronic Warfare, and Information Technology Divisions, as well as NRL's Naval Center for Space Technology. While the details of such programs usually do not become known until decades later, the same level of talent, ingenuity and perseverance that led to NRL's earliest contributions in radar are hard at work to ensure that the Navy and the country are well served and protected in the future.

Irrespective of which of these R&D efforts bears the greatest return, or if it is one I have not mentioned, NRL will remain a center of microwave R&D. NRL has a special R&D environment where engineers, materials scientists and physicists all work closely together to address the materials, device, component and system challenges that confront Naval radar, communications and electronic warfare systems. ■

To learn how microwave and millimeter-wave systems are being used in material processing at the Naval Research Laboratory, go to www.mwjournal.com/nrl_materials_2011—an MWJ online exclusive by A. Fliflet and M.A. Imam, NRL.



Twitter Together at MTT-S IMS

With all the hype about social media, there is still only a limited microwave audience on Twitter, LinkedIn and Facebook. Let's change that this year and expand the small but growing group of Twitter users involved in the MTT-S IMS show.

At last year's symposium, a handful of companies shared their experiences Twittering about their latest product releases, news, social events and happenings on the show floor. Some of the companies that can be found on Twitter include Agilent, Anritsu, AWR, R&S, Reactel, Skyworks, EM Research, Z-Communications, RFMD, Freescale, Resnet Microwave, ADI, Phase Matrix, TriQuint, CST, Tektronix and NXP. Last year, a search feed displayed all Symposium related Tweets on our Online Show Daily website (the official IMS Cyber Café homepage), and IMS attendees could follow these companies from our website or on their mobile phones. We will be doing the same thing this year.

Try using Twitter to note interesting sessions, new products, social events, good giveaways, interesting demos on the show floor, good restaurants and bars. If everyone does a couple of Tweets a day about their favorite (or not so favorite) things that they find around town, everyone will know where the good restaurants and watering holes are located. It will also allow everyone to know in real time the exciting activities that are going on at the show or after hours. There has been some Twittering about the show already so keep the pre-show, during the show and post-show Tweets going.

Taking Twitter a step further and finding your friends and others locally, try Foursquare. This app allows you to "check in" at various locations so your group of friends knows exactly where you are and can meet up with you if they are in the area.

The next big thing could be group messaging. There are many new apps being produced that solve the problem of having private conversations with a small group of friends. While many people use SMS, it is very difficult to message more than one person at a time, making group discussions almost impossible. Using group messaging, the timeline of discussions is visible to only those in the discussion. If someone is added, they immediately receive the discussion string. While e-mail can be used, it is not as immediate and threading not as clean.

Some new apps that address this issue are Beluga, Yobongo, GroupMe, Fast Society and Disco, which was bought by Google. These apps avoid text messaging fees for the most part as the string is only considered a single message and not individual messages from each person.

The social media market is fast moving and there are new apps releasing all the time, so it is difficult to keep up with everything that is going on. Just try some of the different apps from time to time and see how they work for you and your friends. Talk about them and share experiences – you will learn quickly which ones work for you.

Join in the real time social media scene by using the Hashtag **#IMS2011** in your Tweets so everyone can follow the action [# indicates the word is a Hashtag (developed by Hashtags.org) and allows people to follow that keyword easily].

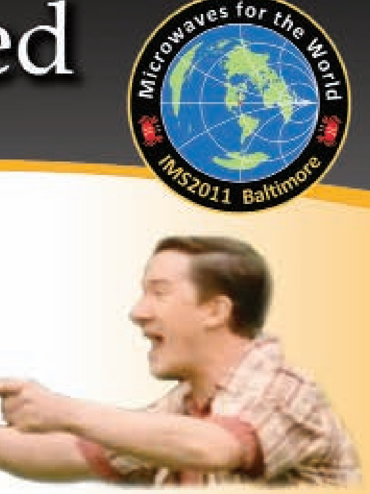
Visit the *Microwave Journal* website for the Twitter feed on the MTT-S IMS show page at www.mwjournal.com/IMS2011 and trace the MWJ staff on Twitter by following David Vye @mwjournal, Pat Hindle @pathindle and Kristen Anderson @KAatMWJ. ■

Pat Hindle and Kristen Anderson
MWJ Staff

A PROUD MARYLAND BUSINESS FOR OVER 30 YEARS

Reactel, Incorporated

Microwaves for the World
IMS2011 Baltimore



Crab Cakes & ~~Football~~ FILTERS
That's what Maryland does!

Learn more at www.reactel.com/mtts2011

It is no secret that Maryland is best known for their Crab Cakes.

Reactel would like to celebrate the IMS MTT-S Show's presence in Baltimore, Maryland by offering a fabulous Crab Cake giveaway.

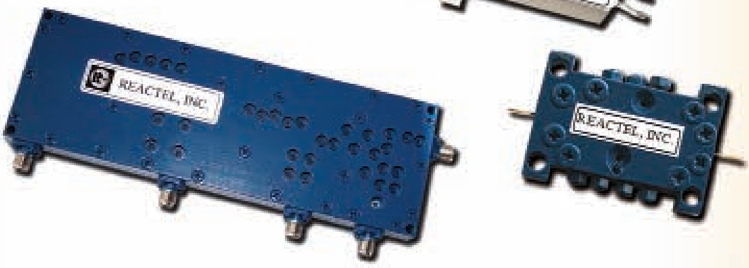
Please stop by Booth #3915 to enter for your chance to win a
Celebrate Crab Cakes and Filters Gift Package
featuring gigantic Crab Cakes from the famous
G & M Restaurant in Linthicum, Maryland.

G & M has been voted best Crab Cake in Baltimore 5 times.

A less well known secret is that Maryland is home to nearly a dozen RF & Microwave Filter Manufacturers.

Reactel is a proud Maryland company offering RF & Microwave Filters, Multiplexers and Multifunction Assemblies for Military, Space, Commercial and Industrial applications.

While at our booth, we also invite you to visit with our Engineers to discuss your requirements, see some of our latest offerings and pick up a copy of our newest catalog.

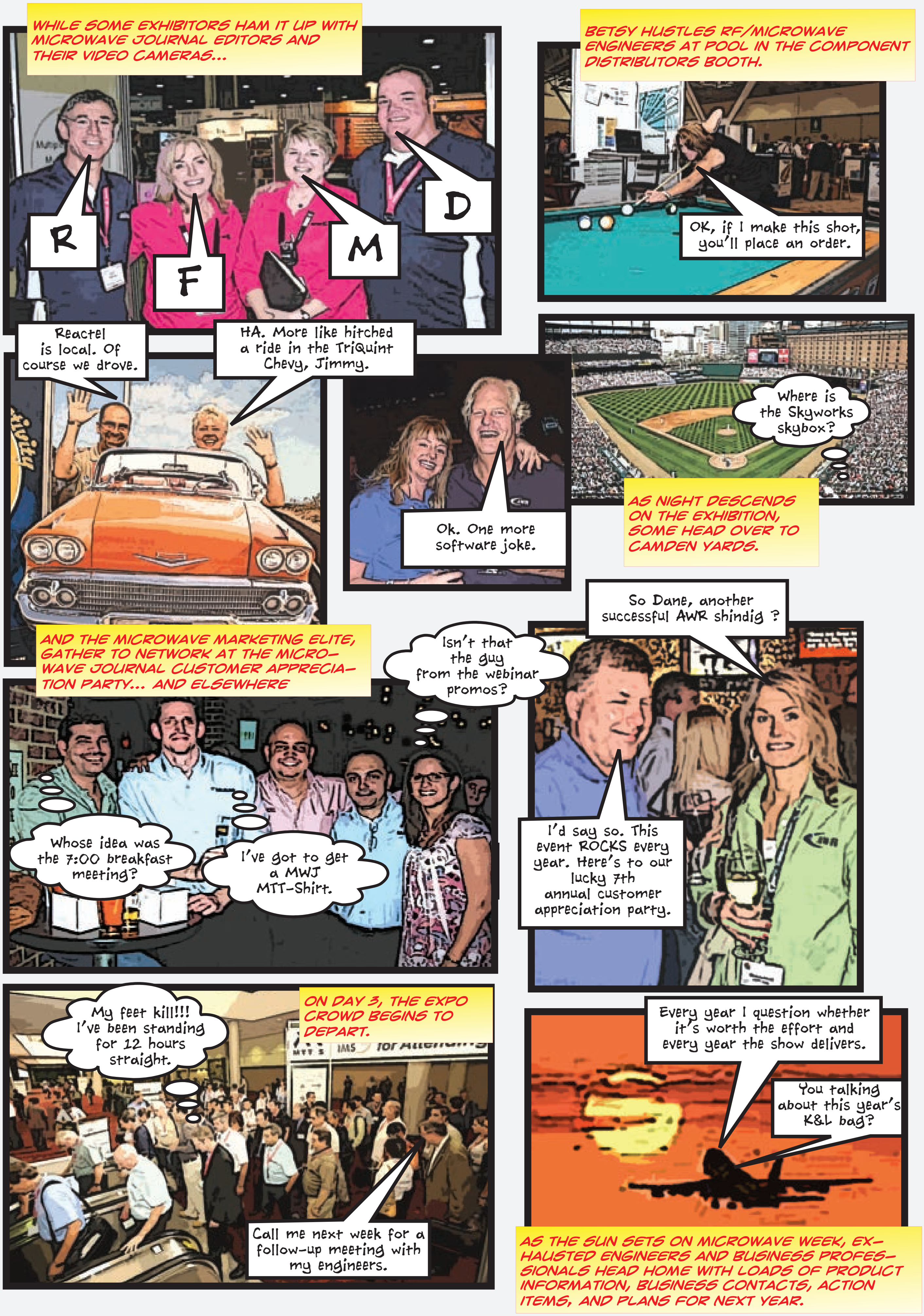


8031 Cessna Avenue • Gaithersburg, Maryland 20879 • Phone: (301) 519-3660 • Fax: (301) 519-2447
For general inquiries, please email reactel@reactel.com • http://twitter.com/reacteljim
Go online to www.reactel.com to download your Reactel catalog today.

See us at MTT-S Booth 3915

FROM ACROSS THE GLOBE, MICROWAVE PROFESSIONALS BOARD PLANES BOUND FOR IMS 2011. ONE DESTINATION, COUNTLESS AGENDAS.
How do I know that guy in 18c?
I heard you guys are launching a new product family.
Yeah, stop by our booth and I'll give you a demo.
How did I get a middle seat?
BALTIMORE AT LAST, "CHARM CITY", HOME OF THE ORIOLES, THE RAVENS AND MICROWAVE WEEK 2011.
GENERAL CHAIR, JEFF POND ADDRESSES IMS ATTENDEES AT THE PLENARY SESSION WITH OPENING REMARKS AND AN INTRODUCTION OF KEYNOTE SPEAKER, PROFESSOR J. DAVID RHODES.
Jeff Pond
General Chair
Professor Rhodes founded Filtronic over 30 years ago and grew it into an international microwave company. Today, he will speak about the migration of W-CDMA and 4G LTE into existing cellular bands.
Baltimore Convention Center
MTT-STORIES
Front row, center. Sweet!!
Hmmmm. Special memorials for Saad and Sudbury on Wednesday.
AS MICROWAVE WEEK PROGRESSES, IMS, RFIC AND ARFTG ATTENDEES GET DOWN TO BUSINESS AT THE TECHNICAL, PANEL AND RUMP SESSIONS AS WELL AS THE WORKSHOPS.
MEANWHILE, ATTENDEES DIRECTLY ENGAGE AUTHORS AT THE POSTER SESSIONS.
Why am I thinking about Crab Cakes?
Welcome to this technical session on Compact Reconfigurable and Tunable Filters.
I could introduce you to my professor at the student reception.
STUDENT WORK IS HIGHLIGHTED IN BOTH THE STUDENT PAPER COMPETITION AND DESIGN COMPETITION.

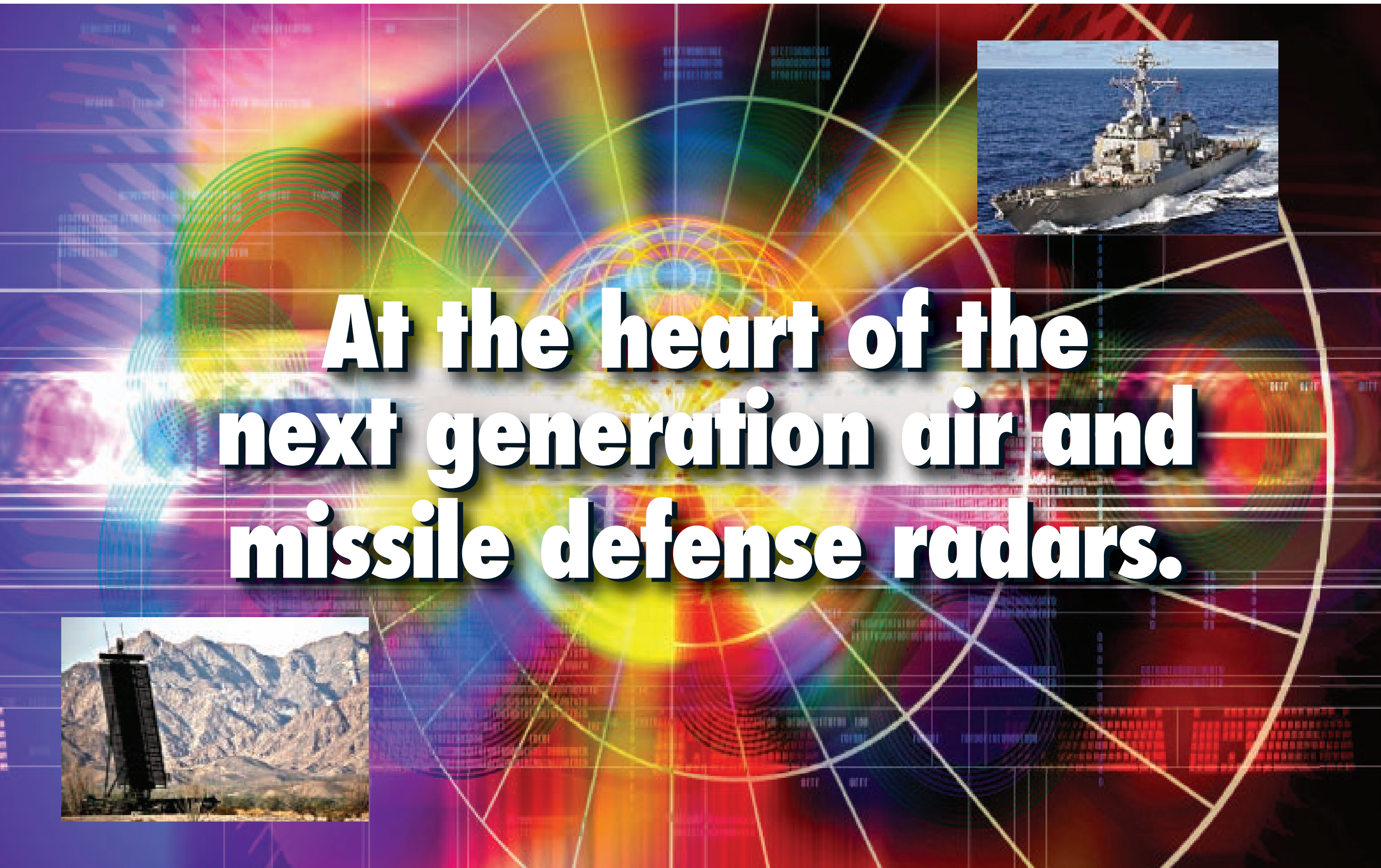

ON TUESDAY MORNING, THE MICROWAVE EXHIBITION STARTS. TO PARAPHRASE CALVIN COOLIDGE, "THE BUSINESS OF MICROWAVES IS ... BUSINESS"
IEEE
Exhibits
MTT S
Where's that cyber café?
THE EXHIBITION FLOOR BUSTLES WITH ACTIVITY AS OVER 500 EXHIBITING COMPANIES SHOW OFF THEIR LATEST PRODUCTS.
IMS2010
MICROAPPS
Are you going to the MicroApps panel on non-linear characterization organized by Microwave Journal?
Damn straight. They've got the leading measurement gurus from Agilent, Anritsu, Rohde & Schwarz, and Tektronix speaking.
So far, similar traffic as last year, but we've got a better location.
Actually, I do speak Japanese: "Sonnet kara no go aisatsu."
AGILENT TEAMS UP WITH AURIGA, CASCADE, ELECTRO-RENT, ETS-LINDGREN, EMS-CAN, IN-PHASE TECH, MAURY, MODELITHICS, NSI, T-TECH, WIN AND JAZZ SEMI AT AGILENT AVENUE, BOOTH 813.
I should be tweeting about this.
SOME OF THE MOST IMPORTANT NETWORKING OPPORTUNITIES AND BUSINESS DECISIONS HAPPEN IN THE MOST UNLIKELY PLACES...



WHILE SOME EXHIBITORS HAM IT UP WITH MICROWAVE JOURNAL EDITORS AND THEIR VIDEO CAMERAS...
R
F
M
D
BETSY HUSTLES RF/MICROWAVE ENGINEERS AT POOL IN THE COMPONENT DISTRIBUTORS BOOTH.
OK, if I make this shot, you'll place an order.
Reactel is local. Of course we drove.
HA. More like hitched a ride in the TriQuint Chevy, Jimmy.
Ok. One more software joke.
Where is the Skyworks skybox?
AS NIGHT DESCENDS ON THE EXHIBITION, SOME HEAD OVER TO CAMDEN YARDS.
AND THE MICROWAVE MARKETING ELITE, GATHER TO NETWORK AT THE MICRO-WAVE JOURNAL CUSTOMER APPRECIA-TION PARTY... AND ELSEWHERE
Isn't that the guy from the webinar promos?
Whose idea was the 7:00 breakfast meeting?
I've got to get a MWJ MTT-Shirt.
So Dane, another successful AWR shindig ?
I'd say so. This event ROCKS every year. Here's to our lucky 7th annual customer appreciation party.
ON DAY 3, THE EXPO CROWD BEGINS TO DEPART.
My feet kill!!!! I've been standing for 12 hours straight.
Call me next week for a follow-up meeting with my engineers.
Every year I question whether it's worth the effort and every year the show delivers.
You talking about this year's K&L bag?
AS THE SUN SETS ON MICROWAVE WEEK, EX-HAUSTED ENGINEERS AND BUSINESS PROFES-SIONALS HEAD HOME WITH LOADS OF PRODUCT INFORMATION, BUSINESS CONTACTS, ACTION ITEMS, AND PLANS FOR NEXT YEAR.

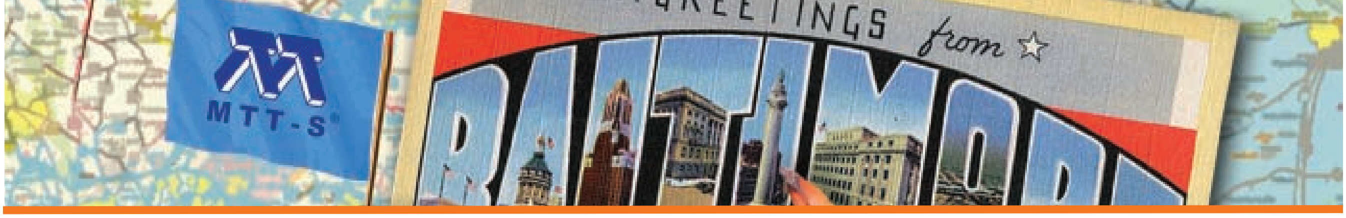
BE FEATURED IN OUR 2011 IMS-WRAP UP
1. CAPTURE THOSE SPECIAL IMS 2011 MOMENTS WITH YOUR CAMERA OR PHONE
IMS 2011
CLICK
CLICK
2. "LIKE" MICROWAVE JOURNAL'S FACEBOOK PAGE @ FACEBOOK.COM/MICROWAVEJOURNAL
3. POST YOUR PICTURES TO OUR WALL (WITH OR WITHOUT CAPTIONS)
4. VISIT AND COMMENT ON THIS YEAR'S CROP OF IMAGES. HELP OUR EDITORS SELECT SCENES FOR OUR IMS 2011 WRAP-UP
Like
Microwave Journal
Frequency Matters.
COMING IN OUR AUGUST ISSUE
Follow us at: http://www.facebook.com/MicrowaveJournal


IEEE
IMS2011 Baltimore
MTT-S
Microwaves for the World
IMS 2011 Baltimore
Conference Hotel Locations
1 Baltimore's Marriott Inner Harbor at Camden Yards
2 Baltimore's Tremont Plaza Hotel
3 Wyndham Baltimore Peabody Court Hotel
4 Courtyard by Marriott Inner Harbor East
5 Days Inn Inner Harbor Hotel
6 Hilton Baltimore - Conv. Center – Co-Headquarters
7 Holiday Inn Inner Harbor
8 Hyatt Regency Baltimore – Co-Headquarters
9 Radisson Plaza Lord Baltimore Hotel
10 Renaissance Baltimore Harborplace Hotel
11 Sheraton Baltimore City Center Hotel
12 Sheraton Inner Harbor Hotel
<< W. Madison St.
W. Centre St. >>
<< W. Franklin St.
W. Mulberry St. >>
<< W. Saratoga St.
<< W. Fayette St.
W. Baltimore St. >>
<< W. Lombard St.
W. Pratt St. >>
Camden St.
Conway St.
<< Lee St.
Key Highway
W. Montgromery St. >>
Henrietta St.
MLK Jr. Blvd.
Eastern Ave.
Fleet St.
Aliceanna St.
Thames St.
<< Green St.
Paca St. >>
S. Eutaw St.
Howard St. >>
<< Hopkins Place
Park Avenue >>
<< Cathedral St.
<< Liberty St.
S. Charles St. >>
<< Light St.
<< St. Paul St.
Calvert St. >>
Sharp St.
Hanover St.
President St.
Caroline
Oriole Park at Camden Yards
395
Inner Harbor
National Aquarium
Science Center
Federal Hill Park
N
map not to scale


At the heart of the next generation air and missile defense radars.

Map of Baltimore area provided courtesy of CTT, Inc. Stop by CTT's Booth 2302

USA-based thin-film microwave production facility



2011 IMS Exhibitors

The following list is complete as of April 8, 2011. Exhibitors in bold have an ad in this issue.

2COMU 1929
3G Metalworx Inc. 4012
A-Alpha Waveguide Co. 2510
A.J. Tuck Co. 424
A.T. Wall Co. 429
Accumet Engineering Corp. 337
Acewavetech Co. Ltd. 4405
Actipass Co. Ltd. 1038
Active Spectrum Inc. 347
Advanced Mobile Tecnology 4707
AdTech Ceramics 3713
Advance Reproductions Corp. 4410
Advanced Test Equipment Rentals 3802
AEM Inc. 4907
Aeroflex Inc. 2212
Aethercomm Inc. 3304
Agilent Technologies 813
AI Technology Inc. 538
AKON Inc. 307
Aldetec Inc. 425
Aliner Industries Inc. 4412
Allwin Technology Inc. 645
AMCAD Engineering 714
Amcom Communications Inc. 3503
American Microwave Corp. 4319
American Standard Circuits Inc. 3809
American Technical Ceramics 1906
Ametek HCC Industries 3710
AML Communications Inc. 2024
Amplifier Solutions 4205
AmpliTech Inc. 2303
ANADIGICS 1144
Analog Devices Inc. 820
Anapico Ltd. 2323
Anaren Inc. 928
Anatech Electronics 4507
Anoison Electronics 631
Anritsu Co. 1818
ANSYS Inc. 1020
Antenna Research Associates Inc.-ARA. 5119
APA Wireless Technologies 317
API Technologies 446
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AR RF/Microwave Instrumentation 1103
ARC Technologies Inc. 1140
Arlon Tech. Enabling Innovation 4613
Artech House 3412
ASB Inc. 1143
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Auriga Microwave 912
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Axiom Test Equipment Inc. 341
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Bliley Technologies Inc. 4515
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CapeSym Inc. 306
Carlisle Interconnect Technologies 2309
Cascade Microtech Inc. 911
Centellax Inc. 312
Centerline Technologies LLC 4502
Century Seals Inc. 3705
Cernex 3207
Channel Microwave 1514
Charter Engineering Inc. 4809
Chengdu BoCen Microwave Tech. Co. 4606
Chin Nan Precision Electronics Co. Ltd. 641
Ciao Wireless Inc. 3609
Cirexx International Inc. 4009
Cirtek Electronics Corp. 944
Cobham 1024
Coherent Logix 4306
Coilcraft Inc. 2402
Coining Inc. 4404
Coleman Cable Systems Inc. 804
Coleman Microwave Co. 840
COM DEV Ltd. 334
Communication Power Corp. (CPC) 5011
Communications & Power Industries 2411
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Connecticut Microwave Corp. 850
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Continental Resources Inc. 5109
Corning Gilbert Inc. 1902
CORWIL Technology Corp. 648
CPS Technologies 4413
Crane Aerospace & Electronics 1822
Crane Polyflon 2023
Cree Inc. 1925
Cristek Interconnects Inc. 506
Crystek Corp. 325
CST of America Inc. 1423
CTT Inc. 2302
Cuming Microwave Corp 3209
Custom Cable Assemblies Inc. 3812
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DeWeyl Tool Co. Inc. 4802
Diablo Industries Thin Film 4115
Diamond Antenna & Microwave Corp. 3511
Dielectric Laboratories Inc. 1006
Diemat Inc. 3612
DiTom Microwave Inc. 702
Dorado International Corp. 706
Dow Key Microwave Corp. 907
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Dyne Tech Co. LTD 5118
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Eclipse Microwave Inc. 703
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ElectroMagneticWorks Inc. 338
Elisra Electronic Systems Ltd. 3504
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EM Software & Systems - FEKO 936
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EMSCAN 1010
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Epoxy Technology Inc. 352
ET Industries 4106
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EZ Form Cable Corp. 2124
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Farran Technology Ltd. 1515
Ferrite Co. The 1136
Ferro-Ceramic Grinding 745
Filtel Microwave Inc. 322
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Focus Microwaves Inc. 2119
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Geib Refining Corp. 748
Gerotron Communication GmbH 340
GGB Industries Inc. 2004
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GigaLane Co. Ltd. 3709
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GNI Microwave Co. Ltd. 637
Gowanda Electronics 730
Greenray Industries Inc. 3712
GuangShun Electronic Tech. Research Inst. 4110
H Rollet 3613
Harbour Industries Inc. 3813

HEI Inc. 547
Herley Industries 919
Herotek Inc. 940
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Holzworth Instrumentation Inc. 2419
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Hughes Circuits Inc. 444
HXI LLC 5019
IBM Corp. 5114
IEEE Microwave Magazine 3502
IHP GmbH 3605
IMST GmbH 2224
IMT 3903
In-Phase Technologies Inc. 711
Infinite Graphics 5315
INGUN Pruefmittelbau GmbH 3804
Innertron Inc. 4407
Instek America Corp. 3913
Instruments For Industry (IFI) 4504
Integra Technologies Inc. 4015
Integrand Software Inc. 3305
Intercept Tecnology Inc. 332
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Ion Beam Milling Inc. 3307
IROM Tech. Inc. 549
Isola 2104
ISOTEC Corp. 4409
ITF Co. Ltd. 833
iTherm Technologies 5318
ITT Corp.-Microwave Systems 2007
IW Insulated Wire Microwave Products 407
Jersey Microwave LLC 630
JFW Industries Inc. 2002
Johanson Manufacturing Corp. 439
Johanson Technology Inc. 1609
John Wiley & Sons 807
Johnstech International 4402
JQL Electronics Inc. 3909
Jye Bao Co. Ltd. 3606
K&L Microwave Inc. 902
Kaben Wireless Silicon Inc. 4807
Kaelus 1509
KCB Solutions 3911
Kemac Technology Inc. 806
Keragis Corp. 705
KJ Comtech 4305
KMIC Technology Inc. 3905
Krytar Inc. 1712
KVG Quartz Crystal Technology GmbH 5107
Kyocera America Inc. 628
L-3 Communications 502, 602
LadyBug Technologies LLC 737
Lake Shore Cryotronics Inc. 3603
Lanjian Electronics 3805
Lark Engineering Co. 1535
Laser Process Mfg. 747
Laser Processing Technology Inc. 4915
Laser Services 2123
LCF Enterprise 406
Leader Tech. Inc. 346
Liberty Test Equipment 848
Linearizer Technology Inc. 530
Lintek Pty Ltd. 4006
Litron Inc. 443
LNX Corp. 1147
Logus Microwave Corp. 328
Lorch Microwave 1512
LPKF Laser & Electronics 2202
M/A-COM Technology Solutions 1418
M2 Global Technology Ltd. 2509
Mag Layers USA Inc. 550
Marcel Electronics International 5113
Massachusetts Bay Technologies 4303
Materion 4111
MathWorks 4304
Maury Microwave Corp. 1016
McGraw-Hill Professional 3506
MECA Electronics Inc. 4014
Mega Circuit Inc. 524
MegaPhase 4202
Meggitt Safety Systems Inc. 918
Mentor Graphics Corp. 605
Mersen 4909
MESL Microwave Ltd. 743
Metropole Products Inc. 803
Mician GmbH 740
Micreo Ltd. 4007
Micro Communications Inc. 644
Micro Electronic Tech. Development 441
Micro Lambda Wireless Inc. 2502
Micro Tool Inc. 849
Micro-Coax Inc. 3404
Micro-Mode Products Inc. 435
MicroApps 413
MicroFab Inc. 4503
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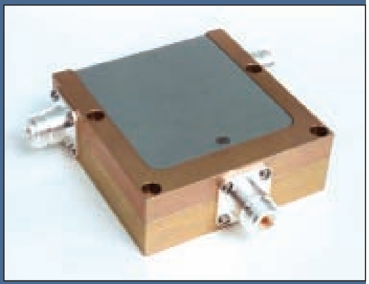
Microphase Corp. 529
Microsemi Corp. 722
Microtech Inc. 2125
Microwave Applications Group 326
Microwave Circuits 704
Microwave Communications Labs Inc. 610
Microwave Development Labs Inc. 2519
Microwave Dynamics 802
Microwave Engineering Europe 546
***Microwave Journal* 3414**
Microwave Packaging Technology Inc. 3611
Microwave Product Digest 617
Microwave Technology Inc. 1046
Microwavefilters S.R.L 533
MIG-Microwave Innovation Group 1605
Millennium Microwave Inc. 3403
Millitech Inc. 1610
Mini-Circuits 1031
Mini-Systems Inc. 935
MITEQ Inc. 1909
Mitsubishi Electric & Electronics 510
Modelithics Inc. 713
Modular Components National Inc. 2107
Molex RF/Microwave Business Unit 2102
Momentive Performance Materials 4618
Mosis 950
MPDevice Co. Ltd. 736
MtronPTI 1152
Murata Electronics 1607
Mustang Industrial Corp. 749
Nanjing Jiexi Technologies Co. Ltd. 4918
National Instruments 2420
National Reconnaissance Office 844
NAVICP 5218
NDK 710
Netcom Inc. 1729
Networks International Corp. (NIC) 733
Nitronex Corp. 945
Noise XT 1049
NoiseWave Corp. 837
Norden Millimeter Inc. 635
Northrop Grumman 304
NSI 1110
NTT Advanced Technology 4406

HIGH POWER

100 MHz to 20 GHz

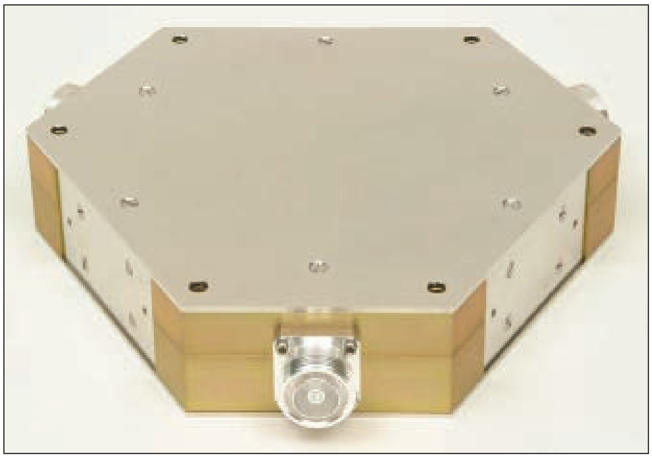


For Military/Radar Applications.

Isolators/Circulators

As one of the leading suppliers of ferrite components in the industry, UTE Microwave has pioneered innovative designs, quality craftsmanship and exceptionally high quality products. Custom designs, standards...many of them off-the-shelf, are the result of over 35 years of experience in the industry. UTE Microwave continues this tradition with new products for ever changing applications. Our broad line of HIGH POWER, low loss circulators and isolators spans the spectrum from below 100 MHz in coax/stripline units to waveguide devices at 18 GHz for both peak and average powers.

100 MHz HIGH POWER Circulator for Medical, Scientific and Industrial applications



A new HIGH POWER Circulator suitable for FM Broadcast, Scientific and Medical applications is now available. The unit provides 10 MHz bandwidth in the 85–110 MHz spectrum.

Specifications are 20 dB min. isolation, 0.3 dB max. loss and 1.25 max. VSWR. Operating power is 1 kW average and 25 kW peak. The 8-1/2" hex x 2" thick unit operates over a 15°–50° C temperature range. DIN 7/16 connectors are standard. Other units are available at higher frequencies.

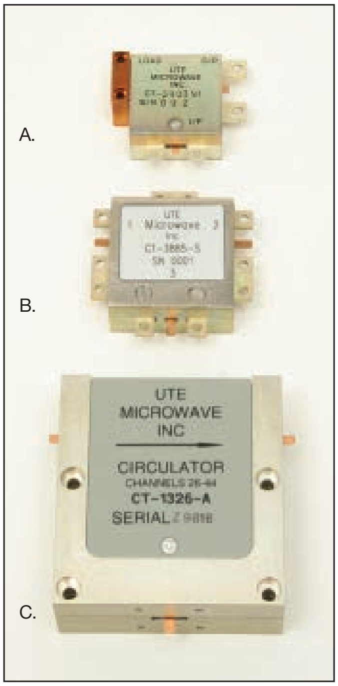
HIGH POWER Drop-in Series

A broad line of low loss HIGH POWER Drop-in circulators are available from VHF to Ku band including Kilowatt average power levels at VHF thru S band. L and S band radar are a specialty. A few of these are shown here.

A) 2.7–3.1 GHZ 1 kW pk, 100 W av

B) 1.2–1.4 GHZ 3 kW pk, 300 W av

C) UHF TV Band 5 kW pk, 500 W av



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CT-3877-S	2.5 Kw Pk 250 W Av	"Drop-in"	2.7–3.1 GHz
CT-3838-N	5 Kw Pk 500 W Av	N Conn.	2.7–3.1 GHz
CT-1645-N	250 W Satcom	N Conn.	240–320 MHz
CT-1739-D	20 Kw Pk 1 Kw Av	DIN 7/16	128 MHz Medical

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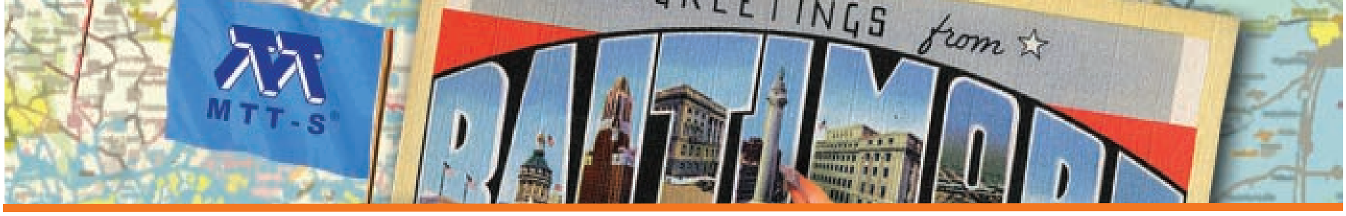

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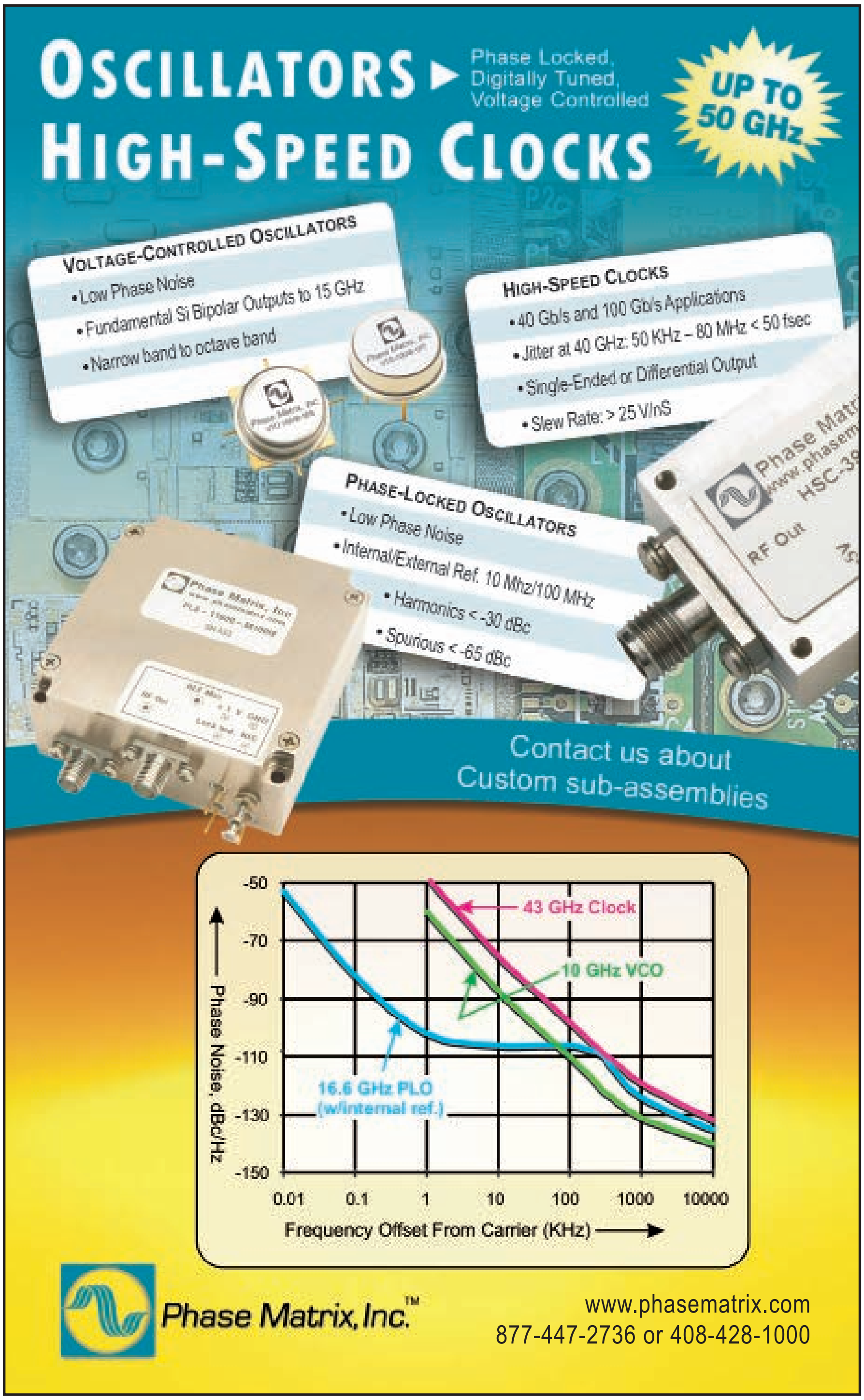

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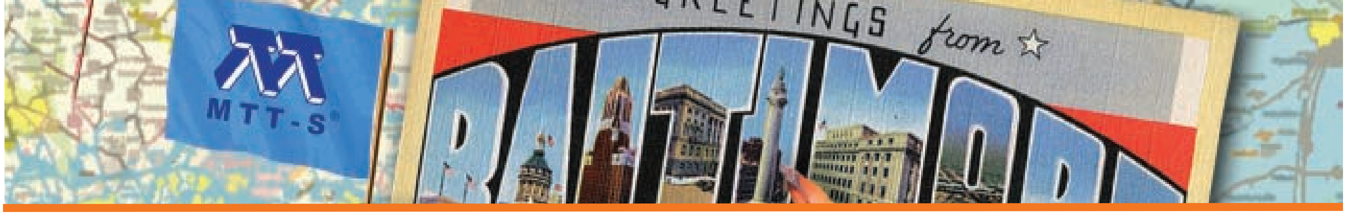

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Defense News

Dan Massé, Associate Technical Editor

Cobra Judy Replacement Team Completes Radar Delivery Milestone

Raytheon Co. and Northrop Grumman Corp. recently completed a significant milestone for the Cobra Judy Replacement program. The CJR S-band active phased-array antenna was successfully delivered to the CJR integration site at Kiewit Offshore Services, Corpus Christi, TX, completing the development phase of the program.

The mission of the CJR program is to provide the government with long-loiter ballistic missile data collection capability. Its dual-band radar suite consists of X-band and S-band phased-array sensors, a common radar suite controller, and other related mission equipment. The program now progresses to full dual-band radar integration and testing.

"This radar suite will provide an integral sea-based treaty verification capability to the US and its allies."

"This delivery represents a tremendous step forward for the CJR program and the entire industry team," said Raytheon Integrated Defense Systems' Patrick "Kevin" Peppe, Vice President of Seapower Capability Systems. "This sophisticated radar suite will provide an integral sea-based treaty verification capability to the United States and its allies."

Northrop Grumman GaN-based Modules Set New Standard for High Power Operation

Northrop Grumman Corp. has set a new standard for its gallium nitride-based high power transmit/receive (T/R) modules by reliably operating them for more than 180 days during continuous high power testing. In a rigorous evaluation conducted by the company's Advanced Concepts and Technology Division, the T/R modules were tested by using high-stressing operational long-pulse waveforms, which operated on the modules nonstop for more than six months. These waveforms were designed to simulate the electronic activities of actual radar functions, in a relevant environment allowing Northrop Grumman engineers to understand how well they would perform in tactical operation.

The successful tests prove that the next generation of active electronically scanned arrays (AESA) is capable of reliable operation while producing much greater radar sensitivity, at higher efficiency and lower cost. With this new threshold established, the T/R modules can serve as critical technology elements for a wide range of future applications.

"By successfully employing the latest advances in high power semiconductor technology in a functioning T/R module, we have demonstrated the great performance and reliability of our design approach," said Steve McCoy, Vice President of the Advanced Concepts business unit within the company's Electronic Systems sector. "This new level of maturity also supports technology readiness for the next generation of Northrop Grumman's high performance, low cost AESA radars, and opportunities for cost reduction and performance upgrades to our current AESA product line."

By successfully employing the latest advances…we have demonstrated the great performance and reliability of our approach.

Harris Corp. Introduces First Unfurlable, High Frequency Ka-band Space Antenna

Harris Corp. introduced an unfurlable space antenna designed to support emerging requirements for high-throughput Ka-band satellites. The new Harris Ka-band antenna greatly increases the gain and potential spot beams currently available to spacecraft manufacturers and service providers. The increased frequency reuse provided by the additional spot beams enables higher data rates required by providers of bandwidth-hungry services such as satellite Internet, HDTV and 3D TV, and by businesses that transfer large amounts of data between remote locations, such as oil and gas companies and maritime users.

The antenna features flight-proven design elements that have been refined during development and production for US government and commercial programs, including the application of reflective mesh, surface-shaping technology and thermally stable materials. The antenna's architecture leverages Harris' robust radial rib structure reflector design, 40 of which are currently in operation. The projected aperture ranges from 3.5 meters to 8 meters in diameter, with a compact stowed configuration suitable for most launch vehicles. During launch, the Harris reflectors are stowed onboard the satellite much like an umbrella. Once in orbit, controllers execute a series of maneuvers, and then send commands to deploy an articulating boom and unfurl the reflector.

"This new Ka-band product is a natural extension of our existing offerings for larger apertures, and continues our 35-year legacy of providing high performance antenna solutions with unmatched performance," said Sheldon Fox, Group President, Harris Government Communications Systems. "The Harris solution supports the ever-increasing global demand for higher bandwidth capacity."

Go to www.mwjournal.com for more defense news items

Lockheed Martin Awarded $43.3 M Contract for Concept Definition of Standard Missile-3 Block IIB

Lockheed Martin announced that the US Missile Defense Agency has awarded it a $43.3 M contract for concept definition and program planning for the Standard Missile-3 Block IIB (SM-3 IIB). The new missile, formerly known as the Next Generation Aegis Missile, will provide early intercept capability against intermediate- and long-range ballistic missile threats. It will be a key element of the fourth phase of the Phased Adaptive Approach, which will provide enhanced capabilities against threats on a global basis. The missile will be integrated into the Aegis Weapon System, with the Aegis BMD 5.1 Fire Control and the MK 41 Vertical Launching System, as part of the land-based Aegis Ashore capability.

"This represents a unique opportunity to develop and field a critical addition to our nation's missile defense capability…"

"This represents a unique opportunity to develop and field a critical addition to our nation's missile defense capability, one that complements existing systems," said Doug Graham, Vice President of Advanced Programs, Strategic and Missile Defense Systems, Lockheed Martin Space Systems Co. "Working in partnership with the Missile Defense Agency and the US Navy, Lockheed Martin will leverage extensive missile defense interceptor and weapon system integration expertise to deliver a new interceptor that addresses emerging ballistic missile threats, with the flexibility to operate across the globe."

Raytheon Awarded $42 M for Next Generation Standard Missile-3 Interceptor

Raytheon Co. was awarded $42 M for the initial concept development and program planning for the Standard Missile-3 Block IIB, which is the Missile Defense Agency's next-generation Aegis missile.

"Raytheon is the lowest-risk, lowest-cost, most-technically capable provider of missile defense solutions," said Frank Wyatt, Vice President of Raytheon's Air and Missile Defense Systems product line. "SM-3 has successfully defeated 18 incoming ballistic missile threats in realistic test scenarios; it's in a class by itself. Spiral development of the Standard Missile program is the right choice for developing and delivering this capability for the country."

Raytheon's Standard Missile-3 family is a core element of the administration's Phased Adaptive Approach for missile defense. Raytheon engineers have decades of experience in radars, airborne and space-based sensors, interceptors and kill vehicles.


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PERSEUS Project to Develop and Test European Maritime Surveillance System

The Protection of European BoRders and Seas through the IntElligent Use of Surveillance (PERSEUS) project, led by Indra, has been instigated to provide protection of the European seas and borders with the smart use of technologies. The project, with a budget of €43.7 M and an execution period of four years, is one of the most significant initiatives within the 7th Framework Programme of the EC and will be the flagship of R&D in the maritime security segment.

PERSEUS addresses the call for an integrated European system for maritime border control. Its purpose is to build and demonstrate an EU maritime surveillance system integrating existing national and communitarian installations and enhancing them with innovative technologies. By means of two large scale demonstrations the project will prove its feasibility and will set the standards and grounds for the future development of EU maritime surveillance systems.

Indra will undertake the coordination of the consortium comprising 29 partners from 12 EU member countries. Collaboration with non European countries and international agencies such as NATO or the International Maritime Organisation (IMO) is also envisaged. The new maritime surveillance system is expected to increase the effectiveness of the current systems by creating a common maritime information sharing environment for the benefit of the network, including National Coordination Centres, Frontex and the European Maritime Safety Agency (EMSA).

PERSEUS will incorporate technological innovations regarding detection and analysis applied to maritime security, particularly for the detection of low flying targets and small vessels. Multiple sensors and sources of information will be incorporated into the system, which will also employ technologies and capabilities under development by other EU projects, including other segments such as Space.

FP7 Programme Update

The PERSEUS Project is part of the 7th Framework Programme. The Project, which is set to end on 31 December 2014, will contribute to Europe's efforts to monitor illegal migration and combat related crime and goods smuggling by proposing a large scale demonstration of an EU Maritime surveillance System of Systems. To discover the project's objectives, participants, funding, etc., visit: www.mwjournal.com/FP7MAY2011.

V3DIM Project to Develop 3D SiP Solutions in Millimetre-wave Range

The German V3DIM (standing for design for vertical 3D system integration in millimetre-wave applications) research project aims to lay the foundations for establishing the design requirements to develop innovative, highly integrated 3D System-in-Package (SiP) solutions for systems in the 40 to 100 GHz range.

Five partners from industry, science and research have joined forces in the project funded by the German Federal Ministry of Education and Research (BMBF) to explore how innovative 3D integration technologies can be exploited in chip and package manufacture. In their quest, special attention will be paid to miniaturization, performance (including power loss, signal integrity, noise and cost), energy efficiency and reliability.

> *. . . special attention will be paid to miniaturization, performance... energy efficiency and reliability.*

The five project partners are Fraunhofer Institutes in Dresden, Munich and Berlin lead-managed by the Dresden Institute for Integrated Circuits, SYMEO GmbH, Siemens AG, the Institute of Technical Electronics at the University of Erlangen-Nuremberg, and the project manager, Infineon Technologies AG.

The project is scheduled for completion at the end of August 2013. The five partners will devise new design methods, models and SiP technology components to meet the special challenges of vertical 3D system integration in the sphere of millimetre-wave applications.

V3DIM's overall project cost amounts to €6.8 M, with approximately 40 percent being funded by the three industry project partners. In addition, the project will receive BMBF support of about €4.1 M over a three-year term under the Information and Communications Technology 2020 (ICT 2020) programme as part of the German Federal Government's High-Tech Strategy. The V3DIM project also collaborates closely with the European CATRENE 3DIM3v project, which works on complementary aspects of vertical 3D system integration.

Alcatel-Lucent Bell Labs, Thales and CEA-Leti Join Forces in III-V Lab

CEA-Leti has joined the III-V Lab in a move to strengthen the industrial research capabilities of the R&D centre, which is Europe's most advanced in the field of III-V semiconductors. CEA-Leti joins Alcatel-Lucent Bell Labs and Thales, which established the III-V Lab, south of Paris, France, in 2004.

Since then the lab has enabled the rapid development of a common platform for dual-use optoelectronic and microelectronic technology for markets addressed by the two groups such as telecom, space, defence and security. CEA-Leti will significantly broaden the scope of the lab's targeted applications by combining its IP and expertise in silicon, microelectronics and microsystems, and in heterogeneous integration.

The new public-private partnership will combine III-V

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"The new III-V Lab will be a strong source of value creation."

semiconductor and silicon technologies, opening up new research perspectives and dynamics. The enlarged III-V Lab will include more than 130 researchers, technicians and doctoral candidates.

"This innovative joint venture is a unique model of partnership for joining competences, technologies and ambitions, and it will enable the partners to accomplish things they couldn't do alone," said Leti CEO Laurent Malier. "Each of us brings very specific and complementary expertise to our pursuit of common goals. Moreover, each partner can capitalize on the developments and transfer new technologies to our customers. The new III-V Lab will be a strong source of value creation."

Newtec Joins Asia-Pacific Satellite Communications Council

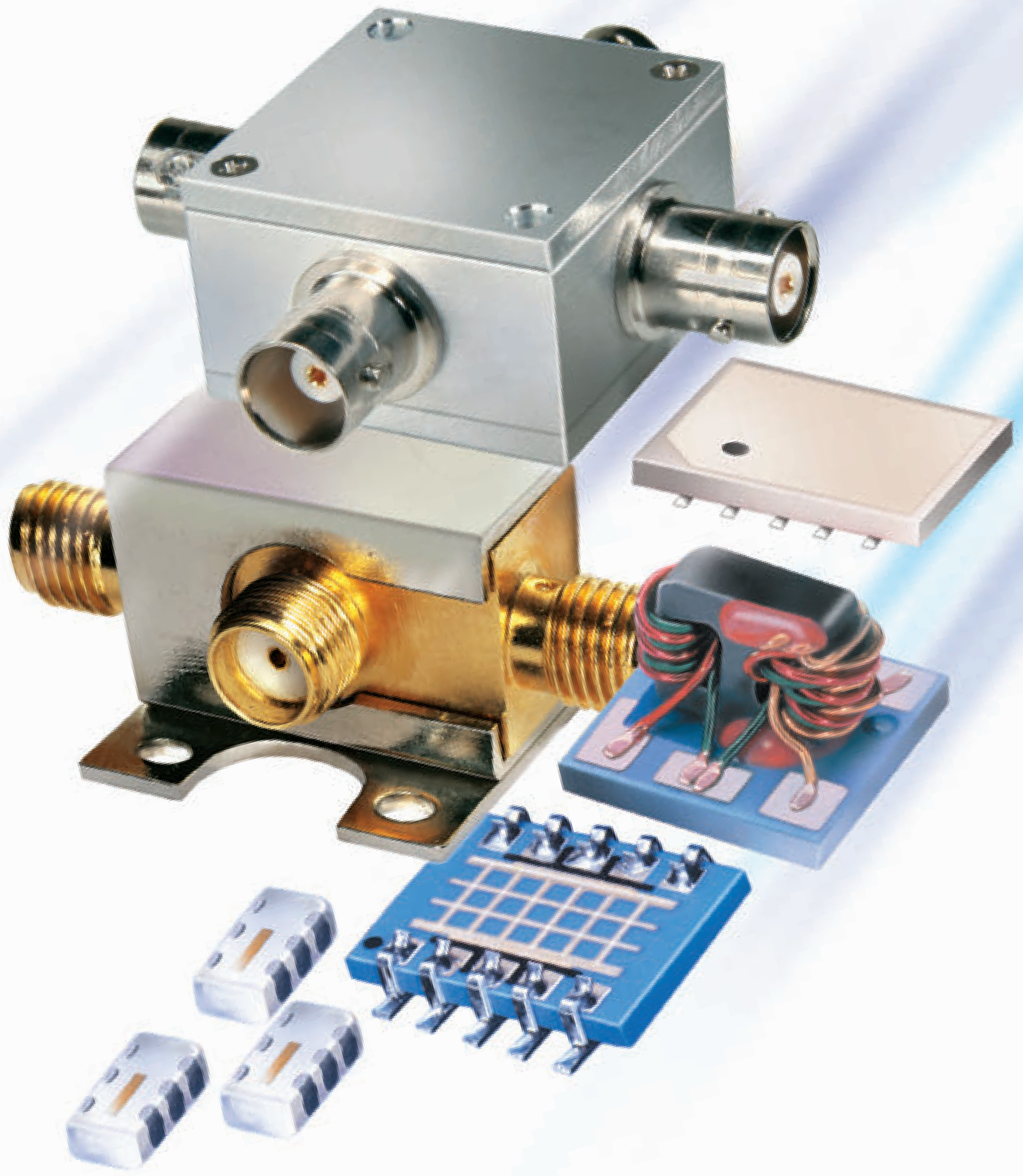
Newtec has marked ten years in Asia by joining the Asia-Pacific Satellite Communications Council (APSCC) as a member. APSCC is a non-profit international organization representing all sectors of satellite and space related industries, including private companies, government ministries and agencies, and academic and research entities. Its overall objective is to promote communications and broadcasting via satellite as well as outer space activities in the Asia-Pacific, for the socio-economic and cultural development of the region.

"Newtec's involvement with APSCC will enable us to build new relationships..."

Yutaka Nagai, President of APSCC, said, "APSCC is delighted to welcome Newtec into the organisation. Newtec is a progressive, exciting, innovative company and technology leader in the satellite industry. We look forward to their contribution to APSCC activities."

After a decade of activity in the Asian region, Newtec is now ready to become more firmly established in the region. The company has recently augmented and re-organised its team in Asia and has offices in Singapore and Beijing in order to direct more focus towards its products and solutions in the region. Joining the APSCC is the next logical step for further progression in the region.

Serge Van Herck, CEO of Newtec, commented, "This was the right time for Newtec to join APSCC. We have built a firm foundation in the Far East and we now want to build upon this to strengthen our presence in the region. Newtec's involvement with APSCC will enable us to build new relationships and gain further knowledge of the satellite and space industry in the region. We are proud to be members of such an organisation."

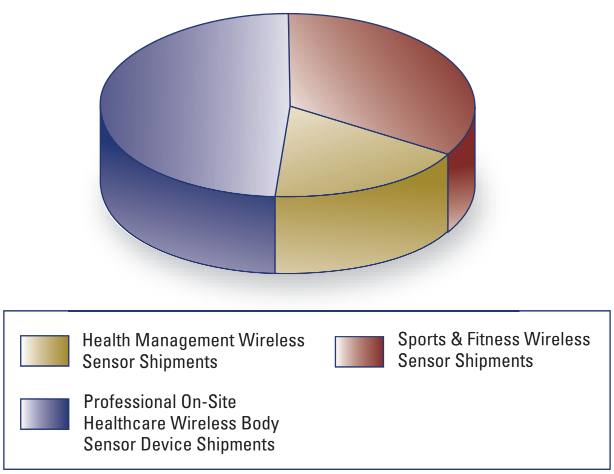


Dan Massé, Associate Technical Editor

Half-billion Dollar Market at Risk, Due to Delays in Bluetooth Low Energy Standard Adoption

Bluetooth Low Energy (BLE) has the potential to power a range of new applications collecting and sharing personal fitness and health management data, but delays in product deliveries to markets over the past 12 months have some application developers looking to rival technologies and protocols. The Bluetooth SIG did not formally adopt the Bluetooth Core Specification Version 4.0 which encompasses Bluetooth Low Energy technology until July 2010 – more than six months later than many in the industry had expected.

Wireless Sensor Shipments by Market Segment
World Markets, Forecast: 2016



Source: ABI Research

With the huge potential of the Bluetooth Low Energy technology, the wait for adoption by the Bluetooth SIG has put a brake on many wireless health and sports devices' market launches. Where it has not halted product development it has fostered adoption of rival traditional Bluetooth and proprietary offerings in the market. In addition, application developers have looked to build offerings around smartphone handsets' current sensor and data collection capabilities. However, ABI Research believes that Bluetooth Low Energy remains of key importance to the proliferation and adoption of wearable wireless-enabled sports and health sensors.

ABI Research's "Wireless Healthcare and Fitness Market Data" provides forecast data for a number of significant types of wireless equipment in a healthcare environment including Wi-Fi access points and Wi-Fi RTLS appliances. It includes examination of remote patient monitoring, telehealth and telepresence, and contains data about "body area networks."

This product is included in the firm's Wireless Healthcare Research Service, which also includes Research Reports, a home security Survey, ABI Insights, and analyst inquiry support.

Median Pricing for 200 mm Production CMOS Wafers Increases at the Same Rate as 300 mm Wafers QoQ

The Global Semiconductor Alliance (GSA), the voice of the global semiconductor industry, announced the results of its quarterly Wafer Fabrication and Back-end Pricing Survey, analyzing prices paid per wafer and mask set and for outsourced assembly services by fabless semiconductor companies and integrated device manufacturers (IDM). The results of the Q1 2011 Wafer Fabrication and Back-end Pricing Survey include:

- Median pricing for both 200 and 300 mm production CMOS wafers increased by about 5 percent quarter-over-quarter (QoQ).
- After decreasing for two consecutive quarters, survey participants reported a sequential increase in the median mask set cost for 200 mm CMOS wafers. Participants indicated that the median cost increased 21 percent QoQ and 20 percent YoY.
- The median cost for QFN packages with ≤ 64 leads increased 3 percent QoQ.
- 90 percent of survey participants are getting the capacity they need, with the "Yes" percentage increasing by 13 percentage points QoQ.

The survey results provide detailed insight into wafer and mask costs using factors such as development stage, process geometry, number of metal layers, number of poly layers and epitaxial/non-epitaxial processes. Subscribers can also search assembly costs by such factors as package family, leads, units per week and substrate cost. These results are published in GSA's quarterly Wafer Fabrication and Back-end Pricing Report which includes a written analysis of the survey results, a downloadable MS Access database of all aggregated results, and interactive online results showing rolling average and median prices for four consecutive quarters by varying factors.

Note: The Q1 2011 results represent purchases made/received between 10/1/2010 to 12/31/2010.

MEMs Market to Approach Five Billion Shipped in 2016

MEMS (Micro-electromechanical Systems) are starting to be the "Swiss Army Knives" of modern consumer electronics: they can take the form of (or be incorporated in) accelerometers, gyroscopes, magnetometers, altimeters, screens, projectors and microphones. New data from ABI Research indicates that strong growth in the MEMS market over the next

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five years will result in nearly five billion MEMS being shipped during 2016.

MEMS are found in smartphones, netbooks, media tablets, eReaders, games consoles and handheld gaming platforms, where some of them assist with navigation, dead reckoning, image stabilization and augmented reality. (Often, more than one MEMS will reside in any given consumer device.) Still others will underpin new forms of display that use far less power than today's screen technologies (although initially at greater cost).

"Initially, smartphones will provide the greatest boost to uptake," notes Practice Director Peter Cooney, "but if OEMS embrace MEMS displays, they may deliver the strongest overall growth in revenue over time. ABI Research's MEMS market forecasts depend on device shipments growing as expected. At this point however, we are confident about the prospects for CE devices market growth."

The MEMS market is currently split between seven quite specialized major vendors – STMicroelectronics, Asahi Kasei, InvenSense, Bosch, Knowles, Kionix, Freescale Semiconductor – and a number of smaller ones.

"Over time, competition in the MEMS market will result in falling ASPs," says Cooney. "Two of the larger vendors, Bosch and STMicroelectronics, have more diversified product offerings, taking shares across a number of applications. This positions them well to prosper as market conditions change, while other vendors continue to specialize. There is still room for new vendors with new products, however."

Dual Platform 4G Strategy Rewards Mobile Network Operators, Chip and Device Makers

There is no question that in the long term LTE will become the mainstay 4G network technology, although its universal use is still in the future. Until then, says ABI Research, some service providers will benefit from a dual-platform strategy based on both LTE and WiMAX.

Who stands to benefit? Some operators, such as Sprint and Clearwire, KDDI and UQ Communications, and KT, will use both technologies for some time. Multi-standard base stations now being deployed support several generations of technologies as well as both 4G standards. There will also be multi-mode 4G chipsets in devices. New data on these and other 4G topics are presented in ABI Research's "4G Subscriber, Device, and Networks Market Data" which contains regional and selected country-level segmentation for the mobile WiMAX and LTE markets. It is part of the firm's 4G Research Service.

Jennifer DiMarco, Staff Editor

INDUSTRY NEWS

Texas Instruments has signed a definitive agreement to purchase **National Semiconductor** in an all-cash transaction of about $6.5 B. This merger will unite two industry leaders who have a common commitment to solving analog needs. Both companies will operate independently pending close of the acquisition that is expected to take six to nine months.

API Technologies Corp., a provider of secure communications, electronic components and subsystems, and contract manufacturing services to the global defense and aerospace industries, and **Spectrum Control Inc.**, a designer and manufacturer of custom solutions for the defense, aerospace, industrial and medical industries headquartered in Fairview, PA, announced that they have entered into a definitive merger agreement providing for the cash acquisition of Spectrum by API. Upon closing of the transaction, Spectrum will operate as a wholly owned subsidiary of API. Pursuant to the terms of the definitive agreement, API will acquire 100 percent of the issued and outstanding equity of Spectrum for $20.00 per share for a total purchase price of approximately $270 M.

AML Communications Inc. announced that it had signed a definitive agreement and plan of merger with **Microsemi Corp.** and a wholly-owned subsidiary of Microsemi. Microsemi shall acquire AML for $2.50 per share in cash, subject to the terms and conditions of the Microsemi Merger Agreement. The transaction is subject to customary closing conditions, including the approval of AML Communications' stockholders, and is expected to close around the end of June, 2011.

Ducommun Inc. announced that it has entered into a definitive agreement to acquire all outstanding stock of **LaBarge Inc.** LaBarge, with revenue of $324 M for the 12 months ended January 2, 2011, is a supplier of electronics manufacturing services (EMS) operating across many high-growth industries. The acquisition will nearly double Ducommun's revenue base, improve the company's position as a Tier 2 leader in both aerostructures and electronics, and bring access to new customers and markets. Pursuant to the terms of the definitive agreement, Ducommun will acquire all issued and outstanding shares of LaBarge at $19.25 per share in cash for a total purchase price of approximately $340 M, including the assumption of LaBarge's outstanding debt ($30 M as of January 2, 2011).

Alpine Investors, a middle-market private equity firm based in San Francisco, CA, announced that it has acquired **Linx Technologies**, a provider of cost-effective wireless modules, antennas, connectors and wireless design services. Linx enables Wireless Made Simple® by providing design engineers with robust easy to implement wireless control and data modules and components. As part of the transaction, Alpine has announced Tolga Latif, an executive-in-residence with Alpine, as the new President and CEO of Linx. Latif brings marketing, sales and product development experience from various leadership roles at Danaher Corp. The financial terms of the transaction were not disclosed.

Cornell Dubilier Marketing Inc. has sold its KVX mica product line to **Custom Electronics**. Custom Electronics will support all Cornell Dubilier customers for this capacitor line moving forward.

AWR® Corp. announced that it plans to open its third direct sales and support office in Asia with a Shanghai, China location. The announcement aligns with the end of AWR's fiscal year and in particular one that has seen double-digit growth in AWR sales for the Asia-Pacific sub-region of Japan, China and Korea versus the year prior.

United Monolithic Semiconductors' (UMS) BES MMIC Schottky diode process has been successfully Space Evaluated and is now part of the European Preferred Part List established by ESA/ESCIES. Due to its very high cut-off frequency (>3 THz), BES is the preferred process for the design of MMICs, mixers, multipliers and switches at very high frequencies.

In order to provide RF test and measurement technology from a single source, **HUBER+SUHNER** and **SPINNER** have agreed to provide each other with parts of their measurement technology product range. HUBER+SUHNER will add SPINNER calibration components to its product range, and, in return, SPINNER will sell the established SUCOFLEX® and SUCOTEST® measurement cables. The extent of the collaboration is underlined by a joint internet site—www.rfmeasuring.com—where more information can be found.

After several years of intensive technical development, **Protium Technologies Inc.** is shipping the P6010 tuner, an advanced yet inexpensive component from the company's growing SIGINT receiver product line. The SDR/FPGA-based modular design covers the 20 to 6000 MHz frequency range in a small brick package specifically designed for cost-sensitive tactical applications.

RF Micro Devices Inc. (RFMD) announced it has teamed with **Atmel Corp.**, a leader in microcontroller and touch solutions, to deliver ZigBee® solutions for a broad range of smart energy applications.

Tahoe RF Semiconductor has achieved another first pass success with the delivery of a highly integrated Specialty GPS Receiver IC with exceptional performance in a small

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plastic molded package. The company has successfully delivered an M-code GPS Receiver IC to **ITT Corp.** to enhance its SINCGARS radio solution with position, navigation and timing capability.

Agilent Technologies Inc. announced shipment of the latest release of its flagship RF and microwave design and simulation platform, Advanced Design System 2011. As the industry's most comprehensive multi-technology design platform, ADS 2011 represents a significant breakthrough in electronic design automation. Agilent also announced that its work with GaAs/GaN and RF SiGe/BiCMOS/CMOS foundries and relevant SMD component vendors has resulted in their support for ADS 2011. During the past six months, the majority of existing ADS process design kits and libraries have been upgraded and verified on early access releases. These upgraded kits and libraries will be made publicly available to foundry and component vendor customers in the coming days, enabling them to take advantage of new capabilities in ADS 2011.

Accel-RF Corp. announced the successful shipment and installation of two advanced semiconductor reliability test systems to customers in Asia. The systems were delivered in Q4 of 2010 with installation completed in early January 2011. Shipped to both government research and commercial entities, these systems will be instrumental in the development of compound semiconductor device performance characterization in Asia.

LPKF headquarters located in Germany recently invested 5 M Euros into purchasing a neighboring building, giving an additional 32,000 square feet for product development and production. With the new space, LPKF will combine its research and development departments and will use the existing building for manufacturing laser systems. The new building is currently under renovation, joining it to the company's existing complex and will be completed by June 2011.

Tektronix Inc. announced plans to expand its presence in the San Francisco Bay Area by opening an RF Design Center in Santa Rosa, CA. This announcement comes on the heels of the opening of a new technology and service center in Santa Clara, CA. The new RF Design Center is intended to expand Tektronix' efforts to develop next-generation RF and microwave test capabilities to better serve customers. By adding this new center in a desirable and highly livable community, Tektronix will have more options for attracting world-class technical talent to accelerate time to market. The company confirmed intentions to hire approximately 15 local RF design engineers and researchers during the initial ramp up phase.

RF Micro Devices Inc. (RFMD) announced it is proudly celebrating its 20th anniversary with commemorative events planned at company locations throughout the year. RF Micro Devices was incorporated on February 27,

1991, and held its initial public offering on June 3, 1997. From its earliest days, RFMD has been an innovator in the semiconductor industry. RFMD was a pioneer in the commercialization of RF components using gallium arsenide (GaAs) compound semiconductor technology, and today RFMD is a leading manufacturer of GaAs technology. In the 1990's RFMD was a primary contributor to the rapid growth in the cellular handset market, and in 2000 RFMD was identified by *Fortune* magazine as the second-fastest growing company in America. In 2004, RFMD became the first semiconductor company to ship one billion cellular power amplifiers, and today RFMD routinely ships greater than three million RF components per day.

Mini-Circuits was recently presented with the 2011 RF-Crystals Co-Supplier of the Year Award by Clay Jones, Chairman, President and CEO, during the company's Annual Supplier Conference. The Supplier of the Year award is an acknowledgment of significant contributions made during the year by suppliers and is based upon quality, delivery, total cost of ownership, lead time and customer service.

TriQuint Semiconductor Inc. announced it has received ZTE Corp.'s "Supplier of the Year" award for 2010. ZTE is a leading Chinese manufacturer of wireless communication system equipment and annually recognizes top suppliers who exhibit superior quality, delivery, cost and service performance. TriQuint has achieved top supplier recognition for the fourth consecutive year and is ZTE's largest provider of power amplifiers for mobile devices.

TRU Corp., a provider of RF and microwave cable assemblies and interconnects, was listed as the 34th largest women-led company in Massachusetts by *Boston Business Journal* in the December 2010 publication. The ranking was compiled based upon 2009 revenue.

CONTRACTS

Cobham has received a five-year, US $45 M long-term agreement from **Pratt & Whitney**, a United Technologies Corp. company, to manufacture advanced composite products for multiple military aircraft engine applications. Cobham will produce advanced, medium and high temperature composite structures for both the F135 and F119 engines at the company's state-of-the-art production facilities in San Diego, CA and Suffolk, VA.

An innovative combination of **DragonWave** high capacity packet microwave backhaul and backbone networking solutions will enable **KeyOn Communications Holdings Inc.** to bring unprecedented services to rural communities across Nevada. The Horizon Compact and Horizon Duo high-capacity packet microwave solutions from DragonWave are being deployed to anchor the "middle mile" network components for KeyOn's stimulus-funded 4G wireless network service rollout to rural homes, businesses and critical community facilities such as healthcare providers.

PERSONNEL

ANADIGICS Inc. announced the resignation of President and Chief Executive Officer **Mario Rivas** and Senior Vice President **Greg White**. The company also announced that its first quarter 2011 revenue guidance remains on track with previous revenue guidance of $42 to $44 M. **Ron Michels**, who was the SVP, Chief Technology and Strategy Officer, will assume the responsibilities of the CEO, **Tom Shields**, who currently serves as EVP and CFO, will assume the additional post of COO, and **John Van Saders**, who was the VP Advanced Technology, will serve as SVP RF Products.


▲ David M. Kirk

Murata Electronics North America announced the appointment of **David M. Kirk** as President, Chief Executive Officer (CEO) and a Director of MENA effective April 1, 2011. Kirk brings to the new role more than 27 years of engineering, marketing and management experience in the electronics industry. Before joining Murata Electronics North America Inc., Kirk held the position of President, CEO and a Director of RF Monolithics Inc. Prior to that, he spent 14 years with Murata Electronics North America where he held positions ranging from product management of various product lines to Director of Marketing for North America. Kirk succeeds Satoshi Sonoda, who will continue his assignment in MENA for a couple of months, to facilitate the transition of his responsibilities to Kirk.


▲ Hiroyuki Hojo

Fujitsu Semiconductor America Inc. (FSA) announced that **Hiroyuki Hojo** has been named President and Chief Executive Officer effective April 1, 2011. He replaces Shinichi "James" Machida, who will return to Fujitsu Semiconductor Ltd. (FSL) in Japan as Corporate Vice President in June. Hojo joined the Fujitsu organization in September 2000. Before being assigned to FSA, he was Corporate Senior Executive Vice President and member of the board of directors of FSL and FSA. From April 2009 through March 2010, Hojo was FML's Corporate Senior Vice President and, from March 2008 through April 2009, was FML's Corporate Vice President. In these positions, Hojo directed the management of the company's planning and sales divisions, developing and implementing corporate strategies to promote Fujitsu's semiconductor business.


▲ Robert Dennehy

M/A-COM Technology Solutions announced that **Robert Dennehy** is appointed Vice President of Operations, reporting to Bob Donahue, Chief Operations Officer. Dennehy will oversee M/A-COM Tech's global manufacturing operations. He will also work with his team to establish long-term goals and strategic planning for the company's


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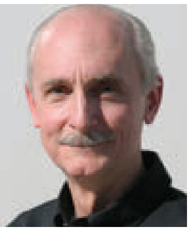
global growth strategy. Dennehy has a long and successful track record with the company. He began as a Test Engineer in 1993 and most recently has been serving as Managing Director of the Infrastructure Group in Cork, Ireland.

KOR Electronics has appointed **David Edwards** and **Chris Michalski** to key leadership roles aimed at extending the company's intelligence-related business for both the defense and intelligence communities. Edwards and Michalski will focus on identifying new business opportunities and developing strategies and products/systems to grow KOR's ISR market position. Edwards as Vice President, ISR Systems, and Michalski as Technical Director, ISR Systems, both join KOR having both spent greater than 30 years at Northrop Grumman ESL.

Auriga Microwave announced the appointment of **Moosa E. Moosa** in the newly created position of Chief Financial Officer. Previously, he served as a part-time financial consultant to the company. He has more than 30 years of extensive and broad business experience as a proactive, business-oriented financial leader and key member of senior leadership teams. His financial and operational experience includes almost 20 years as a CFO of various technology-based and manufacturing companies, including 10 years as CFO of publicly-traded companies. Moosa has a successful track record of growing companies into new markets and repositioning them during changing environments.

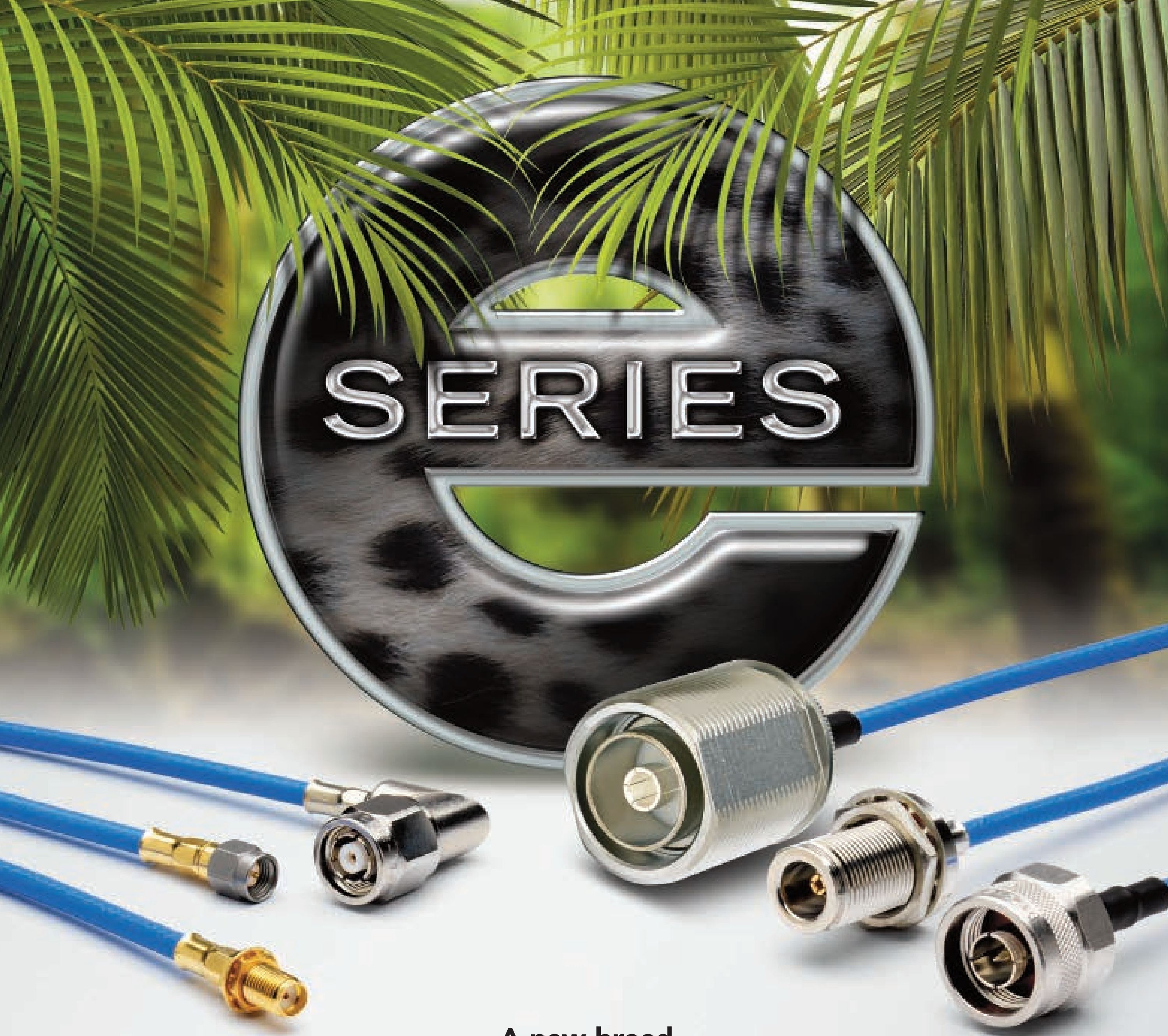
▲ *John P. DiStasio*

Crane Aerospace & Electronics, a segment of Crane Co., has announced the appointment of **John P. DiStasio**, Senior Director of Business Development for Microwave Solutions for the Electronics Group. DiStasio will lead the Microwave Solutions business development team, which includes sites in Beverly, MA, Chandler, AZ, West Caldwell, NJ and San Jose, Costa Rica. DiStasio comes to Crane Aerospace & Electronics with an extensive background in the microwave industry. He joins us from Cobham – M/A-COM Inc., where he held the position of Director of Field Sales. At Cobham, DiStasio managed the worldwide field sales organization for several years.



▲ *Tony Drake*

MFG Galileo Composites announced that **Tony Drake** has been assigned general management responsibility for the company's manufacturing operations in Opp, AL and Adelanto, CA. Drake was promoted to General Manager of sister company MFG West in February 2010, where he had served as Research and Development Engineer since 2008. Drake brings experience in the design and production of composite radomes, as well as more than 20 years of professional experience with composites molding, composite marketing, product development, applied composites design, and research and development.


SERIES

Buyers Bridge Co. announced that **Phillip Wu** has joined the company as Vendor Management Engineer. With highly specialized knowledge in procurement, quality systems and international trade, Wu joins Buyers Bridge's team in Taiwan, Republic of China at an important time in its development and will facilitate the expansion of outsourced supply chain management services. In this assignment, Wu is responsible for directing Buyers Bridge's fee based sourcing programs. Wu has broad experience in apparel, consumer products, industrial hardware and electronic contract manufacturing (ECM). Most recently Wu was employed by Dynamic Flex, an electronics manufacturer in Taiwan.

▲ Jenn DiMarco

Jenn DiMarco has recently been promoted to *Microwave Journal* Managing Editor. In her previous role as Staff Editor, DiMarco has worked closely with the industry's marcom professionals, Product Managers and media relations to publish their press releases and product information in *Microwave Journal* magazine, online media and newsletters. Readers are likely more familiar with her work compiling the 'Around the Circuit', 'New Products' and 'Mark your Calendar' features every month as well as the news and editorial that appears in the publication's family of Microwave Flash and Show Daily newsletters. DiMarco takes over the production of the print and online versions of *Microwave Journal*, in addition to the newsletters. DiMarco received a Bachelor of Science degree in Marketing in 1998 from Johnson & Wales University, Providence, RI.

REP APPOINTMENTS

AWR® Corp. announced that it has signed an agreement with **CapeSym** that names AWR as the global and exclusive reseller of CapeSym's SYMMIC software package for thermal analysis of microwave integrated circuits (MMIC). Marketed as AWR Connected™ for CapeSym SYMMIC, the product offering allows high power RF designers to perform thermal analysis on MMICs designed within AWR's Microwave Office™ software.

Reactel Inc., a manufacturer of RF and microwave filters, multiplexers and multifunction assemblies to the military, commercial, industrial and medical industries, announced the appointment of **WLM Components** as the company's exclusive representative in upstate New York. For more information about WLM Components, please contact Bill Morin at (978) 390-5545 or billmorin@wlmcomponents.com.

Star Microwave Inc., a provider of technology solutions for the growing requirements for catalog and specialized designs of high power drop-in and connectorized isolators and circulators, for the US and international markets, has announced the expansion of regional sales representatives with the appointment of E-Squared Marketing Inc., Kings Park, NY, phone: (631) 544-4788; and Associated Tech-

nical Sales, of Tustin, CA, phone: (877) 287-1737, Web: www.ats1rep.com. **E-Squared Marketing Inc.** will represent the company in New York and northern New Jersey. **Associated Technical Sales** will represent the company in southern California areas.

WEBSITES

Richardson RFPD Inc. announced the launch of a new "microsite" to help design engineers incorporate **Freescale**'s rugged 50 V LDMOS technology into either new or existing designs. The microsite contains a broad array of technical support material, such as white papers, reference designs and links to ADS/AWR models. Please visit the new microsite at www.rell.com/ruggedldmos.

EM Research Inc. has unveiled a new website design, marking the company's 20th year in business. The new website features a fresh, sophisticated look and provides customers with the ability to sort and customize individual products to meet their specific requirements. With the new website, customers are able to tailor electrical specifications for individual packages. One of the more exciting additions to the new website is the ability to search for a specific product based on the frequency and package type of interest, rather than a list of products. For more information, visit: www.emresearch.com.

Lunch with Strategy Analytics at IMS 2011

Join Strategy Analytics for lunch to hear their experts discuss forecasts, enabling trends and opportunities from both commercial and defense industry segments that will shape the future use of semiconductor technologies including InP, GaAs, GaN and Si and SiGe. Hear key insights on topics such as:

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- **Trends for future wireless terminals**
- **Implementing next generation wireless and wired infrastructure rollout**
- **Complementary strengths or competing technologies; where do the different semiconductor technologies stand?**

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PASSIVE INTERMODULATION (PIM) TESTING MOVES TO THE BASE STATION

Passive intermodulation (PIM) has been recognized as a potential problem in communications systems for nearly 50 years. The phenomenon occurs when two or more signals encounter a nonlinear junction and "child" frequencies are generated that are mathematically related to the "parent" signals. With the advent of cellular communications, PIM began to rise in prominence as a concern, due to the quality of service impact these unintended signals could have by interfering or blocking the uplink (receive) channels of the base station.

As the network technology progressed from 2G to 3G and now 4G, we have gone from wondering what would be the "killer app" that would justify the investments being made in spectrum, infrastructure and technology to now struggling with delivering sufficient bandwidth and capacity to gratify the consumers' appetite for data intensive applications that are delivered faster and more reliably. And consumers do not just want this, they expect it.

As a result, controlling or eliminating any interfering signals that impair data rates and signal quality is a must in optimizing network performance. Because PIM is a measure of nonlinearity in the system and is highly sensitive in detecting inadequate construction quality, it has become the preferred performance metric at the base station.

A BRIEF HISTORY

In the early days of commercial telecommunications, manufacturers of RF components used in the high power path of the base station were loosely required to verify PIM performance. Some companies "verified by design," some through first article testing, some through sample testing and some of the more enterprising companies did 100 percent acceptance testing. Those companies doing testing would cobble together signal generators, amplifiers, a spectrum analyzer and a bench full of filters to realize their test bench.

Summitek introduced its first PIM analyzer in September 1996 and brought standardization to the industry and PIM testing. In this same time period, The International Electrotechnical Commission (IEC), Technical Committee 46, formed a working group tasked with defining recommended test methods for PIM. The first edition of IEC 62037 specification was released in 1999. Although this specification covered only "RF connectors, connector cable assemblies and cables," it was widely adopted as the recommended test method for all components. In its simplest terms, it proposed testing PIM at 2 × 43 dBm (20 W).

The follow-up specification that defines test methods and procedures for a larger variety of components, antennas, filters, cables, connectors and cable assemblies, has been in process for the last ten years and is nearing formal release. This version expands upon the test methods and specifically recommends the need for dynamic testing, where the device under test is mechanically stressed (tapped or flexed, as appropriate).

In 2005, as high data rate networks were becoming a focus, Telstra, in Australia, realized the importance of "clean" infrastructure and

RICK HARTMAN
Kaelus Inc., Thousand Oaks, CA

engaged Triasx to develop a rugged, field suitable PIM unit. Telstra was the first network operator to require that PIM be measured and confirmed to be within acceptable levels as a requirement in site certification. It is important to note that PIM does not replace the need for return loss verification. It is a complementary test that identifies a set of problems that might go undetected with a return loss measurement. Summitek teamed with Triasx in 2007 to introduce the first 2 × 20 W portable PIM (PPIM) unit in the United States. PIM testing at the base station to verify construction quality is now a widely accepted requirement by nearly every network operator in the US.

THE TEST PROCESS

Conceptually, PIM testing at the base station is simple. The jumper cable is disconnected at the BTS input, the PPIM unit is attached in its place, the two high power signals are turned on and the resultant IM (typically the third-order product, IM3, because it has the highest signal strength) is monitored.

If the IM level is within performance limits, then dynamically testing of the infrastructure needs to be started. Contrary to the belief of some that a pass in a static test is sufficient for certification, a site cannot be certified unless it can maintain acceptable PIM performance under mechanical stress. This is the standard procedure for every network operator, which is consistent with the emerging specification from the IEC.

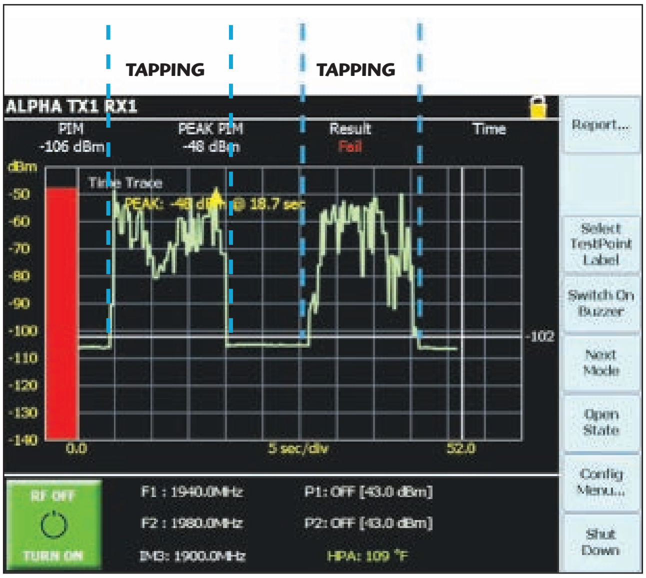
Dynamic testing involves tapping all connector interfaces, all filters (diplexers and tower mounted amplifiers) and the back of the antennas. This should not be destructive in force, but sufficient to move any minor mechanical discontinuities that might exist in the component. Additionally, jumper cable assemblies should be gently flexed.

A word of caution about transmitting two high power signals through the antenna: in most cases, if an operator wants to stay within their licensed band, they cannot get enough separation between the two test frequencies to have the IM3 frequency land within the receive (uplink) band. Consequently, they will need to transmit outside their licensed band. Summitek recommends that the carriers be placed at guard band frequencies to minimize the chance that they will interfere with another operator. This should always be done with a good neighbor policy in mind.

It is not recommended to transmit swept frequency signals through the antenna and into the air. A swept frequency test at 2 × 20 W (43 dBm) will almost guarantee that it will interfere with at least one other operator. If a swept frequency measurement is desired, then the antenna should be replaced with a low IM termination to eliminate the possibility of interference.

Locating the Source of PIM

As mentioned above, whether the line being tested passes PIM with a static test or not, it is a requirement to dynamically test all components and interconnects to certify that there are no unacceptably high PIM sources that are hidden under static conditions. It becomes evident in a hurry where the PIM source is if, when tapped or flexed, the PIM goes up or down measurably (more than several dB), as shown in ***Figure 1***.



▲ *Fig. 1 Dynamic PIM testing showing PIM rising above limits while being tapped but acceptable when static.*

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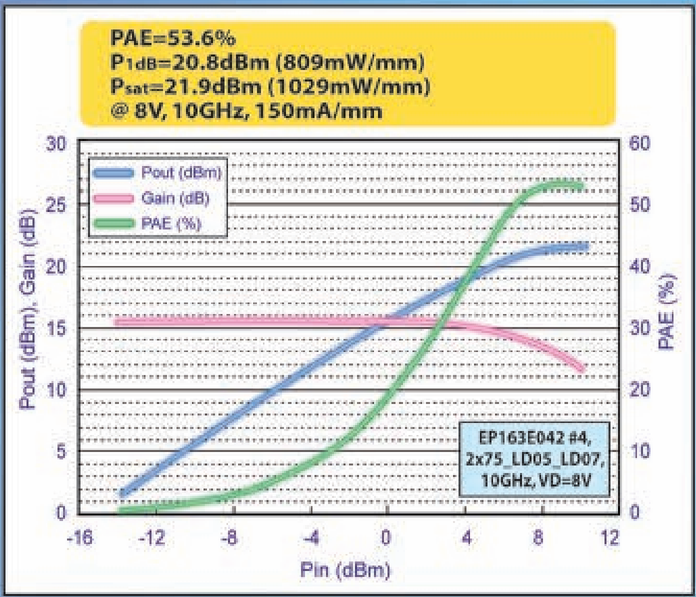

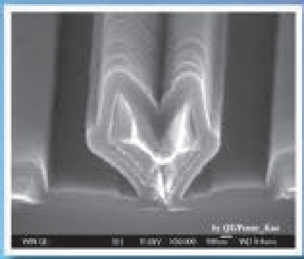

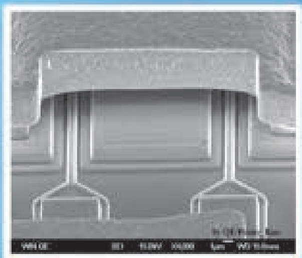

Comparison Table for 0.1μm, 0.15μm, 0.25μm and 0.5μm pHEMT

	PP10	PP15	PP25-21	PP50-11
Vto (V)	-0.9	-1.2	-1.2	-1.4
Idss (mA/mm)	450	500	345	350
Idmax (mA/mm)	720	650	460	480
GM (mS/mm)	750	495	380	310
VDG (V)	9	10	19.2	20
ft (GHz)	130	85	65~72	32
Fmax (GHz)	175	180	160	85
PldB (mW/mm)	533.25 (3.5V)	670 (5V)	809 (8V)	587 (8V)
Psat (mW/mm)	764.3 (3.5V)	820 (5V)	1029 (8V)	851 (8V)
Gain (dB)	14.35	18.1	15.6	15.5
PAE (%)	53.57	55	53.6	53.5
Frequency	29 GHz	10 GHz	10 GHz	10 GHz

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Several suppliers have developed a range-to-fault (RTF) technology that includes the additional hardware and signal processing software to generate time domain plots similar to those generated in network analysis distance-to-fault. RTF technology is an analysis tool developed to enhance, not replace, standard fixed tone PIM testing.

The most effective way to use RTF analysis is to systematically remove the largest magnitude PIM source identified on the line. Repeat the analysis and continue removing the largest PIM source found until all significant static PIM sources have been removed. Regardless of its location on the line, the distance to the largest PIM source will be predicted most accurately by the algorithm. Each time a PIM source is repaired, the accuracy for locating the next largest PIM source will improve.

As initially stated, RTF analysis is not a replacement for dynamic PIM testing. RTF analysis will enhance site testing and potentially speed the removal of static PIM sources at the cell site. The analysis alone, however, should not be used to certify construction quality because:

- Knowing the range to a fault provides a helpful starting point, but does not ensure there are no other hidden PIM sources within the RF feed system
- The absolute value of the RTF PIM magnitude may not be accurate due to distortion brought about by frequency sensitive group delay in RF devices, such as surge arrestors, filters and TMAs. Furthermore, the windowing function used in the transform can affect the magnitude of the data in the time domain.
- "Ghost" PIM sources can be created as a product of the mathematics and/or by impedance mismatches in the system, that reflect PIM generated at different locations on the line

What Transmit Power Should Be Used?

Two, four, 20, 40 W, or more? This is an often asked question. The IEC PIM standard committee confronted this question many years ago and recommended a test power of 20 W (43 dBm) per carrier. Consequently, this has become the industry standard—nearly all manufacturers specify and verify their products based on the third-order IM level, when measured with 2 × 43 dBm carrier powers.

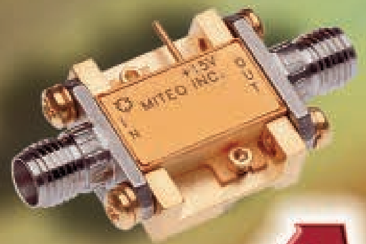
What conditions would have to exist for the benefit of testing at higher power levels?

1) The PIM power level would have to increase in a nonlinear manner, relative to the carrier power.
2) Or, the higher power would have to excite a PIM source not excited at lower power levels.

If either of the above were true, there would be a dilemma as to when to stop increasing the test power, because there would always be a level of uncertainty. Fortunately, based upon more than 15 years of real world experience, as well as theoretical analysis confirmed by experimentation, neither of the above is true.

Theoretically, the IM3 increases by 3 dB for every 1 dB increase in the carrier power. Although it is known from experience that the relationship is rarely 3 dB/dB in passive components, it is indeed linear. The slope will vary depending upon the characteristics of the PIM source, but it is always linear. To demonstrate, three different devices were measured with carrier powers from 33 dBm (2 W) up to 46 dBm (40 W) in 1 dB increments. The devices under test are a jumper cable built on site at a base station, a jumper cable build in the factory and a resistive termination (high PIM source). The test results are plotted in ***Figure 2***. Overlaid on each plot of the raw data is a best fit line. As can be seen, in all cases, the PIM is linear with power and testing at higher power does not result in the illumination of a PIM source that is not already excited at lower power—even all the way down to 2 W.

But what about the second condition postulated above; will testing at higher power cause an intermittent PIM source to show up that might not be seen at lower power? The answer is—possibly. But this is exactly why PIM testing must always be a dynamic test. Each component being manufactured in the factory and every joint and component comprising the base station infrastructure must be subjected to mechanical stress such as a tapping on connectors, tuning screws of filters, backplanes of antennas, etc.,



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OCTAVE BAND AMPLIFIERS								
AFS3-00120025-09-10P-4	0.12-.25	38	0.50	0.9	2.0:1	2.0:1	+10	125
AFS3-00250050-08-10P-4	0.25-0.5	38	0.50	0.8	2.0:1	2.0:1	+10	125
AFS3-00500100-06-10P-6	0.5-1	38	0.75	0.6	2.0:1	1.5:1	+10	150
AFS3-01000200-05-10P-6	1-2	38	1.00	0.5	2.0:1	2.0:1	+10	150
AFS3-01200240-06-10P-6	1.2-2.4	34	1.00	0.6	2.0:1	2.0:1	+10	150
AFS3-02000400-06-10P-4	2-4	32	1.00	0.6	2.0:1	2.0:1	+10	125
AFS3-02600520-10-10P-4	2.6-5.2	28	1.00	1.0	2.0:1	2.0:1	+10	125
AFS3-04000800-07-10P-4	4-8	32	1.00	0.7	2.0:1	2.0:1	+10	125
AFS3-08001200-09-10P-4	8-12	28	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-08001600-15-8P-4	8-16	28	1.00	1.5	2.0:1	2.0:1	+8	100
AFS4-12001800-18-10P-4	12-18	28	1.50	1.8	2.0:1	2.0:1	+10	125
AFS4-12002400-30-10P-4	12-24	24	2.00	3.0	2.0:1	2.0:1	+10	85
AFS3-18002650-30-8P-4	18-26.5	18	1.75	3.0	2.2:1	2.2:1	+8	125
MULTIOCTAVE BAND AMPLIFIERS								
AFS3-00300140-09-10P-4	0.3-1.4	38	1.00	0.9	2.0:1	2.0:1	+10	125
AFS2-00400350-12-10P-4	0.4-3.5	22	1.50	1.2	2.0:1	2.0:1	+10	80
AFS3-00500200-08-15P-4	0.5-2	38	1.00	0.8	2.0:1	2.0:1	+15	125
AFS3-01000400-10-10P-4	1-4	30	1.50	1.0	2.0:1	2.0:1	+10	125
AFS3-02000800-09-10P-4	2-8	26	1.00	0.9	2.0:1	2.0:1	+10	125
AFS4-02001800-24-10P-4	2-18	35	2.00	2.4	2.5:1	2.5:1	+10	175
AFS4-06001800-22-10P-4	6-18	25	2.00	2.2	2.0:1	2.0:1	+10	125
AFS4-08001800-22-10P-4	8-18	28	2.00	2.2	2.0:1	2.0:1	+10	125
ULTRA WIDEBAND AMPLIFIERS								
AFS3-00100100-09-10P-4	0.1-1	38	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-00100200-10-15P-4	0.1-2	38	1.00	1.0	2.0:1	2.0:1	+15	150
AFS1-00040200-12-10P-4	0.04-2	15	1.50	1.2	2.0:1	2.0:1	+10	50
AFS3-00100300-12-10P-4	0.1-3	32	1.00	1.2	2.0:1	2.0:1	+10	125
AFS3-00100400-13-10P-4	0.1-4	30	1.00	1.3	2.0:1	2.0:1	+10	125
AFS3-00100600-13-10P-4	0.1-6	30	1.25	1.3	2.0:1	2.0:1	+10	125
AFS3-00100800-14-10P-4	0.1-8	28	1.50	1.4	2.0:1	2.0:1	+10	125
AFS4-00101200-22-10P-4	0.1-12	34	1.50	2.2	2.0:1	2.0:1	+10	150
AFS4-00101400-23-10P-4	0.1-14	24	2.00	2.3	2.5:1	2.5:1	+10	200
AFS4-00101800-25-S-4	0.1-18	25	2.00	2.5	2.5:1	2.5:1	+10	175
AFS4-00102000-30-10P-4	0.1-20	20	2.50	3.0	2.5:1	2.5:1	+10	125
AFS4-00102650-42-8P-4	0.1-26.5	24	2.50	4.2	2.5:1	2.5:1	+8	135

Note: Noise figure increases below 500 MHz.

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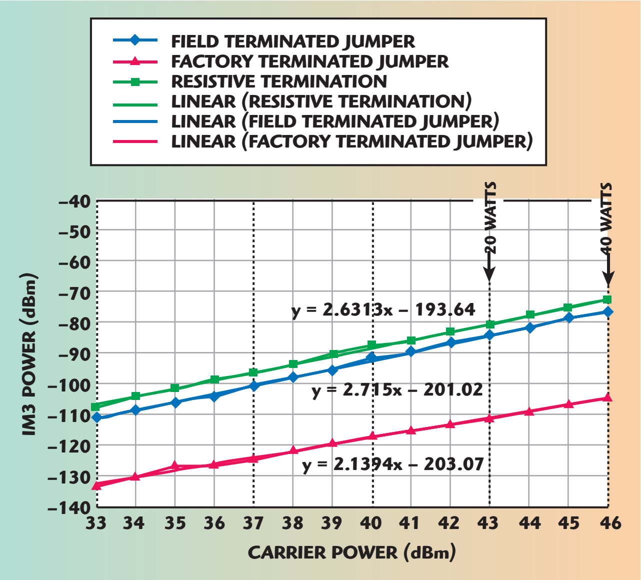
and light flexing of cable assemblies. If the component or site is not dynamically tested, the results are invalid.

So, if testing at higher power is not of benefit and PIM is a straight line, why not test at lower powers and adjust the PIM specification to compensate for the lower power? If feasible, this has the added benefit of reducing the potential RF hazard to test personnel. Testing at lower power levels may be acceptable in some cases—particularly for pretesting components—but currently site certification of the base station infrastructure is always done with 2 × 20 W.



▲ *Fig. 2 IM3 power vs. carrier power for three different devices under test.*

Testing Antennas Before Installation

Base station antennas have become increasingly complex as demands for network optimization require greater flexibility and versatility. What began as a simple array of linearly polarized dipoles has evolved into highly complex electrical and mechanical structures that support multiple bands, multiple polarizations and remotely variable radiation patterns. Now the advent of antennas that integrate the radio and the radiating elements is happening.

The complexity of these antennas means that there is a greater opportunity for mechanical failure during the transportation process. Consequently, it has become common practice to test and verify the PIM performance of the antenna prior to installation.

Accurate characterization of the antenna prior to installation requires keen awareness of the surrounding environment and the potential for creating PIM from external sources. Ideally, the antenna should be situated on a non-metallic structure at least one to two feet above the ground pointing straight up into the sky, as shown in ***Figure 3***. The area around the antenna must be clear of any metallic structures (fences, fork lifts and towers) that might cause PIM. The antennas cannot be tested inside a warehouse unless tested inside an anechoic chamber.

▲ *Fig. 3 Test set-up for antenna PIM measurement.*

CONCLUSION

Passive intermodulation has long been recognized as a potential impairment to the performance of telecommunications systems and was formalized as a quality metric by the IEC in 1999. Modern telecommunications systems are more dependent than ever on a "transparent" RF infrastructure to achieve their performance objectives. Realizing these goals is directly dependent upon the quality of construction of the components used in building the sites, and the quality of the interconnections that join them together. The most sensitive and effective parameter for determining construction quality is PIM. Consequently, PIM testing has become an essential part of the site certification process. ■

Rick Hartman *is President of North American operations at Kaelus Inc. (fomerly Summitek Instruments).*

WHITE PAPER

Agilent Technologies

Application of Agilent's PNA-X Nonlinear Vector Network Analyzer and X-Parameters in Power Amplifier Design

By Loren Betts, Agilent Technologies
and Dylan T. Bespalko and Slim Boumaiza, University of Waterloo, Canada

Recent improvements in semiconductor technology, such as laterally diffused metal oxide semiconductor (LDMOS) and gallium nitride high electron mobility transistors (GaN-HEMT), are empowering researchers to develop high-performance microwave circuits and systems. When operated in their nonlinear regions and properly terminated, these devices result in high-efficiency power amplifiers (PA).[1] Such developments underscore the need for accurate nonlinear characterization and modeling of radio frequency (RF) transistors to enable the predictable design of high-performance circuits and systems.

One solution offering an answer to this dilemma is Agilent Technologies' PNA-X vector network analyzer, the world's most integrated and flexible microwave test engine for accurately measuring active devices like amplifiers, mixers, and frequency converters in coaxial, fixtured, and on-wafer environments **(Figure 1)**. The PNA-X features an optional Nonlinear Vector Network Analyzer (NVNA) application for fast, accurate characterization and design of active devices and components.[2] The award-winning Agilent NVNA is the industry's first interoperable measurement and simulation environment for designing nonlinear components. Using the PNA-X's NVNA, X-parameters* are measured and then used to create X-parameter models that can be imported into Agilent's Advanced Design System (ADS), SystemVue, and Genesys to simulate actual linear and nonlinear component behavior. X-parameters represent a new category of nonlinear network parameters for deterministic, high-frequency design, which can be used to characterize both a components' linear and nonlinear behavior. Thanks to the PNA-X and its NVNA application, engineers and scientists can now have the highest level of insight into nonlinear device behavior. Let's take a closer look.

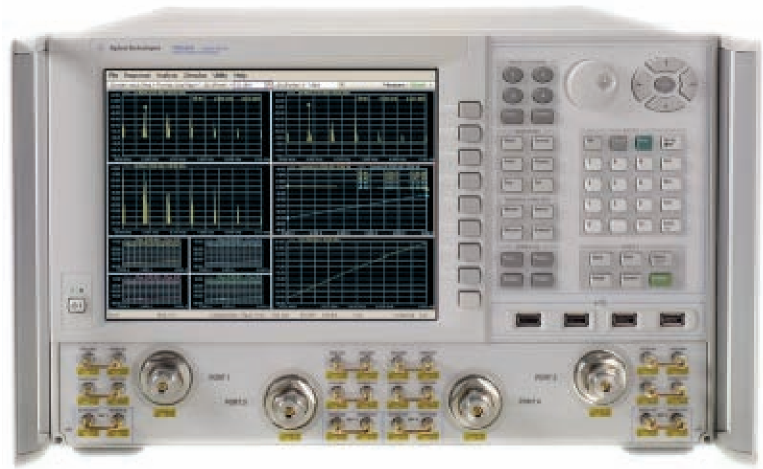


Figure 1. *Built on Agilent's 40-year legacy of technical leadership and innovation in RF network analysis, the PNA-X provides excellent passive measurements, and a variety of active measurements (e.g., nonlinear, gain compression, intermodulation distortion, and noise figure) with an unsurpassed combination of speed, accuracy and flexibility. Available in five frequency ranges: 13.5, 26.5, 43.5, 50, and 67 GHz, it enables today's engineers to realize higher levels of test integration, as well as reduced setup time, measurement complexity, time to make measurements, and test costs.*

** "X-parameters" is a registered trademark of Agilent Technologies. The X-parameter format and underlying equations are open and documented. For more information, visit: http://www.agilent.com/find/eesof-x-parameters-info.*

Wanted: Nonlinear Characterization

When driven with a stimulus that places a component in a nonlinear operating region, the component may generate distorted input and output currents and voltages (or traveling waves) that include multiple spectral components.

While device characterization provides accurate performance information under a given set of operating conditions, extracting a measurement-based simulation model of the transistor offers all-encompassing design insight and flexibility. Two alternative nonlinear device modeling approaches that have been investigated include compact and behavioral models.

Compact models are analytical models generated from device measurement data and are suitable for use in computer-aided design (CAD) simulations for circuit-level design. They are less amenable to system-level simulation where the design may consist of many circuit-level models and where the stimulus involved consists of complex modulated signals. Moreover, they are not always reliable for high powers and non-linear circuit design because they usually lead to intolerable disparities between predicted and measured performance. As a result, microwave circuit engineers —particularly PA designers—have been forced to choose between sometimes inaccurate and simulation-friendly compact models or an explicit measurement-based load-pull technique that does not support a robust simulation. This "broken link" in the design chain dramatically increases the cost and development time required. Bringing accurate device behavioral models into the simulation environment will empower circuit and system designers to develop advanced circuit topologies and system architectures in a systematic manner.

The X-parameter model is a sophisticated behavioral model that describes the linear and non-linear behavior of the component by describing the relationship between the input-output frequency spectrum on a multi-port device for a given large-signal operation condition.[3-6] The recent integration of X-parameter modeling with load-pull measurements allows PA designers to develop measurement-based behavior models of unmatched devices that can be imported into ADS. [7-8]

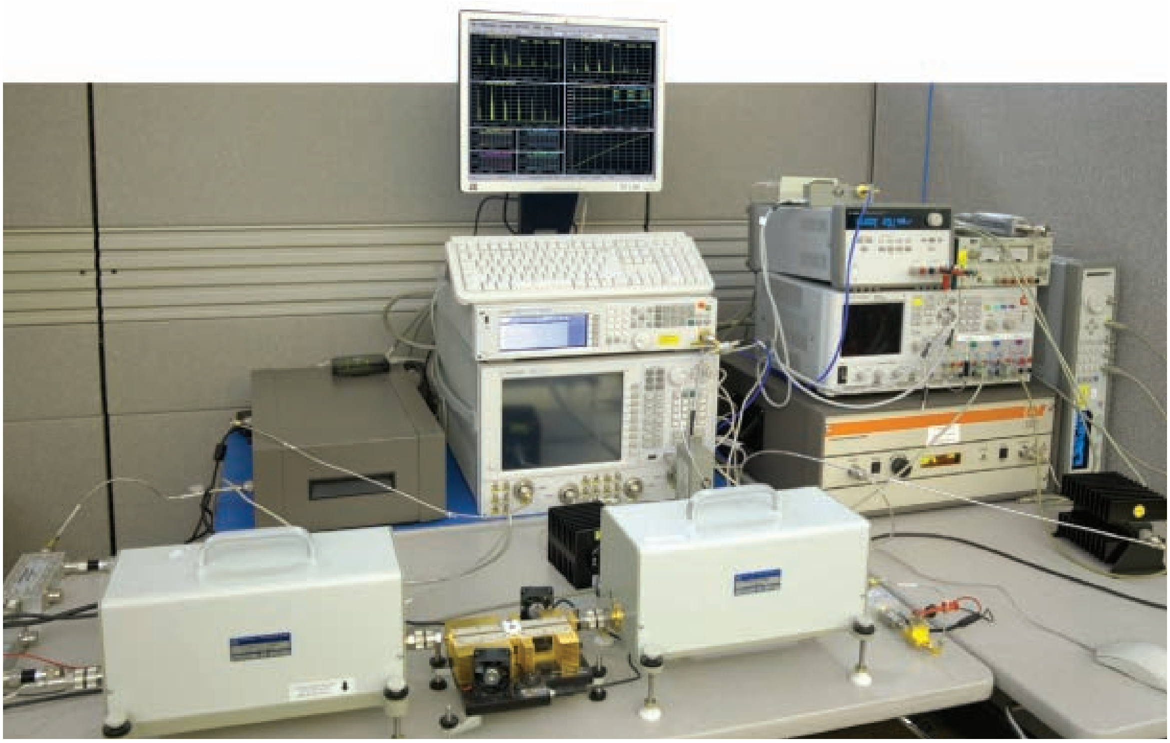


Figure 2. *The PNA-X with NVNA X-parameter high-power load-pull measurement configuration.*

Understanding the X-parameter measurement system

As an example of how to utilize a measurement-based X-parameter model, consider the design of a Class AB 45-Watt GaN amplifier, developed entirely inside the circuit simulator. The measurement system utilized in this example is shown in **Figure 2**. This setup is used to construct the X-parameters of a power transistor. It consists of the PNA-X with the NVNA firmware Option 510 (base NVNA firmware), Option 514 (X-parameters), and Option 520 (load-dependent X-parameter extension). The Agilent U9391C phase reference is also utilized to provide the cross-frequency phase calibration information that is critical to identify the X-parameter coefficients.

In addition to the NVNA, external hardware may be required to measure the X-parameters of a high-power unmatched transistor.[9] Internal signal-routing switches in the PNA-X allow connection of other test equipment to the device-under-test (DUT) via the network analyzer's test-port connectors **(see Figure 3 below)**.

Fundamental frequency	1.2 GHz
Harmonics	3
Gain	15 to 20 dB
Output power	45 Watts
Impedance	Unmatched
Bias	Gate (<5 Volts, <100 mA) Drain (<30 Volts, <3 Amps)

Table 1. *General transistor measurement characteristics*

To determine the required hardware, the component's general characteristics should be identified (for example, frequency, input power, output power, and DC bias). For the following analysis, the general requirements are listed in **Table 1.**

Since the transistor's output power (approximately 46 dBm) exceeds the maximum input power rating at the PNA-X test ports (typically 30 dBm, or 40 dBm with Option H85), external high power couplers must be connected to the front panel jumpers of the PNA-X to bypass the internal couplers. The external couplers utilized should cover the frequency range of the measurements (1.2 to 3.6 GHz) and handle up to 45 Watts of average power.

Because the transistor under test has a rated small signal gain of 15 to 20 dB, with a typical output power of about 46 dBm, it may require an input stimulus (large-drive) of about 30 dBm (1 Watt) to drive it to saturation. The measurement data is collected with the transistor driven by a pulsed RF signal (carrier frequency = 1.2 GHz, pulse width = 400 μs, and duty cycle = 1%). The NVNA X-parameter measurements, conducted with an input power of 10 dBm to 32 dBm, includes up to the first three harmonics. The X-parameter measurements (refer to the Appendix, *"The NVNA X-Parameter Measurement Sequence" on page 13*) require an additional measurement signal with a frequency up to the 3rd harmonic and therefore, a broadband pre-amplifier that covers up to three times the test frequency (1.2 GHz).

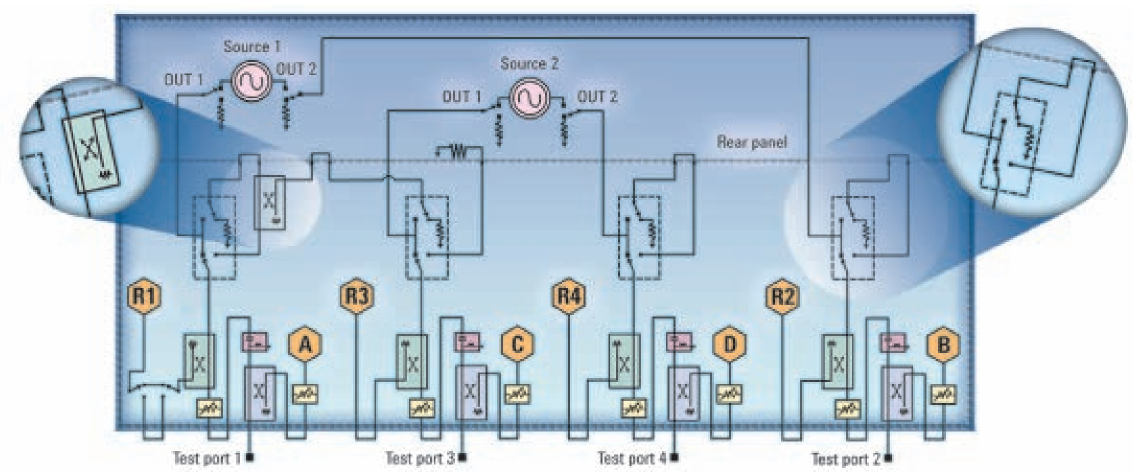


Figure 3. *Internal signal-routing switches in the PNA-X provide increased flexibility for adding signal conditioning hardware or additional test equipment for single connection measurements. They also enable alternate measurement paths, re-routing of signal paths and the addition of amplifiers, filters, and attenuators to optimize system setup.*

The X-parameter measurements also require an RF stimulus to be applied to the output port while the large drive signal is simultaneously provided to the input. This reverse stimulus signal must be approximately 20 dBc below the saturated output power of the transistor. Therefore, the expected saturated output power (approximately 46 dBm) requires a measurement signal on the drain of 26 dBm. If there is any additional attenuation between the drain and the second source of the PNA-X, additional power will be required. In this case, a 60-Watt driver was chosen that operates over the measurement bandwidth.

The input impedance of the unmatched transistor may be different than 50 Ohms. Consequently, obtaining the required input power at the gate of the transistor requires a source tuner. Additionally, a load-dependent X-parameter model requires a load tuner on the drain. Fundamental frequency source-pull is not required during X-parameter model extraction, since a power sweep is performed over a range of input powers at the fixed optimum input impedance (as provided by the source tuner). This measurement process is equivalent to keeping the source power fixed, while sweeping the source impedance provided to the transistor. The tuners also need to cover the bandwidth of the stimulus (up to 3.6 GHz) during the X-parameter measurements because the measurement stimulus must pass through the tuners before reaching the transistor.

Since the X-parameter extraction procedure performs phase-swept measurements at the harmonic frequencies, any variations of the harmonic source and load impedances are implicitly defined inside the X-parameter model. Therefore, independent control of the harmonic impedances may not be necessary for the X-parameter model extraction of the given nonlinear device. As a result, fundamental frequency tuners were chosen and must provide a gamma high enough to match the potential low impedance of the transistor.

The impedance tuners must be characterized using the tuner software and PNA-X before X-parameter measurements are performed. This characterization process provides a pre-computed configurable input impedance and an S-parameter model of the tuner. The S-parameter data is used to de-embed the tuners from the measured results so that the measurement is done at the transistor reference plane. Note that the tuner characterization is performed with a 50-Ohm impedance supplied by the PNA-X at both measurement ports. Based on this calibration, the tuner then provides an impedance transformation from 50 Ohm to an impedance designated by the user, under the assumption that a matched device is presented to the 50-Ohm port of the tuner. If this condition is not satisfied, such as when a poorly matched driver amplifier is connected, the calibration of the tuner is no longer valid and the mismatch of the driver must be characterized and taken into account.

A test fixture connects the transistor to the X-parameter measurement system. It consists of a 50-Ohm microstrip transmission line with the equivalent width of the packaging leads of the transistor so that the insertion loss between the transistor port and the impedance tuner is minimized. This ensures that a transistor without standard measurement connectors can be connected to the impedance tuners without jeopardizing the configurable impedance range of the tuners. Furthermore, this fixture can be calibrated using the PNA-X and the measurements can be de-embedded through the fixture to the package of the DUT.

For the chosen transistor characteristics, a gate voltage of less than 5 Volts (at less than 100 mA) and drain voltage less than 30 Volts (at less than 3 A) is anticipated. External high power bias networks were placed, before the tuners, on the gate and drain sides of the component to apply the necessary voltage and current coupled on the RF ports of the transistor.

Couplers	Mini-Circuits ZGDC10-362HP+
Input pre-amplifier	AR 5S1G4
Output pre-amplifier	AR 60S1G4
Tuners	Maury Microwave MT982
DC supply	Agilent N6705A (with N6752A (gate) and N6754A (drain) modules)

Table 2. *External hardware used for the measurements*

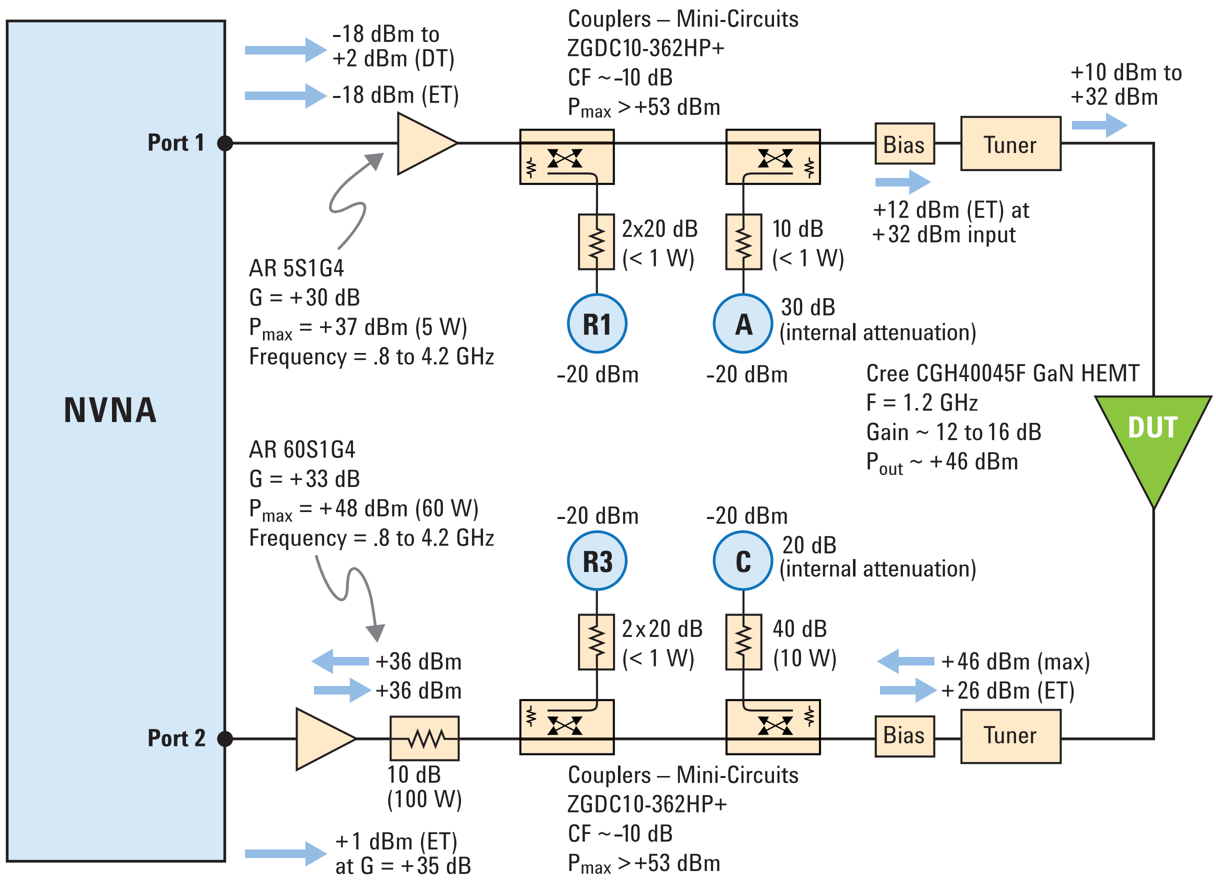


Figure 4. *The NVNA power budget.*

Table 2 lists the external hardware chosen for the measurements. Before measurements are performed, a power budget must be completed **(See Figure 4)**. This is done to ensure instrumentation is not damaged and all system components are operating in their linear range (e.g., no pre-amplifier compression or PNA-X receiver compression at peak powers).

The first step in the power budget is to determine the stimulus/response powers presented at the transistor ports and measurement receivers based on the component's specifications. Next, the required external components can be chosen to satisfy the high-power and receiver linearity requirements. Care should be taken when choosing the pre-amplifier that provides the forward and reverse RF stimulus. If the pre-amplifiers are saturated by the large-drive signal level (which determines the large-signal operating point of the X-parameter model extraction), then adding the extraction signal will result in an invalid model extraction. Therefore, the X-parameters will appear to be incorrect at the higher drive level powers. This is generally seen during a power sweep when there is a divergence between the simulated (X-parameters) and measured results at the higher input power levels. The maximum RF power at the receiver should be limited to –20 dBm for best receiver linearity. Appropriate external and internal attenuation is chosen to meet this requirement based on the power budget shown in **Figure 4.**

Calibration

Once the power budget is computed and the necessary instrumentation is connected, the PNA-X's NVNA can be calibrated. The NVNA calibration consists of three steps: vector calibration using a vector calibration kit or ECal, amplitude calibration using a power sensor and cross-frequency phase calibration using a phase reference.

The pre-amplifiers behind the couplers are often removed during calibration and then inserted back into the measurement system after the calibration procedure is complete. This does not invalidate the calibration since an eight-term error model is utilized in the NVNA. However, adding the pre-amplifiers may affect the tuner characterization. Consequently, the source and load impedances behind the tuners should be measured with the NVNA and must be accounted for to ensure that the impedance presented to the component by the tuners corresponds with the predicted impedance in the tuner characterization file. This process is usually part of the tuner software.

X-parameter verification

When it comes to X-parameter verification, one of the first things to confirm is that the measured X-parameter model is valid in the expected stimulus/response range. This is accomplished by comparing simulated performance using the X-parameter model against the measured performance of the actual component. If the actual measured performance is the same as the simulated one, then the X-parameter model is valid.

When comparing simulated versus measured performance, it is critical that the source and load impedance terminations at the fundamental and harmonic frequencies in the simulation match the impedances that are used during the measurement. The impedances chosen were not the same as those used to create the X-parameter model. As discussed in the previous section and in the Appendix, *"The NVNA X-Parameter Measurement Sequence,"* the component behavior versus harmonic source and load impedances is implicitly defined in the X-parameter model and identified during the application of the measurement signal. At the fundamental frequency, the application of physical impedance from a tuner was used to generate load-dependent X-parameters. Therefore, the X-parameter model is valid over a full gamma at the harmonic source and load impedances, and valid over the fundamental frequency load 'grid' conditions presented by the tuner. The impedances are shown in the simulation network depicted in **Figure 5. Figure 6** illustrates a comparison between the measured and simulated delivered power and thus, validates the behavior of the model.

Designing the power amplifier

To design a Class AB 45-Watt GaN amplifier, the Cree CGH40045F GaN-HEMT transistor was employed. **Table 3** contains a performance overview of the transistor taken from its datasheet.

A design frequency of 1.2 GHz was chosen so that a third-order X-parameter model could be generated using the X-parameter extraction setup described in **Figure 4,** page 5. Before the X-parameters are extracted, the DC quiescent point must be set. A Class AB operation was chosen for the targeted PA. Corresponding supply voltages are listed in **Table 4.**

Frequency	Up to 4 GHz
Gain (small signal)	15 to 20 dB
Psat (typical)	45 Watts
Drain efficiency (typical)	55%

Table 3. *Cree CGH40045F transistor specifications*

Frequency	1.2 GHz
VGS	-2.87 V
VDS	28.0 V
IDS_Q	400 mA

Table 4. *Class AB bias conditions for X-parameter model extraction*

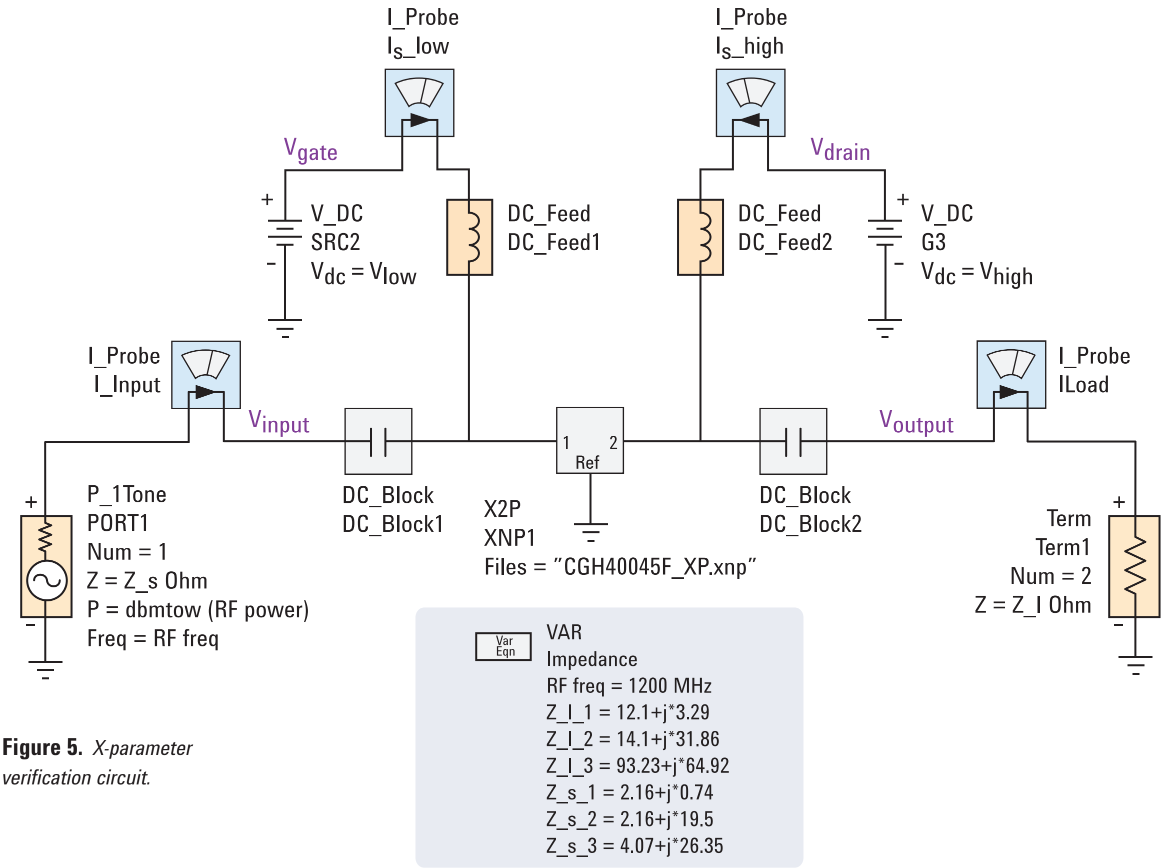


Figure 5. *X-parameter verification circuit.*

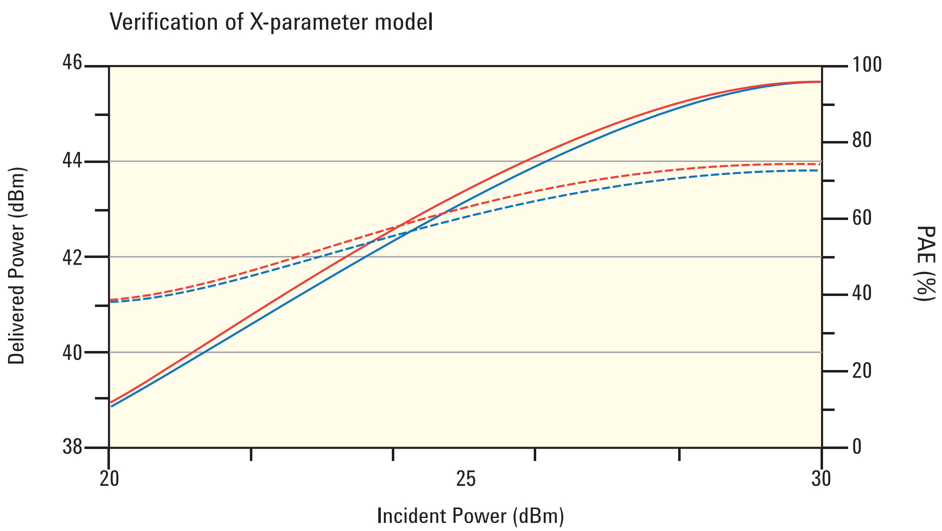


Figure 6. *X-parameter verification results.*

Source/load-pull X-parameter simulations

Source and load-pull simulations were conducted based on the measured X-parameter model to determine the optimal impedance matching conditions. The X-parameter model provides an implicit prediction of the harmonic source and load impedance variations. The simulated source and load-pull contours for the first three harmonics are presented in **Figure 5**. In this case, a compromise was struck between maximizing output power and maximizing power-added-efficiency (PAE) to ensure that suitable output power, greater than 45 dBm, would be obtainable. Given this trade-off, the results in **Figure 7** demonstrate the maximum PAE and output power that can be achieved with harmonic matching networks that have explicit control over the 2nd and 3rd harmonic impedance at the source and the load of the transistor.

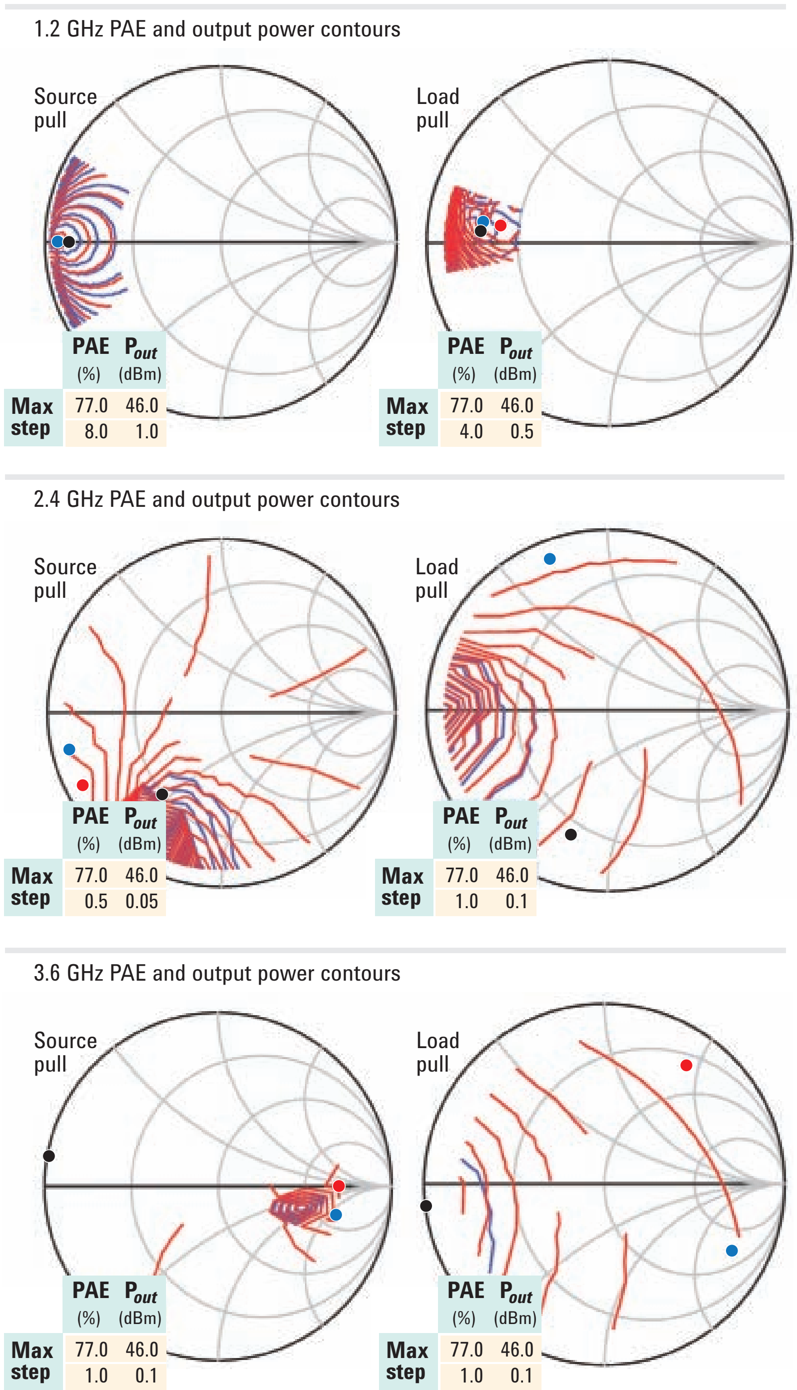


Figure 7. *Source and load-pull simulated contours of the first three harmonics.*

Legend

- Red line: Power added efficiency contours
- Blue line: Output power contours
- Red dot: Maximum power added efficiency impedance condition
- Blue dot: Maximum output power impedance condition
- Black dot: Matching network impedance condition

Matching networks and simulation results

The matching networks for the PA were designed using a variable-width, sequential transmission line topology and were simulated using the RF-ADS harmonic balance simulator, followed by electromagnetic (EM) simulations that were run in Momentum-ADS. This type of matching network guarantees optimal matching at the fundamental frequency; however, it provides limited control over the source and load impedance that is presented to the device at the harmonic frequenci es. Therefore, this simple matching network cannot provide the maximum efficiency predicted in the harmonic source/load-pull simulations of **Figure 7**. Instead, a more sophisticated harmonic matching network would be required.

Since the purpose of this article is to demonstrate the application of X-parameters modeling tech nology in PA design it was beneficial to use a simple matching network topology to minimize fabrication related errors. Furthermore, the size of the input and output tab of the transistor (0.22" x 0.25") behaves as a capacitance that effectively short-circuits the third harmonic impedance on the gate and drain. For these practical reasons, it was impossible to design a matching network that has the same harmonic impedances as the simulated source and load-pull analysis.

The matching networks shown in **Figure 8** below include integrated microstrip bias networks that are constructed from a bank of capacitors, and a quarter-wavelength transmission line, which ensure that RF leakage does not occur through the bias network. The source and load impedance presented by the matching networks are listed in **Table 5** and are indicated by the black dots in **Figure 7**.

Frequency	Source impedance (Ω)	Load impedance (Ω)
1.2 GHz	3.03 - j0.07	8.85 + j2.42
2.4 GHz	16.5 - j23.4	12.7 + j36.1
3.6 GHz	0.08 + j4.53	0.20 + j2.85

Table 5. *Matching conditions provided by the impedance matching networks*

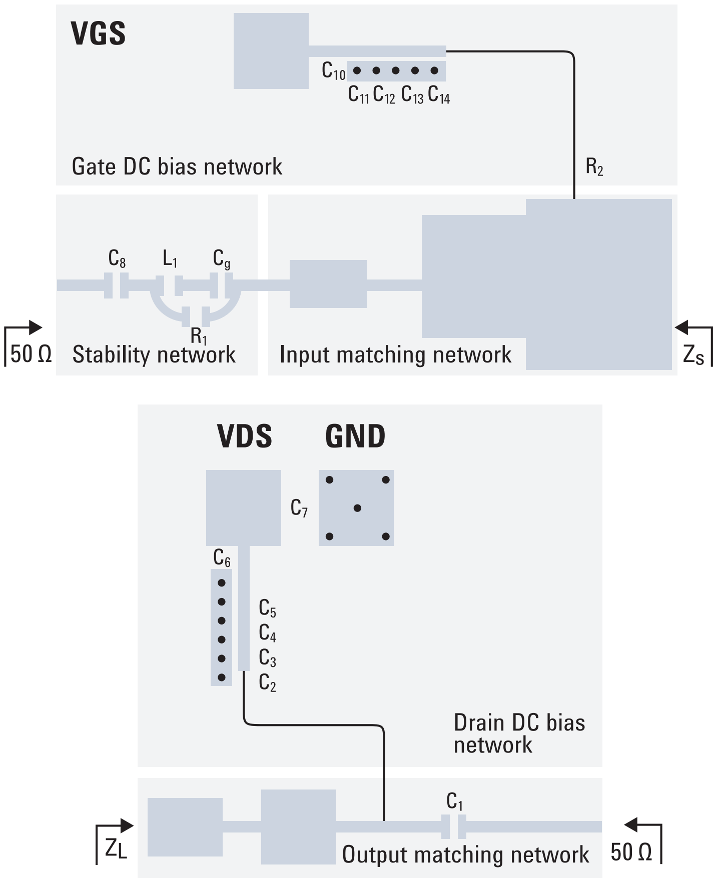


Figure 8. *Input and output matching network design.*

To predict the effects of connecting the input and output matching networks to the transistor ports, a PA simulation design was created by combining the matching networks (as a Momentum-ADS component) and the X-parameter model inside a single simulation. From this simulation, the overall performance of the PA was simulated at the reference plane outside of the matching networks as shown in **Figure 9**. The final simulation results of the PA are listed in **Table 6**

Figure of merit	Value
Input power	30 dBm
Drain efficiency	64.1%
PAE	62.3%
Output power	45.3 dBm

Table 6 *Power amplifier simulation results*

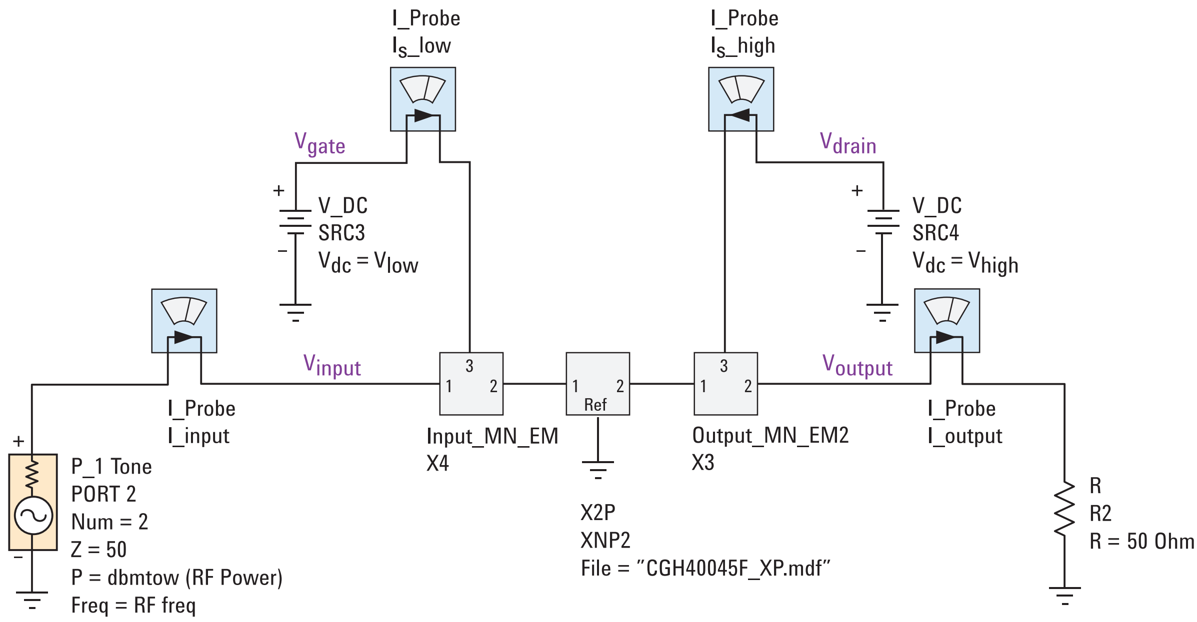


Figure 9. *Power amplifier simulation schematic.*

Comparing the results

The PA was fabricated **(Figure 10)** and measured using the NVNA. **Table 7** compares the simulated results to the measurement results at a fixed input power at 30 dBm.

The measurements show excellent correlation with the simulation results and demonstrate that the X-parameter model prediction is accurate to within 1% of the measured drain efficiency and 0.4 dB of the measured output power. Consequently, the measurement results prove that the X-parameter model is a viable solution for modeling high-power unmatched nonlinear devices.

Figure of merit	Simulation results	Measurement results
Input power	30 dBm	30 dBm
Drain efficiency	64.1%	64.6 %
PAE	62.3%	62.6 %
Output power	45.3 dBm	44.93 dBm

Table 7. *Power amplifier measurements versus simulation results*

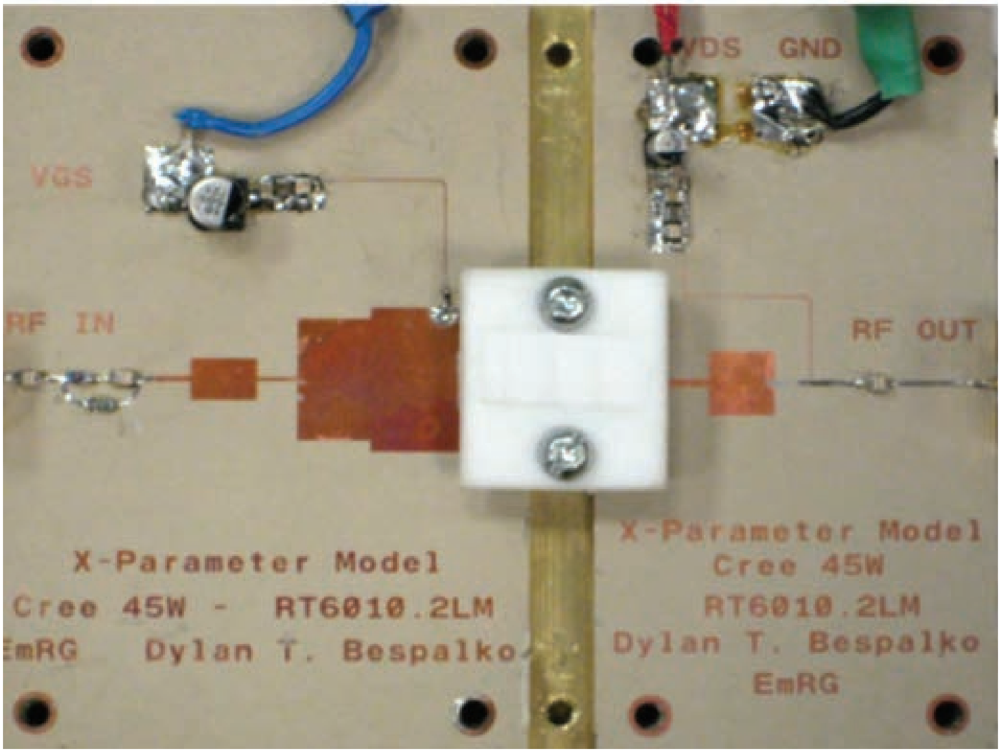


Figure 10. *A 45-Watt Class AB power amplifier.*

Conclusion

Traditionally, barriers have existed between device characterization and modeling and microwave circuit design. Luckily, a new approach to bridging this gap has now been proposed that can be extremely helpful in streamlining the high-power amplifier design process.

Using the example of a Class AB 45-Watt GaN amplifier, the first step of this process combines load-pull characterization with the advantages of Agilent's NVNA application for the PNA-X network analyzer to generate an X-parameter model of an unmatched 45-Watt GaN device that is imported into the ADS simulation software. The resulting model is used to identify adequate source and load matching networks to be presented to the transistor. In this article, the design was simulated using the RF-ADS harmonic-balance analysis and the ADS dynamic link with the accurate EM simulator Momentum, to accurately synthesize the biasing and matching networks. When compared to the simulation results, the measurement results for the fabricated PA prototype were in excellent agreement. Consequently, this example demonstrates the true power of bringing accurate device behavioral models into the simulation environment to systematically develop advanced circuit topologies and system architectures.

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Appendix

The NVNA X-Parameter Measurement Sequence

Linear scattering parameters (S-parameters) describe the linear behavior of a component and can be used to design predictable linear systems **(Figure A)**. They relate the incident independent 'a' waves to the reflected dependent 'b' waves at the component input and output ports. For a two-port component, the S-parameter can be written as two independent equations with four unknowns (S_{11}, S_{21}, S_{12}, and S_{22}). A vector network analyzer (VNA) is utilized to measure the 'a' and 'b' waves at the component to determine a solution for the S-parameters. This is typically done by performing a forward and reverse stimulus sweep on the component, which provides a set of four independent equations for the four unknowns. The S-parameters, by definition, cannot change versus the stimulus drive direction when determining the solution. This is often the case for a component that exhibits nonlinear behavior.

When measuring a component that exhibits non-linear behavior, the definition of the linear scattering model is no longer valid. Examples of nonlinear component behavior are multiple input and output frequencies (harmonics) generated by the component, or changes in the linear scattering parameters as previously discussed. A new model must be generated that accurately encompasses both the linear and nonlinear characteristics of the component.

Figure B shows an example realization of this model consisting of scattering coefficients called X-parameters. Like S-parameters, X-parameters relate the incident independent 'a' waves to the reflected dependent 'b' waves, but across the full linear and nonlinear component behavior.

$$b_i = \sum_k S_{ik} \cdot a_k$$

$$b_1 = S_{11} a_1 + S_{12} a_2$$

$$b_2 = S_{21} a_1 + S_{22} a_2$$

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$\begin{bmatrix} b_1^{fwd} & b_1^{rev} \\ b_2^{fwd} & b_2^{rev} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1^{fwd} & a_1^{rev} \\ a_2^{fwd} & a_2^{rev} \end{bmatrix}$$

$$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \begin{bmatrix} b_1^{fwd} & b_1^{rev} \\ b_2^{fwd} & b_2^{rev} \end{bmatrix} \begin{bmatrix} a_1^{fwd} & a_1^{rev} \\ a_2^{fwd} & a_2^{rev} \end{bmatrix}^{-1}$$

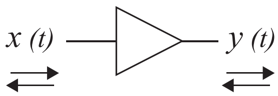

Figure A. *Scattering parameters—linear systems S-parameters.*

Definitions

i = Output port index
j = Output frequency index
k = Input port frequency
l = Input frequency index

$$b_{ij} = X_{ij}^{(F)}(DC, |A_{11}|, \Gamma_2)\, P^{j} + \sum_{k,l \neq (1,1)} \left(X_{ij,kl}^{(S)}(DC, |A_{11}|, \Gamma_2)\, P^{j-l} \cdot a_{kl} + X_{ij,kl}^{(T)}(DC, |A_{11}|, \Gamma_2)\, P^{j+l} \cdot a_{kl}^{*} \right)$$

For example: $X_{21,21}^{T}$

Means: Output port = 2
Output frequency = 1 (fundamental)
Input port = 2
Input frequency = 1 (fundamental)

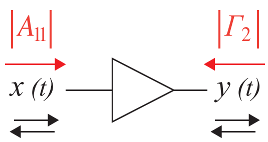

Figure B. *Scattering parameters—nonlinear systems X-parameters.*

Definitions

i = Output port index
j = Output frequency index
k = Input port frequency
l = Input frequency index
$|A_{11}|$ = Large signal drive to the amplifier input port (port #1) at the fundamental frequency (#1)
$|\Gamma_2|$ = Load dependent X-parameters with variable gamma at port #2

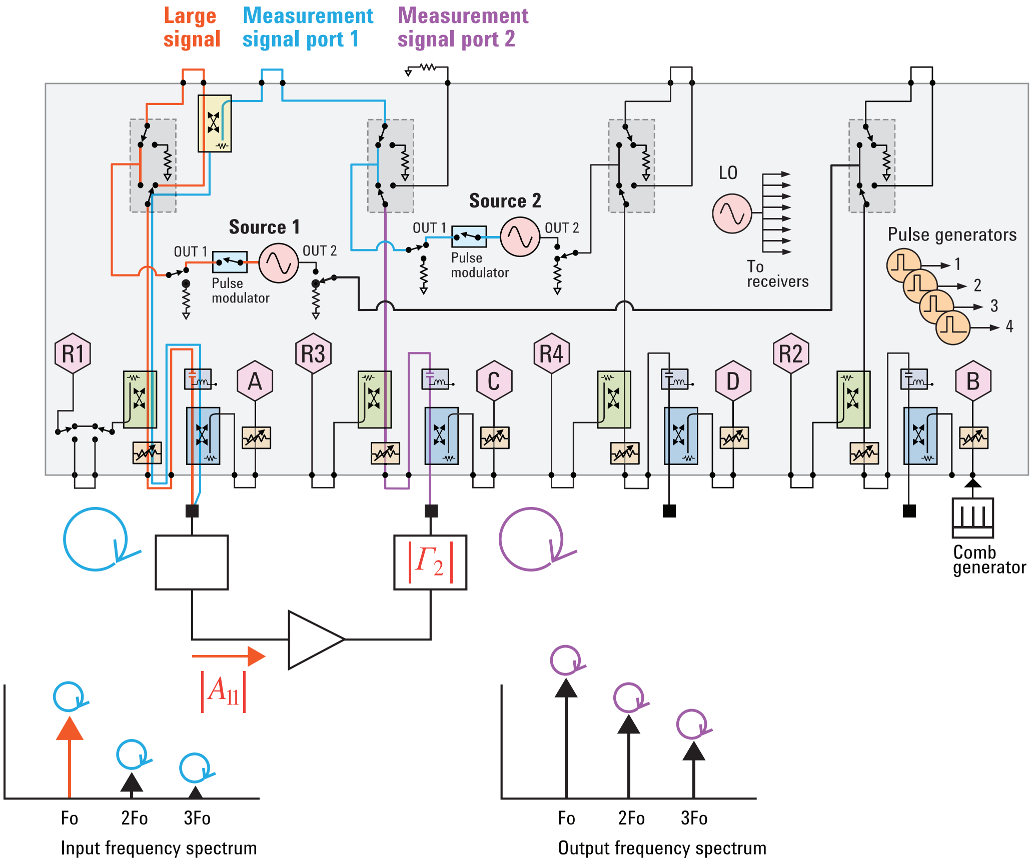

Figure C. *The sequence used by the Agilent PNA-X with NVNA application to measure X-parameters.*

As an example, consider that an amplifier is stimulated with a large-drive signal from one source on its input port that sets a specific large-signal-operation-point (LSOP). The X-parameters are measured utilizing a second source. The input power of the large-drive signal is then swept across the linear and nonlinear range of the component. At each input power point, a set of X-parameters is generated that are mathematically and analytically correct over the full linear and nonlinear range of the component.

The Agilent PNA-X network analyzer with the NVNA software application is used to measure the X-parameters following the sequence illustrated in **Figure C.** To simplify the analysis, the input large signal is assumed to be set at a single frequency and power level. During the measurement process, the following steps are taken:

Step 1:
A large drive signal is applied only to the PNA-X's port 1.

Step 2:
Simultaneously with the large signal on port 1, the measurement signal is applied to port 1 sequentially to all fundamental and harmonic frequencies. At each frequency, the phase is rotated at steps around 360 degrees.

Step 3:
Simultaneously with the large signal on port 1, the measurement signal is applied to the PNA-X's port 2 sequentially to all fundamental and harmonic frequencies. At each frequency, the phase is rotated at steps around 360 degrees.

The 'a' and 'b' waves are measured at each stimulus change (e.g., port, frequency and phase) in the large drive and measurements signals. Once all the sequences are complete, the resulting waves are utilized to identify the X-parameters.

Authors

Loren Betts, Ph.D. is currently a research scientist and senior engineer at Agilent Technologies focusing on complex stimulus/response measurements and modeling of nonlinear components utilizing vector network analyzers. He co-developed the pulse measurement detection algorithms utilized in current Agilent PNA and PNA-X VNAs. Loren holds a B.Sc. degree in computer engineering and M.Sc. and Ph.D. degrees in electrical engineering. His Ph.D. research focused on the PNA-X NVNA.

Dylan T. Bespalko is a Ph.D. student at the University of Waterloo, ON, Canada, (B.Sc. Electrical Engineering '07 University of Calgary) and is a member of the Emerging System Research Group. His research is devoted to measurement-based characterization and modeling of high-power nonlinear devices for applications in the development of sophisticated multi-standard RF front-end design.

Slim Boumaiza is an associate professor with the Department of Electrical and Computer Engineering, University of Waterloo, Waterloo, ON, Canada, where he is leading the Emerging Radio System Research Group that is conducting multidisciplinary research activities in the general areas of design of RF/microwave and millimeter components and systems for wireless communications. His specific current research interests include RF/DSP mixed design of intelligent RF transmitter; design, characterization, modeling and linearization of high efficiency power RF amplifiers, reconfigurable and software defined transceivers.

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Nonlinear Reference Website

Get the latest nonlinear reference information, download a free copy of *"High Power Amplifier Measurements Using Agilent's Nonlinear Vector Network Analyzer,"* (App Note 1408-19), and find pertinent X-parameter and nonlinear technical papers at: **www.agilent.com/find/nonlinear**

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METHODS FOR CHARACTERIZING THE DIELECTRIC CONSTANT OF MICROWAVE PCB LAMINATES

Copper clad laminates used in the microwave Printed Circuit Board (PCB) industry have many properties of concern. The dielectric constant (relative permittivity or ε_r) is one of the most critical. Many design engineers have made the assumption that this property is a rigid value; however, often that is not the case. The suppliers of copper clad laminates give the ε_r value on the product datasheet with accompanying information regarding the test method and testing frequency. One confounding issue is that the ε_r value of a particular material using one test method may not be the same value when testing the exact same material while using a different test method. Another concern is by the nature of the microwave circuit design, the fields within the material could be significantly different as compared to the method used to generate the ε_r value and this could give unexpected results as well.

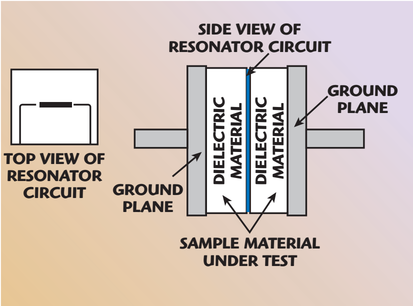
This article will give an overview of the most common test methods used to determine the ε_r value for microwave laminates. The limits and capabilities of these tests will be demonstrated as well. Several other electrical characterization techniques will be discussed, which are typically employed by means of simple microwave circuit evaluations.

GENERAL TEST METHOD AND CONSIDERATIONS

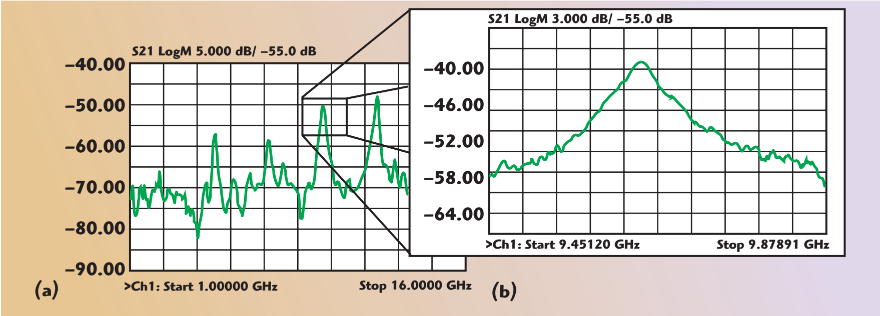
In a very broad sense there are two different types of electrical characterization techniques for microwave PCB laminates; one is a method using resonance and the other is using transmission/reflection techniques. Resonance methods are typically more accurate for determining ε_r; however, they are limited to a specific frequency or a few discrete frequencies. The transmission/reflection methods usually yield results over a range of frequencies. Both of these general test procedures are usually done in frequency domain; however, there are derivatives of both using time domain. In this article, frequency domain techniques will be considered.

Understanding electromagnetic field orientations within the material under test can be very important in assessing how applicable the resultant ε_r value from a test method is related to a given microwave application. For example, assuming a test method that generated an ε_r value within the x-y plane or the length-width plane of the material and not the z-axis (thickness) and if the microwave application has fields that are dominant in the z-axis, then the given ε_r value may have significant accuracy issues for that particular application. The significance is really related to several factors, some of which are the sensitivity of the circuit application as well as the anisotropic ε_r nature of the laminate. A laminate with higher anisotropy will have a larger difference in ε_r when comparing values of the x-y plane to the z-axis. It is common for laminates used in the PCB industry to have some level of anisotropy. Sometimes this is due to layers of glass fiber within

JOHN COONROD
Rogers Corp., Rogers, CT



▲ *Fig. 1 Simple drawing of the X-band clamped stripline resonator test.*



▲ *Fig. 2 Broadband frequency response of X-band clamped stripline resonator: (a) and isolated resonant frequency peak at approximately 10 GHz (b).*

the laminate used for mechanical stabilization.

COMMON TEST METHODS TO DETERMINE ε_r

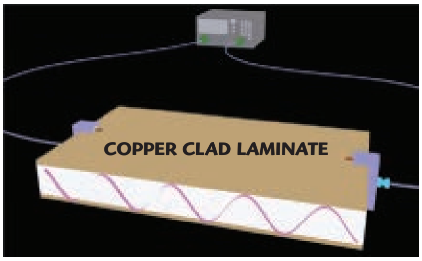
There are typically two test methods that are most often employed by the laminate suppliers to determine dielectric constant. Both of these test methods are defined in the IPC-TM-650 2.5.5.[1]

The first method discussed uses a stripline resonator and is intended to determine the z-axis ε_r value of the material under test. The method is tailored toward the testing of raw laminate in a high volume manufacturing environment. Because of the design of this test method, the ε_r value may or may not apply to a microwave application. The test procedure is per IPC-TM-650 2.5.5.5c and can be found at www.ipc.org. Essentially, the procedure is to have two samples of the material to be tested placed on both sides of a thin resonator circuit and have two ground plates apply pressure from both sides. The outer clamping plates act as the ground planes for the stripline structure, with the resonator circuit pattern in the middle and the material under test making up the dielectric layers (shown in ***Figure 1***).

The circuit pattern is designed to have the resonator element with a physical length of two wavelengths at 10 GHz, given a target ε_r value and a defined dielectric thickness. This test method is capable of determining the ε_r value and the dissipation factor of the material under test at frequency intervals of ½ wavelengths up to about 12.5 GHz. Typically, the resonant peak at 10 GHz is evaluated; this is shown in the detailed view of ***Figure 2b***.

There are two potential issues for this test method. One is that some amount of air can be entrapped with the material under test and the meth-

od reports a lower than expected ε_r value. This issue is exaggerated when a laminate using a high profile copper is tested, due to the samples having more surface area when the copper is removed prior to the test. The second potential issue is the anisotropy effects of the material under test. The resonator circuit design is purposely loosely coupled in order to realize the Q of the material more so than the Q of the overall resonator circuit. The coupling is done by a gap coupling on the resonator circuit pattern and in the gap areas there is higher concentration of fields. It is in these areas where the anisotropy effects of the laminate can alter the center frequency of the resonator and cause a potential difference in the ε_r calculation. The fields in the gap area utilize the x-y plane properties of the material under test, whereas the element of the resonator is generally using the z-axis of the



▲ *Fig. 3 Basic illustration of the full sheet resonance test method.*

material. The calculation for ε_r for this test method follows:

$$\varepsilon_r = \left[\frac{nc}{2f_r\left(L+\Delta L\right)}\right]^2 \tag{1}$$

where n is the resonant frequency node, c is the speed of light in a vacuum, f_r is the resonant frequency, L is the physical length of the resonator element and ΔL is the added length in the gap coupled areas for the effects of electric field fringing.

The second common test method used in determining the ε_r of a high frequency laminate is the Full Sheet Resonance (FSR) test method. This is also defined by an IPC test method: IPC-TM-650 2.5.5.6. This method is a non-destructive test as opposed to the stripline test, which requires the sample to have the copper etched completely off prior to testing the sample. The FSR test method determines the ε_r value of the laminate in the z-axis; however, it does not determine the dissipation factor. The method basically uses the copper clad laminate under test as an open walled parallel plate waveguide and evaluates an established standing wave. A simple drawing to illustrate the test set up is shown in ***Figure 3***.

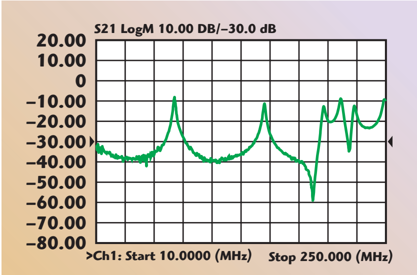
From the resonant frequency peak of a standing wave, the ε_r of the laminate can be determined. As with many resonator test methods, there are several resonant peaks to evaluate. However, most will be at a relatively low frequency for this test. A standing wave frequency peak and specifically the associated wavelength are directly related to the physical size of the panel. Most panels under test are 24" × 18" in size; therefore, the first dominate mode resonant peak will occur on the length axis of the panel and will be a long wavelength and thus a low frequency. It is common to have the

first few measureable resonant peaks to be in the range of 100 to 300 MHz and a broadband image of a panel under test is shown in ***Figure 4***.

The FSR test method does not have the issue of the entrapped air or anisotropy effects mentioned for the clamped stripline test; however, it does have limits. The low frequency testing will be less sensitive to some high frequency effects on determining ε_r. One such effect is related to the copper surface roughness of the laminate, where it was found that the propagation constant can be affected by the copper roughness and therefore the apparent ε_r value is affected as well.[2]

The simple calculation for the ε_r value of a panel under test using the FSR method is given:

$$\varepsilon_r = \left(\frac{c}{2f_r}\right)^2 \left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right] \qquad (2)$$



▲ *Fig. 4 Broadband frequency response of a panel under test using the FSR test method.*

where c is the speed of light in a vacuum, f_r is the resonant frequency, and m and n are the resonant frequency nodes that relate to physical length (L) and width (W), respectively.

There are other common test methods used to evaluate the ε_r value of a PCB laminate and one that has become more popular lately is the Split Post Dielectric Resonator (SPDR) test method. This method uses perturbation methodologies with comparing resonant frequency peaks of the empty resonator verses a loaded resonator. The loaded resonator is a sample of the raw laminate with the copper fully removed. The SPDR test evaluates the ε_r value of the sample under test in the x-y plane only. This is a fast and user friendly test; however, it has a limit of the accuracy for the ε_r value being directly related to the accuracy of the thickness measurement of the sample.

It has been suggested that a good general indicator for anisotropy of a laminate is to use the combination of the SPDR test and either the clamped stripline test or the FSR test. The SPDR test will evaluate the ε_r value of the laminate in the x-y plane, whereas the other two tests evaluate the z-axis of the material.

COMMON MICROWAVE CIRCUIT EVALUATIONS FOR DETERMINING ε_r

There have been a multitude of techniques defined to determine the ε_r value of a laminate by means of microwave circuit evaluations. Typically, a circuit will be designed and modeled for a very specific response, with the assumption of a particular ε_r value of the laminate, while trying to minimize all other effects on the circuit performance.

Three methods will be discussed here that utilize relatively simple microwave circuitry and have been prov-

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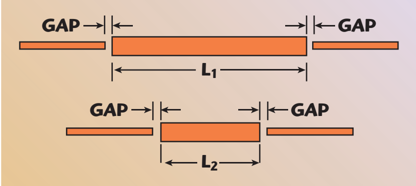
en to yield accurate results for ε_r characterization of a laminate. Due to the depth of information regarding these methods, the first will be discussed in an introductory manner with the appropriate references given for further investigation by the interested reader; the other two will be given with more functional detail.

A test method has been defined that uses a special microstrip resonator circuit to evaluate the ε_r values of a laminate in the x-y plane as well as the z-axis. The method was developed by Sonnet Software Inc. and its procedure and supporting data is explained in detail with several papers.[3-5] The special resonator is a long edge coupled microstrip dual-mode resonator known as a RA Resonator. The circuit is relatively simple to fabricate and offers an accurate means to acquire the ε_r values of a laminate in multiple planes while using the same test circuit.



▲ *Fig. 5 Drawing of top view for two microstrip gap coupled resonators of different lengths.*

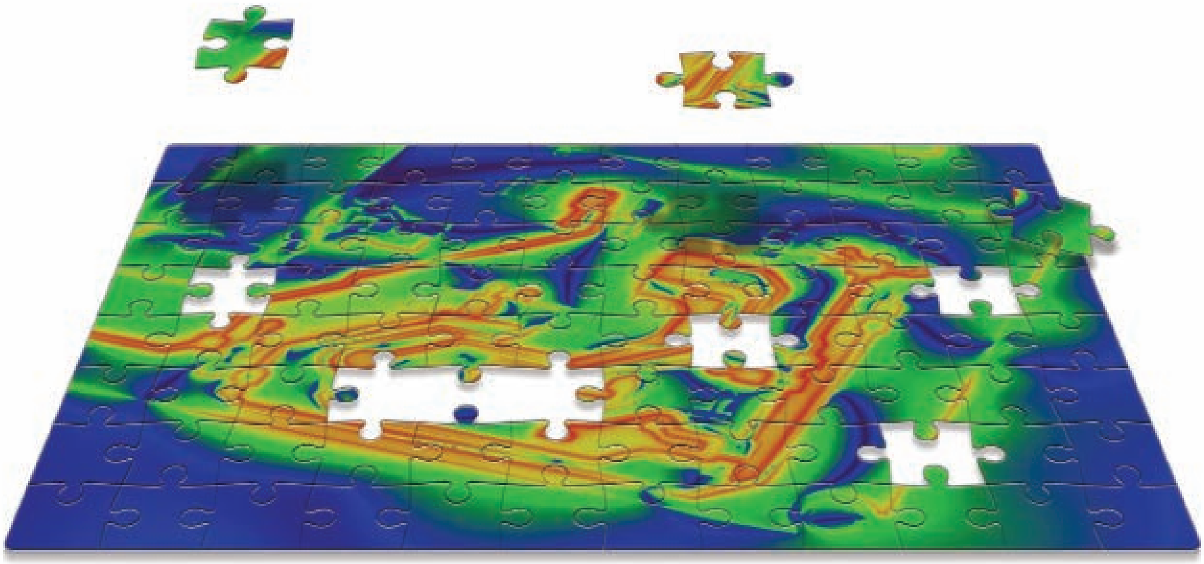
The next test method uses a pair of microstrip circuits to generate a relatively accurate ε_r value at several discrete frequencies. A simple gap coupled microstrip resonator has been used for many years with a few concerns. The major concern has been related to the gap coupling. The resonator should be loosely coupled to better realize the Q of the material, in order to get a more accurate determination of the ε_r value. If the resonator is too loosely coupled, the resonant peak can be distorted and a good measurement compromised. If it is not loosely coupled enough, the resonant peak may shift in frequency and cause the calculation of the ε_r to have some error. Also, since the gap coupling is a microstrip discontinuity, there is a concern for radiation losses adversely affecting the determination of the dissipation factor. With the following technique, the gap coupling concerns have been addressed.

Two microstrip gap coupled resonators are made on the same substrate and within very near proximity of each other. The resonators should be the same in every way, with the only exception being the resonator element length. One circuit should be significantly longer than the other, as shown in ***Figure 5***.

To determine the effective ε_r value of one of these resonators (1) is to be used and in that formula ΔL, is the added length of the resonator due to fringe effects in the gap area. With two resonators of different lengths using the same gap (ΔL), the effects of the gap can be eliminated. This is done by rewriting (1) for each of the two resonators, rearranging terms and finally solving the ΔL item to be eliminated follows:

$$\mathrm{Eff\_}\varepsilon_r = \left[\frac{nc}{2f_r\left(L+\Delta L\right)}\right]^2 \quad (3)$$

$$L_1 + \Delta L = \frac{n_1 c}{2f_{r1}\sqrt{\mathrm{Eff\_}\varepsilon_r}} \quad (4)$$



$$L_2 + \Delta L = \frac{n_2 c}{2 f_{r2} \sqrt{Eff\_\varepsilon_r}} \quad (5)$$

$$Eff\_\varepsilon_r = \left[\frac{c(n_1 f_2 - n_2 f_1)}{2 f_1 f_2 (L_2 - L_1)} \right]^2 \quad (6)$$

Since ΔL has a small dependence on frequency, it is desired that f_1 and f_2 are relatively close in value. This is typically done by designing the resonator lengths to be integral multiples of each other and measuring higher order nodes of resonance. Back calculating the ε_r value from the effective ε_r has been done with the use of close form equations from Hammerstad and Jenson[6] or field solving techniques.

This test method is further described in a book[7] regarding electrical characterization techniques of high frequency materials and a plot of results when using a common high frequency laminate is shown in ***Figure 6***.

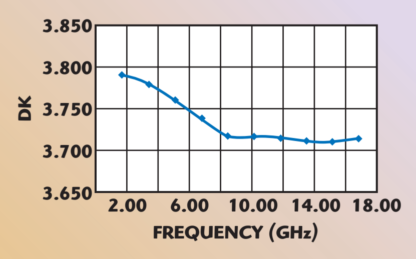


Fig. 6 Results from testing two microstrip gap coupled resonators.

All the test methods described thus far have been resonator methods. The next test method is intended to determine the ε_r value of a laminate over a wide range of frequencies and using a transmission/reflection technique. This method also uses the advantage of having two microstrip circuits built on the same material and eliminating some variables that are common to evaluating this type of circuit. The circuit is a simple single-ended microstrip transmission line having two circuits of significantly different lengths. The procedure is detailed in a paper[8] and the following is an overview.

Two circuits are made on the same substrate and very near in proximity to each other. Both circuits should be identical in every manner with the exception of length. One circuit should be significantly longer than the other by a multiple of three or more. Both circuits should use the same connectors for testing or ideally the same fixture. A measurement is to be taken for each circuit over a range of frequencies to obtain the phase angle at each frequency. The microstrip transmission line phase response formula is used to calculate the effective ε_r value at each frequency. The phase response formula used is:

$$\Phi = 2\pi f \frac{\sqrt{Eff\_\varepsilon_r}}{c} L \quad (7)$$

where Φ is the phase angle, f is the frequency, Eff_ε_r is the effective dielectric constant, c is the speed of light in a vacuum and L is the length of the transmission line. This is for a phase angle measurement at a specific frequency and a discrete transmission line length.

This method uses the two different transmission line lengths (ΔL) and their different phase angle (ΔΦ) at a

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specific frequency to determine the effective ε_r. The frequency is then incremented, the new phase angles accounted for, the effective ε_r determined and then recalculated at the new frequency.

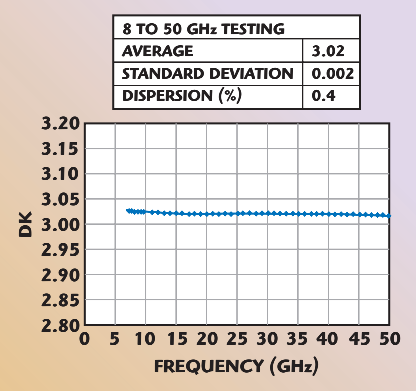
$$\Delta\Phi = 2\pi f \frac{\sqrt{Eff\_\varepsilon_r}}{c} \Delta L \quad (8)$$

$$Eff\_\varepsilon_r = \left(\frac{\Delta\Phi c}{2\pi f \Delta L}\right)^2 \quad (9)$$

At each point in the iteration process where the effective ε_r value is determined, a computer routine is used to back calculate the ε_r value of the laminate, as previously described. A plot of two circuits tested with this procedure using a common microwave laminate is shown in ***Figure 7***.

Several different test methods for evaluating ε_r for microwave PCB laminates have been shown. Different test methods using microwave circuit characterization have been shown as well. Each of these methods have their own set of capabilities and limits that need to be understood in order to appreciate the significance of the ε_r value reported for a laminate in regards to a particular application.

It is strongly recommended for the designer to evaluate and define an appropriate test method that will best approximate their actual circuit application. The ε_r values supplied by the laminate manufacturers should be considered approximate in an effort to support the circuit designer for fine tuning their application with a material under consideration. ■



▲ *Fig. 7 Results of the microstrip differential phase length test method.*

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ANALYTICAL DESIGN OF AN INVERSE CLASS F POWER AMPLIFIER FOR LINEAR AMPLIFICATION

In this article, a 2.5 to 2.6 GHz highly efficient inverse Class F power amplifier (PA), based on Cree's CGH40010 GaN HEMT, is presented for linear amplification. The second and third harmonic load impedances are found by harmonic load pull simulation, and controlled by the output harmonic matching network (HMN). Meanwhile, the second harmonic source impedance, which plays a crucial role in high efficiency PA design, is controlled by the input HMN. The parameters of the HMNs are obtained by analytical calculation. Measurement results show that the drain efficiency of the fabricated PA is over 75 percent at an output power of 41.4 dBm for the 26 dBm, 2.55 GHz CW input signal. For a 20 MHz four-carrier orthogonal frequency division multiplexing (OFDM) signal with 10.39 dB peak-to-average power ratio (PAPR), the adjacent channel leakage ratio (ACLR) of the PA is suppressed to below -45 dBc after employing signal crest factor reduction (CFR) and digital predistortion (DPD).

Recently, in order to achieve highly efficient amplification, switch mode power amplifiers (SMPA) with theoretical 100 percent efficiency have been introduced. However, in practice, the efficiency of SMPA cannot achieve as high as 100 percent because of the parasitic parameters of the transistor, the losses of matching networks, etc. Among the subclasses of SMPA, inverse Class F has the highest drain efficiency, due to shaping the drain voltage waveform as half-sinusoidal and the drain current waveform as a square-wave.[1-2] Many successful design instances of inverse Class F PA have been reported.[3-6]

Modern and next generation wireless communication systems require high data rate and high spectrum utilization. In this case, the orthogonal frequency division multiplexing (OFDM) signal with high peak-to-average power ratio (PAPR) are being used. Although the inverse Class F PA obtains high efficiency at peak power level, the high PAPR causes low efficiency at the average output power. And the higher the PAPR is, the lower the efficiency will be. Therefore, a crest factor reduction (CFR) technique[7-8] is employed to reduce the PAPR so as to enhance the efficiency of the PA.

In this article, a 2.5 to 2.6 GHz inverse Class F PA is implemented using Cree's CGH40010 GaN HEMT for linear amplification in OFDM systems. The input and output harmonic matching networks (HMN) are analytically designed to make the harmonic impedances approximate the values obtained by harmonic source/load pull simulations. CW measurement shows a greater than 75 percent drain efficiency at 2.55 GHz. For a 20 MHz four-carrier OFDM signal with PAPR of 10.39 dB, after employing CFR and digital predistortion (DPD) techniques, the inverse Class F PA achieves good

YINGJIE XU, JINGQI WANG AND XIAOWEI ZHU
Southeast University, Nanjing, China

linearity and 31.9 percent efficiency at an average output power of 34.3 dBm.

INVERSE CLASS F DESIGN PROCEDURE

Inverse Class F Operation and GaN HEMT

Ideally, an infinite number of even-harmonic resonators results in an inverse Class F mode with a half-sinusoidal voltage waveform and a square current waveform at the device output terminal.[9] However, it is impractical to control an infinite number of harmonics using microstrip transmission lines. In this design, only the second and third harmonics are considered. The maximally flat drain voltage and current expressions of inverse Class F PA with the second harmonic open loaded and the third harmonic short loaded are shown below:[10]

$$v_d(\theta) = V_{dd} + (4/3)(V_{dd} - 2R_{on}I_{dc}) \cdot \sin\theta - (1/3)(V_{dd} - 2R_{on}I_{dc})\cos 2\theta \quad (1)$$

$$i_d(\theta) = I_{dc} - (9/8)I_{dc}\sin\theta - (1/8)I_{dc}\sin 3\theta \quad (2)$$

where V_{dd} and I_{dc} are the drain DC supply voltage and current, R_{on} is the switching on-resistance of the transistor.

According to Equations 1 and 2, setting V_{dd} = 28 V, I_{dc} = 0.6 A and R_{on} = 0.5 , the peak drain voltage value for inverse Class F equals to 73.7 V, which is much greater than the peak drain voltage value 55.2 V for Class F operation under the same condition. This results in a higher efficiency of inverse Class F than its Class F counterpart.

GaN HEMT's large material band gap permits it to operate at high drain voltage and high power density.[11] For Cree's CGH40010, the maximum drain to source voltage is 84 V,[12] which is large enough for inverse Class F operation with a peak drain voltage of 73.7 V. While for Freescale's LDMOS FET (such as MRF7S35015), the maximum drain to source voltage is 65 V,[13] which could not meet the requirement of inverse Class F operation. In this case, a GaN HEMT becomes a promising candidate for inverse Class F PA design.

Load Pull/Source Pull Simulation Steps

1. With the large signal transistor model of CGH40010 provided by Cree, load pull and source pull simulations are carried out in Agilent's Advanced Design System (ADS). The center frequency is set at 2.55 GHz, and the transistor is biased at V_{gs} = -3.6 V and V_{ds} = 28 V with an input power level of 26 dBm. The objective of the simulation is to find out the optimum load and source impedances at both the fundamental frequency and harmonics, when the power-added efficiency (PAE) is maximum, with a high output power. The simulation is performed through the following steps: Set the fundamental source impedance at a default value to perform fundamental load pull simulation, the optimum fundamental load impedance Z_{L_fund} is obtained. Perform fundamental source pull simulation with Z_{L_fund} to get the optimum fundamental source impedance Z_{S_fund}. Several iterations are needed before the optimum fundamental impedances converge. After convergence, Z_{S_fund} = (6.4-j4) Ω and Z_{L_fund} = (13.21+j16.906) Ω are obtained.
2. Perform inverse Class F harmonic load pull simulation with Z_{S_fund} and Z_{L_fund}. In this simulation, only the second and third harmonics are considered and the values of the harmonic impedances are restricted to be purely reactive for the successive design. After simulation, the optimum second harmonic load impedance Z_{L_2nd} = j844.097Ω and the optimum third harmonic load impedance Z_{L_3rd} = -j5.987 Ω are obtained.
3. Perform harmonic source pull simulation. From simulation results, the third harmonic source impedance has little effect on the PAE, while the second harmonic source impedance affects it a lot. The optimum second harmonic source impedance is obtained as Z_{S_2nd} = -j27.968 Ω. The PAE simulation results obtained by varying the second harmonic source impedance are shown in ***Figure 1***. Without any losses, the maximum possible PAE could be 83 percent, when Z_{S_2nd} = -j27.968 Ω. If the second harmonic source impedance is not well controlled in the design, the PAE would drop to 67 percent, a considerable decrease

of 16 percent. The input HMN helps to provide a second harmonic source impedance as close as possible to Z_{S_2nd}.

HMN Analytical Design and Schematic Simulation

Figure 2 shows the circuit schematic of the proposed inverse Class F PA. The input/output HMN controls the harmonic source/load impedances for the values obtained by harmonic source/load pull simulation. The input/output fundamental matching network (FMN) then transforms the fundamental impedances $Z^{*'}_S/Z^{*'}_L$ to 50 Ω. The analytical design procedure for both HMNs is described as follows.

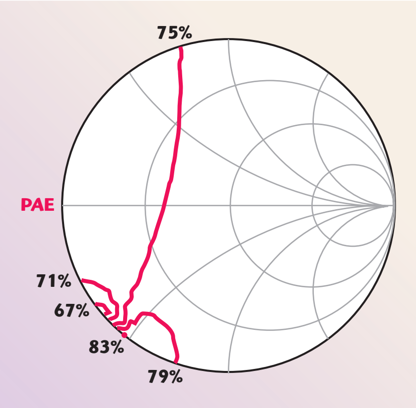

Fig. 1 Harmonic source pull simulation.

In the output HMN, the electrical length θ_4 and θ_6 of the two open stubs are set at π/4 and π/6, which provide a short-circuit at the two junctions for the second and third harmonics, respectively. For the second harmonic load impedance, Equations 3 and 4 can be obtained:

$$Z_c(2f_0) = Z_B(2f_0) \,||\, (-jZ_4 \cot 90^\circ) = 0 \quad (3)$$

$$Z_L(2f_0) = Z_3 \frac{Z_c(2f_0) + jZ_3 \tan(2\theta_3)}{Z_3 + jZ_c(2f_0)\tan(2\theta_3)} = jZ_3 \tan(2\theta_3) \quad (4)$$

By solving the equation $Z_L(2f_0) = Z_{L\_2nd} = j844.097\ \Omega$, when $Z_3 = 50\ \Omega$, one gets $\theta_3 = 43.3°$. The value of Z_3 can be altered according to the width of the transistor's drain pad.

For the third harmonic load impedance, one gets:

$$Z_A(3f_0) = 0 \quad (5)$$

$$Z_B(3f_0) = Z_5 \frac{Z_A(3f_0) + jZ_5 \tan(3\theta_5)}{Z_5 + jZ_A(3f_0)\tan(3\theta_5)} = jZ_5 \tan(3\theta_5) \quad (6)$$

$$Z_C(3f_0) = Z_B(3f_0) \,||\, (-jZ_4 \cot 135^\circ) = Z_B(3f_0) \,||\, jZ_4 \quad (7)$$

$$Z_L(3f_0) = Z_3 \frac{Z_C(3f_0) + jZ_3 \tan(3\theta_3)}{Z_3 + jZ_C(3f_0)\tan(3\theta_3)} =$$

$$jZ_3 \frac{Z_3 Z_4 \tan(3\theta_3) + (Z_4 + Z_3 \tan(3\theta_3)) Z_5 \tan(3\theta_5)}{Z_3 Z_4 + (Z_3 - Z_4 \tan(3\theta_3)) Z_5 \tan(3\theta_5)} \quad (8)$$

By solving the equation $Z_L(3f_0) = Z_{L\_3rd} = -j5.987\ \Omega$, when $Z_4 = 50\ \Omega$ and $Z_5 = 50\ \Omega$, one gets $\theta_5 = 28.9°$. The parameters

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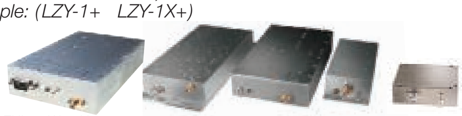
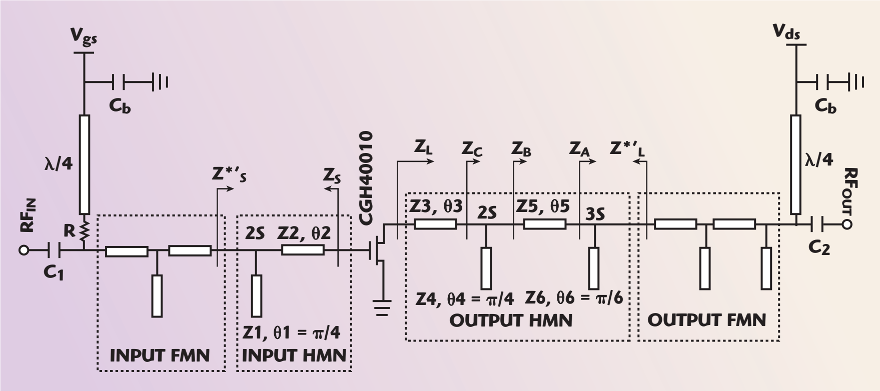
With Heat Sink/Fan										
LZY-1+	20-512	43	+45.7	+47.0	8.6	+54	26	7.3	1995	1895
LZY-2+	500-1000	46	+45.0	+45.8	8.0	+54	28	8.0	1995	1895
ZHL-5W-1	5-500	44	+39.5	+40.5	4.0	+49	25	3.3	995	970
ZHL-5W-2G+	800-2000	45	+37.0	+38.0	8.0	+44	24	2.0	995	945
ZHL-10W-2G+	800-2000	43	+40.0	+41.0	7.0	+50	24	5.0	1295	1220
ZHL-16W-43+	1800-4000	45	+41.0	+42.0	6.0	+47	28	4.3	1595	1545
• ZHL-20W-13	20-1000	50	+41.0	+43.0	3.5	+50	24	2.8	1395	1320
ZHL-30W-252+	700-2500	50	+44.0	+46.0	5.5	+52	28	6.3	2995	2920
• ZHL-50W-52	50-500	50	+46.0	+48.0	6.0	+55	24	9.3	1395	1320
• ZHL-100W-52	50-500	50	+47.0	+48.5	6.5	+57	24	10.5	1995	1920
NEW ZVE-3W-183+	5900-18000	35	+34.0	+35.0	5.5	+44	15	2.2	1295	1220
ZVE-3W-83+	2000-8000	36	+33.0	+35.0	5.8	+42	15	1.5	1295	1220
• ZHL-100W-GAN+	20-500	42	+49.0	+50.0	7.0	+60	30	9.5	2395	2320
ZHL-30W-262+	2300-2550	50	+43.0	+45.0	7.0	+50	28	4.3	1995	1920

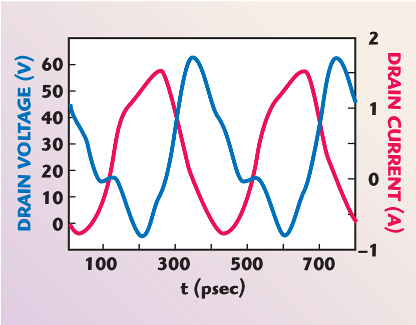
• ***Protected under U.S. Patent 7,348,854***

*For models without heat sink, add **X suffix** to model No.*
Example: (LZY-1+ LZY-1X+)

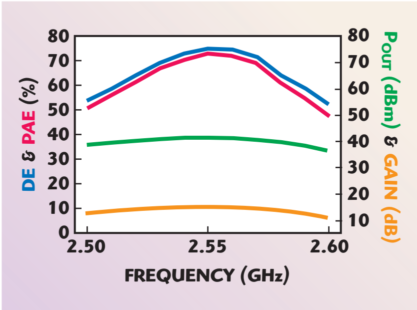




▲ *Fig. 2 Schematic of the designed inverse Class F PA.*



▲ *Fig. 3 Simulated drain voltage and current waveforms.*



▲ *Fig. 4 Measured amplifier performance.*

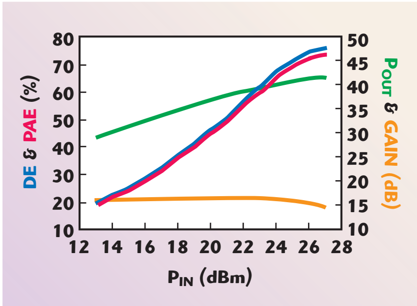
of the output HMN are now determined. According to the same principle, the parameters of the input HMN can be determined.

Figure 3 shows the simulated drain voltage and current waveforms of the proposed inverse Class F PA. It can be observed that the two waveforms are distorted, when compared with the ideal waveforms of inverse Class F operation. This is because the effects of the nonlinear parasitic parameters that exist in the transistor package. If the package is de-embedded and the waveforms are simulated at the intrinsic drain, the results would be closer to the ideal condition.

From the schematic harmonic balance (HB) simulation in ADS, the maximum in-band PAE of 84.2 percent is obtained at 2.55 GHz, with an output power of 39.54 dBm and a transducer power gain of 13.54 dB.

MEASUREMENT AND LINEARIZATION

A 2.5 to 2.6 GHz inverse Class F PA has been fabricated to validate the design approach. The selected substrate is RF-35 from Taconic Co. with a dielectric constant of 3.5 and a thickness of 30 mil.



▲ *Fig. 5 Measured results vs. input power.*

CW Signal Measurement

By setting V_{gs} = -3.6 V and V_{ds} = 28 V with a 26 dBm input power, the measured PAE, drain efficiency (DE), output power and power gain are plotted in ***Figure 4*** within the frequency band from 2.5 to 2.6 GHz. DE is greater than 52 percent, PAE is greater than 47.7 percent and the output power is greater than 36.9 dBm within the 100 MHz bandwidth. The peak DE of 75.2 percent and peak PAE of 73 percent are observed at 2.55 GHz with a maximum output power and power gain of 41.43 and 15.43 dB, respectively.

Driven by a 2.55 GHz CW input signal with the power swept from 13 to 27 dBm, the measurement results of the inverse Class F PA are plotted

in **Figure 5** with V_{gs} = -3.6 V, V_{ds} = 28 V. When the input power reaches 27 dBm, the DE and PAE are 76 and 73.5 percent, respectively. However, the power gain has been compressed to 14.6 dB, a 2.2 dB compression, compared with the maximum power gain observed at a 20 dBm input power.

In **Figure 6**, the drain to source voltage is varied from 20 to 29 V, with the input power fixed at 26 dBm and V_{gs} = -3.6 V. DE and PAE achieve a maximum of 79 and 75.4 percent, respectively, at V_{ds} = 21 V.

Linearization with Digital Predistortion

The PA DPD linearization system consists of a vector signal generator (Rohde & Schwarz SMBV100A), a vector signal analyzer (Agilent VSA-E4445A), a PC with Matlab and Agilent's 89600 and the proposed inverse Class F GaN PA. The SMBV100A, E4445A and PC are connected via a local area network (LAN). The configuration of the system is shown in **Figure 7**.

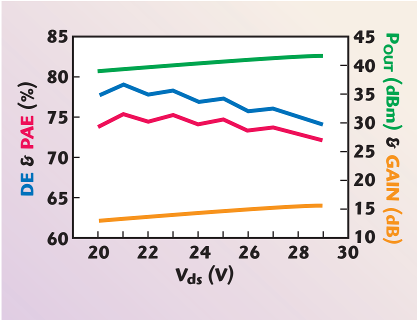
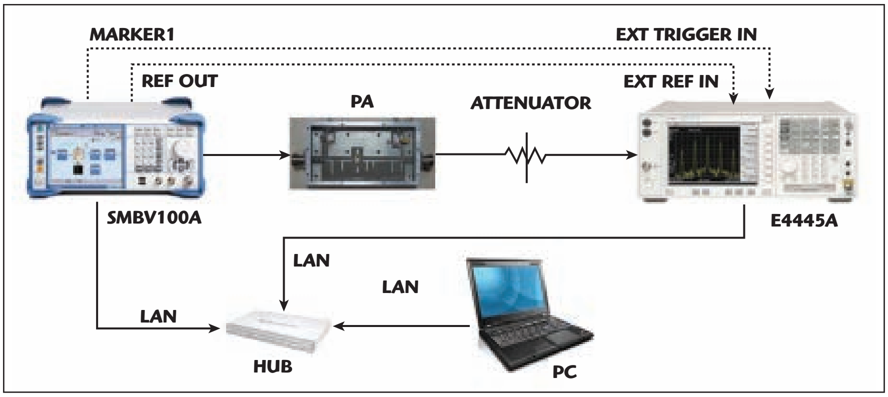


Fig. 6 Measured results vs. drain to source voltage.

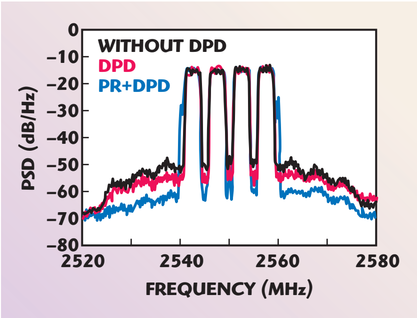
The baseband I/Q signals are modulated and up-converted to an RF signal in SMBV100A, the RF signal is then amplified and distorted by the PA. After attenuation, the RF output signal of the PA is down-converted and demodulated by E4445A. Finally, the output I/Q samples are collected in VSA 89600 for modeling. Using the Hammerstein architecture,[14] the inverse PA model (digital predistorter) can be established with the input and output I/Q samples of the PA. With the digital predistorter, the distortion of the PA can be compensated.

The input signal of the PA is chosen as a four-carrier OFDM QPSK signal with a 20 MHz bandwidth and 10.39 dB PAPR at the 0.01 percent level of the complementary cumulative distribution function (CCDF). After CFR with a soft clipping technique,[8] the PAPR is decreased to 8.05 dB.

Figure 8 shows the measured four-carrier OFDM PSD of the PA before and after linearization. The black trace indicates the original output of the PA. The adjacent channel leakage ratio (ACLR) is -37.48 dBc (lower) and -36.94 dBc (upper) at an average output power of 34.3 dBm. After DPD with Hammerstein, the output PSD of the PA is shown by the red trace, the ACLR of which is suppressed to -41 dBc (lower) and -39.38 dBc (upper). A slight improvement is achieved at this power level of the inverse Class F PA. When the baseband I/Q signal is processed by CFR, distorted by the digital predistorter, and then downloaded to SMBV100A as the input signal of the PA, the output PSD of the PA is shown by the blue trace, the ACLR of which is equal to -48.22 dBc (lower) and -45.8 dBc (upper). The efficien-



▲ *Fig. 7 The PA DPD linearization system configuration.*



▲ *Fig. 8 Measured PSD before and after linearization.*

cy of the PA is 31.9 percent at a 34.3 dBm average output power.

CONCLUSION

This article presented an analytical design approach of inverse Class F PA. The input and output HMNs controlled the source and load harmonic impedances appropriately. The fabricated 2.5 to 2.6 GHz GaN inverse Class F PA achieved a maximum in band drain efficiency greater than 75 percent, with an output power of 41.4 dBm at 2.55 GHz. For linearization, the PAPR of the 20 MHz four-carrier OFDM signal was reduced from 10.39 dB to 8.05 dB through a CFR technique. Then, by using DPD, based on Hammerstein, the ACLR was improved to less than -45 dBc at an average output power of 34.3 dBm with 31.9 percent efficiency. According to the experimental results, the proposed inverse Class F PA is suitable for linear amplification with high efficiency. ■

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Design of a Metamaterial Bandpass Filter Using the ZOR of a Modified Circular Mushroom Structure

In this article, the design of a new bandpass filter, based on a modified circular mushroom metamaterial structure, is proposed. Half circular mushroom cells are used as the zero-order resonators (ZOR), and an intermediate gap is used to capacitively couple neighboring ZOR resonators to make a bandpass filter. The proposed bandpass filter design is validated by circuit 3D EM simulations and measurements, with reference to the target specifications, and the metamaterial properties are proven by showing the ZOR field distributions and dispersion diagram. A size reduction is also achieved.

Wireless communication gadget users nowadays tend to pursue more convenience, such as multi-functions and higher mobility. The former results in a multi-band service oriented device; the latter drives the development of reduced size equipment. Thus, the roles and expectations of RF components are becoming more challenging. In particular, quality filters and couplers are required to be designed by cutting-edge technology. With regard to overcoming the limitations in the current design capabilities and going beyond the boundary, a number of techniques have been exploited. New alternative approaches have been sought, and the concept of metamaterial structures has started to draw a lot of attention.

A composite right-/left-handed (RH/LH) transmission line (CRLH) has been studied for microwave component design. Among these metamaterial applications, the zero-order resonance (ZOR) concept is a valuable key of size reduction methods. The ZOR of no phase variation between two ports is presented based on a one unit cell;[1-3] a CRLH transmission line with 24 cells shows an infinite wavelength.[4] The ZOR and the negative resonance have been realized in the form of multi-cells of a rectangular patch with a shorting pin or a metal strip next to split ring resonators (SRR) under the name of the CRLH-TL structure. Since the multiple cells have one size and are repeated over a lengthened area, they have periodic stop- and pass-bands at integer multiples of the fundamental frequency, which possibly lowers the freedom of design.[4-5] In this article, a new design methodology using a modified circular mushroom structure is suggested for ZORs, and a gap between the ZORs is used as a capacitive coupling element for implementing the target bandpass filtering.

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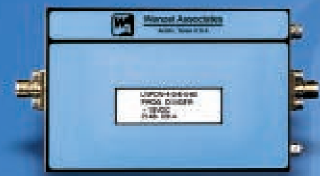

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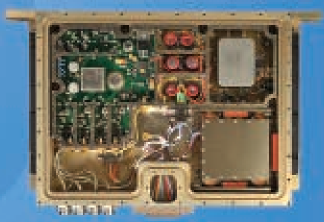

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TABLE I

SPECIFICATIONS OF THE BANDPASS FILTER

Parameter	*Specification*
Center freq.	3 GHz
Order	2
Bandwidth	200 MHz
Passband	0.5 dB

THEORY AND DESIGN

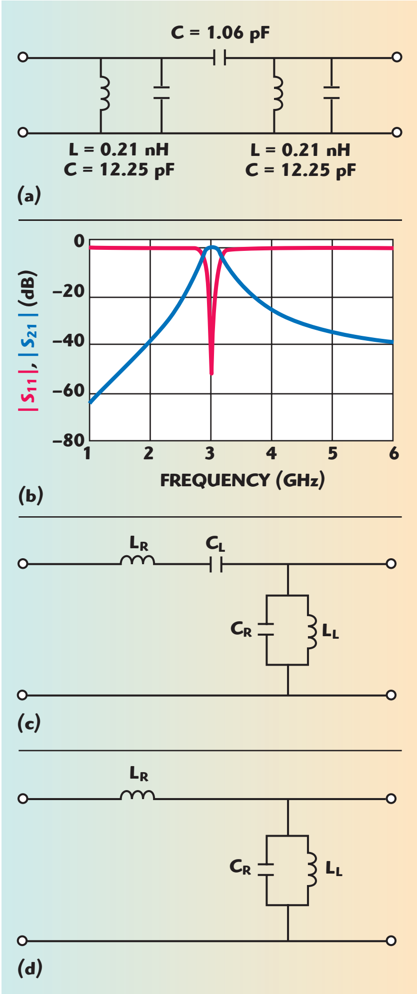
A bandpass filter is designed on the basis of the specifications shown in ***Table 1***. The transfer function, a mathematical expression, which best fits the amplitude of the required frequency response, must be known, because the transfer function will be manipulated by the coupling between the resonators in the prototype circuit. The transfer function is given in Equation 1

$$S_{21}(s) = \frac{1.965}{s^2 + 1.983s + 1.965} \quad (1)$$

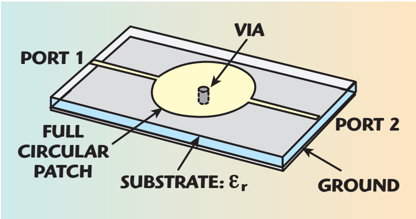
where s = jω and ω = 2πf is the angular frequency.

It is then converted to a prototype, whose schematic is shown in ***Figure 1***. As is typical for a classic filter, it comprises a series capacitance coupling two identical parallel resonators. After the circuit is simulated, the frequency response is obtained, where S_{21} meets the specifications from Table 1. For the same frequency response, this conventional filter can be changed to a metamaterial-version, like the double negative (DNG) or the epsilon negative (ENG), whose zero-order resonance renders size-minimization and performance-improvement very effectively.[1-4] In other words, if the dispersion diagram of a DNG or ENG equivalent circuit is obtained and the phenomenon at its ZOR is considered. The no-phase variation effect will set the size of the resonator free from a half-wavelength resonance condition and this possibly results in size reduction.

The DNG is found by dividing the conventional prototype circuit into the RH and LH parts and making their propagation constants of the same magnitude but out-of-phase. The ENG is obtained by making both the effective capacitance and effective inductance of the resonators become zero and positive, and making their

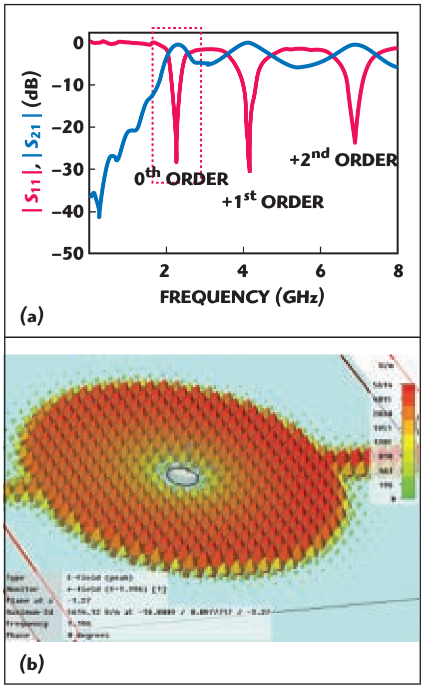


▲ *Fig. 1 Conventional and metamaterial prototype circuits of the bandpass filter: (a) conventional circuit, (b) frequency response, (c) DNG CRLH-TL equivalent circuit and (d) ENG-TL equivalent circuit.*



▲ *Fig. 2 A full circular mushroom structure.*

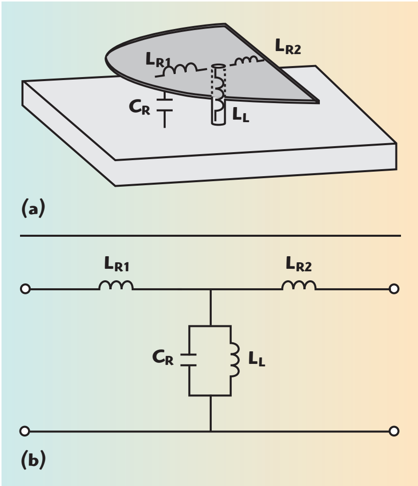
zero crossing point coincide with the aimed center frequency. As addressed earlier, this article uses a circular mushroom or its modification as the resonator and is the basis for implementing a bandpass filter. Considering a circular mushroom (see ***Figure 2***), it consists of a full circular patch supported by a metal shorting pin connecting the patch and the ground. Without a gap from a feeding port, the circular mushroom itself can be-



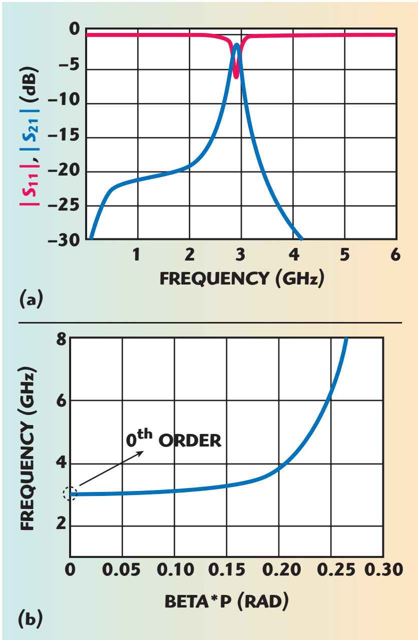
▲ *Fig. 3 ZOR and its RH integer harmonics of a full circular mushroom structure: (a) ZOR around 3 GHz and (b) electric field distribution of the ZOR.*

come an ENG rather than a DNG. If the full circular mushroom has gaps at the ports, it is the DNG. When a full circular mushroom is split to two half circular mushrooms by a gap, each of the two half circular mushrooms is an ENG, though the two half circular mushrooms with a gap can be interpreted as the DNG.

Again, if a full circular mushroom is connected to the input and output ports, the metallic patch, the substrate spacing and the shorting pin are interpreted as the series inductance, shunt capacitance and shunt inductance loading of an ENG circuit, respectively. This full circular mushroom was simulated by a 3D EM analysis, with the dielectric constant = 4.4, the height = 1.27 mm and the circular patch diameter = 20 mm. The frequency response is shown in ***Figure 3***. As shown, the full circular mushroom has a ZOR with the in-phase electric field distribution over the whole structure, and its right-handed (RH) spurious harmonics in the frequency response. Also, if the number of cells of full circular mushrooms was extended to make a bandpass filter, it would work against an effective size reduction. In order to overcome the drawbacks of using full circular mushrooms, half circular mushroom reso-



▲ *Fig. 4 Half circular mushroom resonator (a) and its ENG circuit model (b).*



▲ *Fig. 5 S-parameters (a) and dispersion diagram (b) of a half circular mushroom ZOR.*

nators to minimize the physical size and a coupling element between the resonators to enlarge the stopband are considered, as shown in ***Figure 4***.

The equivalent circuit of a one half circular mushroom resonator is determined to meet the performance of ZOR at 3 GHz and all its elements are calculated: L_{R1} = 6 nH, L_{R2} = 11 nH, C_R = 4.8 pF and L_L = 0.7 nH. According to this resonator circuit, the frequency response and the dispersion diagram of a half circular mushroom resonator are shown in ***Figure 5***. S_{21} has its resonance at 3 GHz, but the bandwidth and the return loss are very poor, because a one half circular

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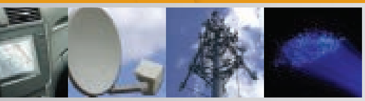

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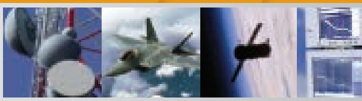

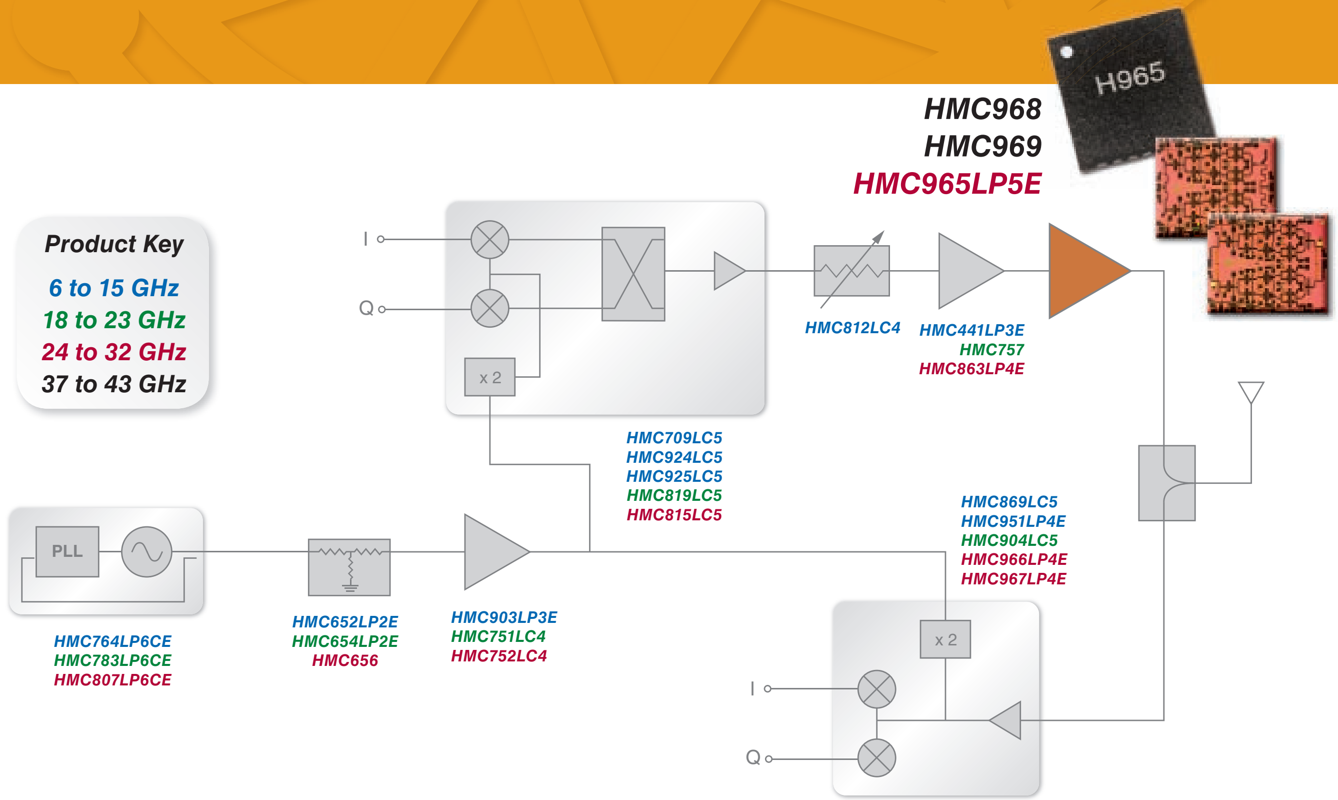

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	12 - 16	Power Amplifier 4 Watt	28	44.5	36.5	+7V @ 2400mA	Chip	**HMC950**
NEW!	12.5 - 15.5	Power Amplifier 2 Watt	27	40	32	+6V @ 1200mA	LP5	**HMC965LP5E**
	16 - 24	Power Amplifier 1/2 Watt	20.5	34.5	26.5	+5V @ 400mA	LP4	**HMC757LP4E**
	22 - 26.5	Power Amplifier 1/2 Watt	21.5	33	26.5	+6V @ 350mA	LP4	**HMC863LP4E**
	27.3 - 33.5	Power Amplifier 2 Watt	23	43	33	+6V @ 1200mA	Chip	**HMC906**
NEW!	37 - 40	Power Amplifier 1 Watt	21	38	30.5	+6V @ 900mA	Chip	**HMC968**
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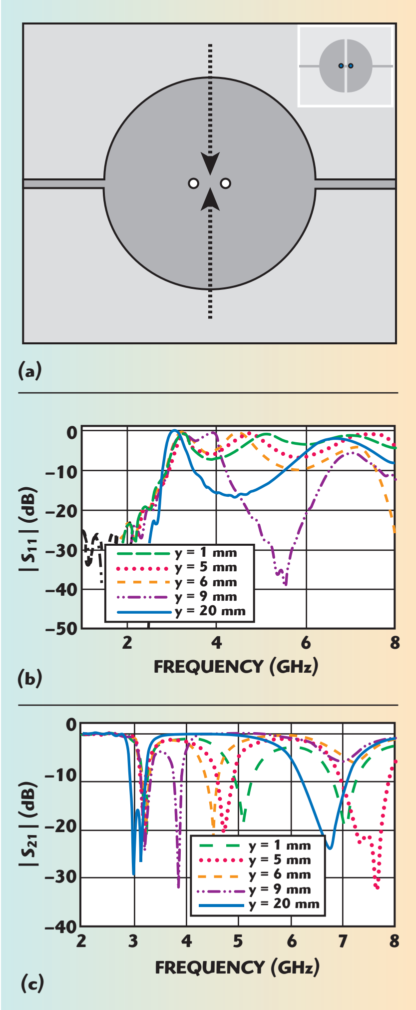
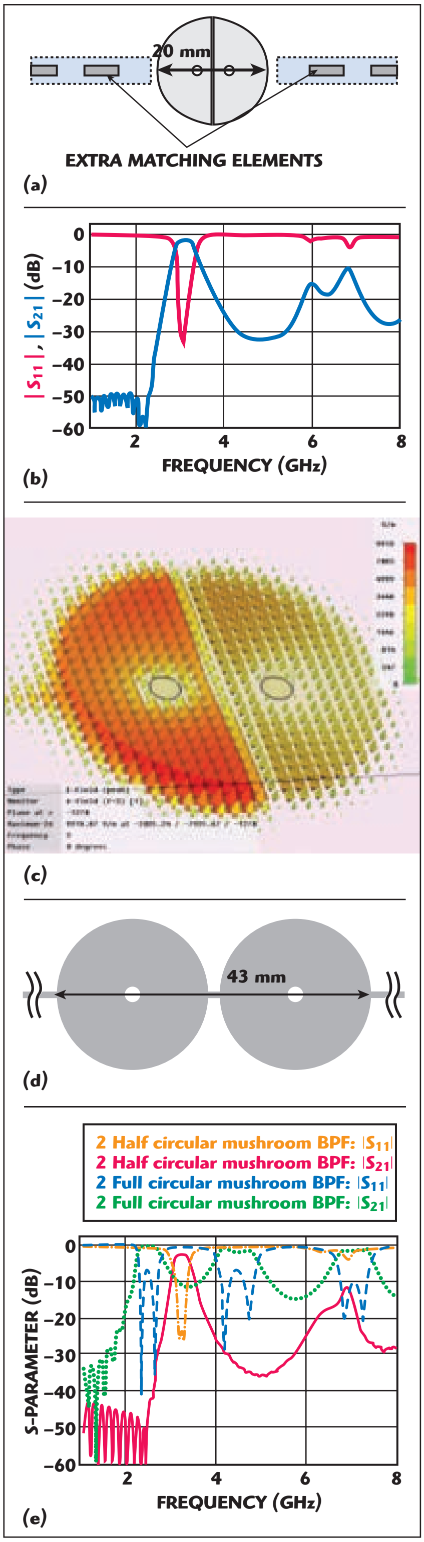


▲ *Fig. 6 Coupling two half circular ZORs: (a) creating the two half circular mushrooms, (b) S_{11} as a function of slit length and (c) S_{21} as a function of slit length.*

mushroom is just a resonator having a ZOR, not a bandpass filter. To make a complete bandpass filter, another coupled half circular mushroom resonator is needed.

When two half circular mushroom ZORs are put together with a coupling element, there are roughly three factors to adjust the coupling between the resonators: the slit gap, the slit length and the positions of the shorting pins. These factors have been varied to find the most appropriate values. In this particular design, among the number of coupling factors, just the slit length has been varied with the others fixed. From **Figure 6**, it is noted that the complete cut of the circle gives an acceptable performance. After undergoing further parameter studies, the optimized filter structure is found.

The gap between the two half circular resonators and the distance of



▲ *Fig. 7 Performance of the proposed metamaterial bandpass filter: (a) geometry, (b) simulated frequency response, (c) ZOR field, (d) fabricated filter and (e) measured response.*

their shorting pins have been adjusted to form a passband centered at 3 GHz, with the closest spurious frequency component far apart. Actually, anoth-

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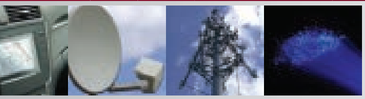

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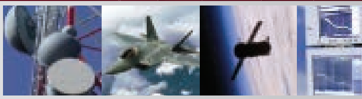

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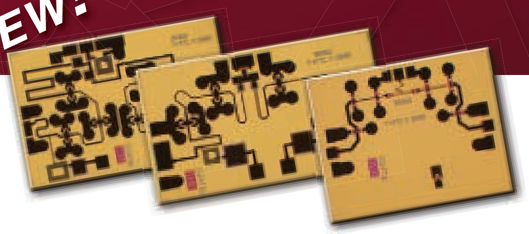

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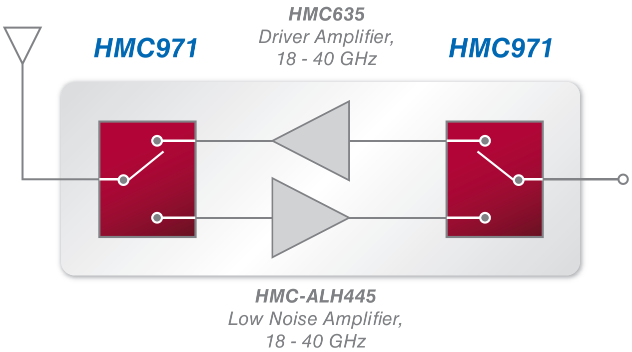

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	DC - 8	SPDT, High Isolation	1.5	45	26	0 / -5V	C8	EAR99	HMC234C8
	DC - 8	SPDT, High Isolation	1.2	48	23	0 / -5V	MS8G	EAR99	HMC270MS8GE
	DC - 8	SPDT, High Isolation	2	44	23	0 / -5V	C8	EAR99	HMC347C8
	DC - 8	SPDT, High Isolation	2.2	35	23	0 / -5V	G8 Hermetic	EAR99	HMC347G8
	DC - 12	SPDT, High Isolation	1.5	55	27	0 / -5V	LP4	EAR99	HMC232LP4E
	DC - 14	SPDT, High Isolation	1.7	44	23	0 / -5V	LP3	EAR99	HMC347LP3E
	DC - 15	SPDT, High Isolation	1.4	50	26	0 / -5V	Chip	EAR99	HMC232
	DC - 15	SPDT, High Isolation	1.7	60	26	0 / -5V	Chip	EAR99	HMC607
	DC - 20	SPDT, High Isolation	1.7	45	23	0 / -5V	Chip	EAR99	HMC347
	DC - 20	SPDT, High Isolation	1.8	47	23	0 / -5V	LP3	EAR99	HMC547LP3E
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NEW!	18 - 40	SPDT, PIN MMIC, 2W	1.4	40	34	-10 / +1.5 (30mA)	Chip	EAR99	HMC971
NEW!	2 - 50	SPDT, PIN MMIC, 0.5W	0.9	45	27	-10 / +1.5 (30mA)	Chip	EAR99	HMC975
	55 - 86	SPDT, PIN MMIC	2	30	-	-5 / 5V	Chip	5A991.h	HMC-SDD112
	DC - 8	SP8T	2.3	40	23	0 / 5V	LP4	EAR99	HMC321LP4E
	DC - 8	SP8T	2.5	25	23	0 / -5V	LP4	EAR99	HMC322LP4E
	DC - 8	SP4T	1.8	42	21	0 / -5V	Chip	EAR99	HMC344
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	DC - 12	SP4T	1.8	42	27	0 / -5V	LH5 Hermetic	EAR99	HMC344LH5
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	DC - 20	SP4T	2.3	45	22	0 / -5V	LP4	EAR99	HMC641LP4E
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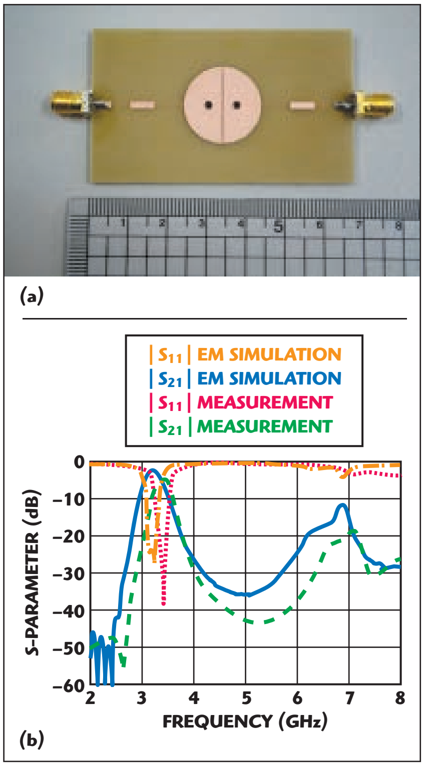

▲ *Fig. 8 Finalized metamaterial bandpass filter with a two coupled half circular mushroom ZOR: (a) photograph and (b) performance.*

er passband is seen at approximately 7 GHz, and to make sure this new filter has a wider stopband for good isolation, a pair of impedance matching elements is placed at the input and output ports, as shown in ***Figure 7***. The proposed design results in a frequency response agreeing with the specification, 200 MHz bandwidth with insertion loss < 1 dB and RL better than 20 dB, with stopband > 2 GHz, checked with the 3D EM simulation. Using this verified proposed design method, the filter was fabricated and the measurements show good agreement with the simulation, except for the shift in frequency and magnitude due to the discrepancy between the actual and ideal substrate, as shown in ***Figure 8***.

Finally, a comparison is made to show the strengths of the proposed filter over the full circular mushroom BPF in terms of size and isolation. Compared to the 2nd order full circular mushroom BPF, the proposed 2nd order half circular mushroom BPF is more than half in size and has a wider stopband.

CONCLUSION

Half circular mushroom cells were used as the ZORs and a gap was introduced as coupling between neighboring ZOR resonators. A size reduction better than half that of a full size circular mushroom is achieved along with an improved stopband, compared to the full circular mushroom case or conventional filters based upon half-wavelength resonators. ■

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Geonho Jang *received his BE degree from the University of Incheon, Incheon, Korea, in 2009. He is currently working toward his MS degree in radio science and engineering in the department of information and telecommunication engineering at the University of Incheon. His interests include microwave components, antennas and metamaterials.*

Sungtek Kahng *received his PhD degree in electronics and communication engineering from Hanyang University, Korea, in 2000, with a specialty in radio science and engineering. From 2000 to early 2004, he worked for the Electronics and Telecommunication Research Institute on numerical electromagnetic characterization and developed RF passive components for satellites. In March 2004, he joined the department of information and telecommunication engineering at the University of Incheon, where he has continued research on analysis and advanced design methods of microwave components and antennas including metamaterial technologies and wireless power transfer.*

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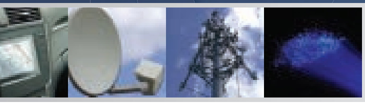

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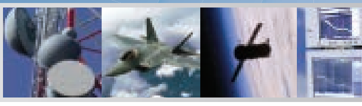

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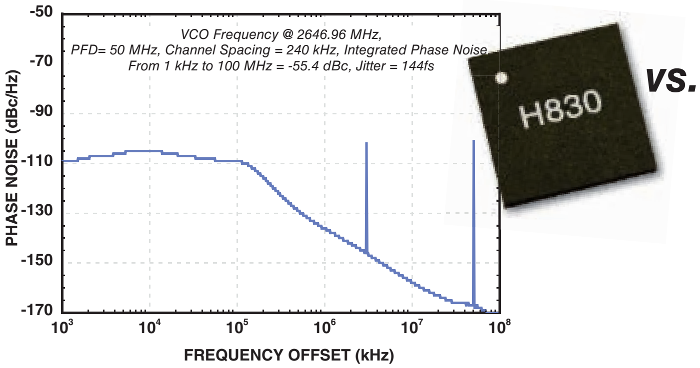

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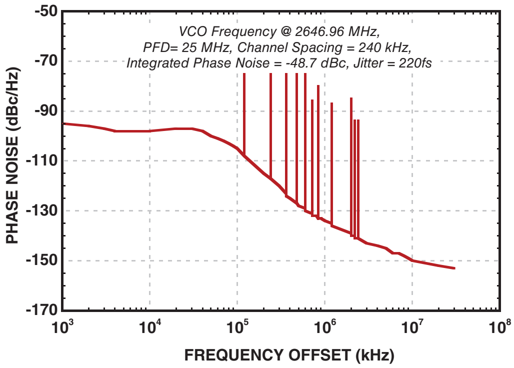

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fo/2									
	665 - 825	Tri-Band RF VCO	-118 dBc/Hz	-148 dBc/Hz	11	180	0.05	LP6CE	**HMC822LP6CE**
	795 - 945	Tri-Band RF VCO	-123 dBc/Hz	-148 dBc/Hz	10	180	0.06	LP6CE	**HMC838LP6CE**
	780 - 870	RF VCO	-116 dBc/Hz	-148 dBc/Hz	14	180	0.06	LP6CE	**HMC824LP6CE**
	860 - 1040	Tri-Band RF VCO	-118 dBc/Hz	-147 dBc/Hz	10	180	0.07	LP6CE	**HMC821LP6CE**
	990 - 1105	RF VCO	-114 dBc/Hz	-146 dBc/Hz	11	180	0.07	LP6CE	**HMC826LP6CE**
NEW!	1025 - 1150	Tri-Band RF VCO	-123 dBc/Hz	-147 dBc/Hz	12	180	0.07	LP6CE	**HMC837LP6CE**
	1050 - 1205	Tri-Band RF VCO	-121 dBc/Hz	-146 dBc/Hz	10	180	0.08	LP6CE	**HMC839LP6CE**
	1095 - 1275	Tri-Band RF VCO	-118 dBc/Hz	-147 dBc/Hz	10	180	0.08	LP6CE	**HMC820LP6CE**
NEW!	1310 - 1415	Tri-Band RF VCO	-121 dBc/Hz	-145 dBc/Hz	10	180	0.09	LP6CE	**HMC840LP6CE**
fo									
	1285 - 1415	RF VCO	-112 dBc/Hz	-143 dBc/Hz	10	180	0.09	LP6CE	**HMC828LP6CE**
	1330 - 1650	Tri-Band RF VCO	-112 dBc/Hz	-142 dBc/Hz	6.5	180	0.11	LP6CE	**HMC822LP6CE**
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	1720 - 2080	Tri-Band RF VCO	-112 dBc/Hz	-141 dBc/Hz	6.5	180	0.13	LP6CE	**HMC821LP6CE**
	1815 - 2010	RF VCO	-112 dBc/Hz	-143 dBc/Hz	7.5	180	0.13	LP6CE	**HMC831LP6CE**
NEW!	2050 - 2300	Tri-Band RF VCO	-117 dBc/Hz	-141 dBc/Hz	10.5	180	0.15	LP6CE	**HMC837LP6CE**
	2100 - 2410	Tri-Band RF VCO	-115 dBc/Hz	-140 dBc/Hz	7.5	180	0.16	LP6CE	**HMC839LP6CE**
	2190 - 2550	Tri-Band RF VCO	-112 dBc/Hz	-141 dBc/Hz	6.5	180	0.17	LP6CE	**HMC820LP6CE**
NEW!	2620 - 2830	Tri-Band RF VCO	-115 dBc/Hz	-139 dBc/Hz	9	180	0.18	LP6CE	**HMC840LP6CE**
2fo									
	2660 - 3300	Tri-Band RF VCO	-106 dBc/Hz	-136 dBc/Hz	-4	180	0.21	LP6CE	**HMC822LP6CE**
	3180 - 3780	Tri-Band RF VCO	-112 dBc/Hz	-135 dBc/Hz	-4	180	0.24	LP6CE	**HMC838LP6CE**
	3365 - 3705	RF VCO	-107 dBc/Hz	-135 dBc/Hz	0	190	0.25	LP6CE	**HMC836LP6CE**
	3440 - 4160	Tri-Band RF VCO	-106 dBc/Hz	-135 dBc/Hz	-4	180	0.27	LP6CE	**HMC821LP6CE**
NEW!	4100 - 4600	Tri-Band RF VCO	-111 dBc/Hz	-135 dBc/Hz	-0.5	180	0.30	LP6CE	**HMC837LP6CE**
	4200 - 4820	Tri-Band RF VCO	-108 dBc/Hz	-135 dBc/Hz	-4	180	0.31	LP6CE	**HMC839LP6CE**
	4380 - 5100	Tri-Band RF VCO	-106 dBc/Hz	-135 dBc/Hz	-4	180	0.33	LP6CE	**HMC820LP6CE**
NEW!	5240 - 5660	Tri-Band RF VCO	-109 dBc/Hz	-133 dBc/Hz	-3	180	0.37	LP6CE	**HMC840LP6CE**
Wideband									
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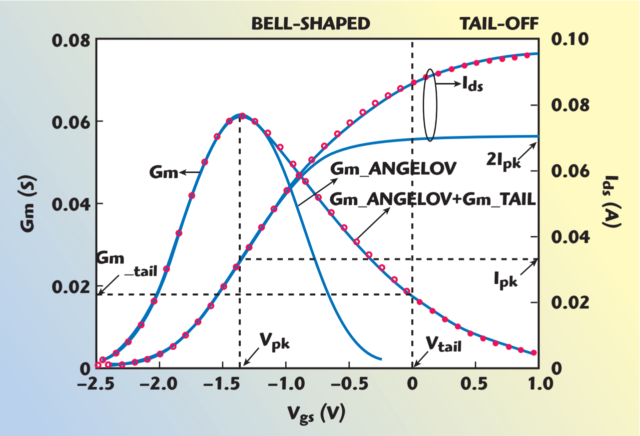
A HEMT Large-signal Model with Improved Transconductance and Gate Capacitance Peaking Characteristics

In this article, an improved large-signal device model of HEMTs is presented, amenable for use in commercial nonlinear simulators. The proposed model includes independent modeling equations to control the peaking and compression behaviors of the HEMT transconductance (G_m) and gate capacitance (C_{gs}). The main advantage of this model is to provide a simple and coherent description of the bias-dependent drain current (I-V) and gate charge (Q-V) relationships, that are valid in all regions of operation. All the aspects of the model are validated for 0.25 μm gate lengths GaAs and GaN HEMTs. The simulation results of I-V, C-V, large-signal power and intermodulation distortion (IMD) characteristics show excellent agreement with the measured data.

The availability of general-purpose harmonic-balance and Volterra-Series simulators has generated a need for accurate nonlinear models of III-V field effect transistors (FET).[1] Due to the heterostructure complexity of HEMTs and the associated physical characteristics, they are most appropriately modeled based on a semi-empirical approach with parameters extracted from measurements.[2]

The major nonlinearities of HEMTs come from the bias-dependent drain current I-V and gate-charge Q-V relationships.[3] In the past years, many equation-based large-signal HEMT models have been proposed to model those nonlinearities.[1-9] Among them, the widely-used Angelov I-V model[2] is one of the most successful drain current models, in virtue of its simplicity, higher-order differentiability, good convergence performances and well-defined fitting parameters. But the Angelov I-V model often faces accuracy issues, where compromises have to be made for the overall fitting.[4-6] On the other hand, the charge conservative EEHEMT Q-V model[7] is one representative gate charge model. Unlike the Angelov capacitance model, which may induce non-convergence during HB simulations,[10] the EEHEMT charge model starts with a single gate charge formulation satisfying the principle of charge conservation to overcome the convergence problem. However, the EEHEMT model fails to model the capacitance peaking characteristics near cutoff found in GaN[8] and GaAs HEMTs.[9]

LIN-SHENG LIU
University of Electronic Science and Technology of China, Chengdu, China



▲ *Fig. 1 Graphical interpretation of the proposed non-linear I-V model.*

For this purpose, an improved large-signal HEMT model is presented with the Angelov I-V model and EE-HEMT Q-V model as prototypes. By maintaining the merits of the original models, the proposed model is capable of representing the nonlinear I-V and Q-V relationships between and across the entire bias range of different regimes. This has been done by introducing new modeling equations to independently control the G_m tail-off and C_{gs} peaking characteristics. Excellent agreement is observed between measured and simulated results by utilizing the 0.25 µm GaAs and GaN HEMT processes.

MODEL DESCRIPTION

Drain-current I-V Model

The Angelov I-V model[2] has frequently been used to model HEMTs with typical bell-shape G_m characteristics (see ***Figure 1***). An analytical drain-source current I-V model as an extension of the Angelov model for GaAs and GaN HEMTs is developed here. This modified I-V model is given as follows:

$$I_{ds}(V_{gs}, V_{ds}) = I\_angelov + I\_Gmtail \quad (1)$$

$$I\_angelov = I_{pk}(1+\tanh(ph))\tanh(\alpha_1 V_{ds}) \quad (2)$$

$$I\_Gmtail = Gm_{\_tail} V_{eff\,t} \tanh(\alpha_2 V_{ds}) \quad (3)$$

$$ph = P_1 V_{gsp} + P_2 V_{gsp}^2 + P_3 V_{gsp}^3 + \ldots, \quad (4)$$

$$V_{gsp} = V_{eff11} - V_{pk}$$

$$V_{eff\,t} = (1/m_1)(1/m_2)\left[1-(1+m_2 V_{eff12})^{-m_1}\right] \quad (5)$$

$$\text{for } m_1 > 0;\ V_{efft} = (1/m_2)\ln(1+m_2 V_{eff12}) \text{ for } m_1 = 0$$

$$V_{eff11} = (V_{gst} - V_{gsta})/2 + V_{tail},\ V_{eff12} = (V_{gst} + V_{gsta})/2 \quad (6)$$

$$V_{gst} = V_{gs} - V_{tail},\ V_{gsta} = (1/n)\ln(2\cosh(nV_{gst})) \quad (7)$$

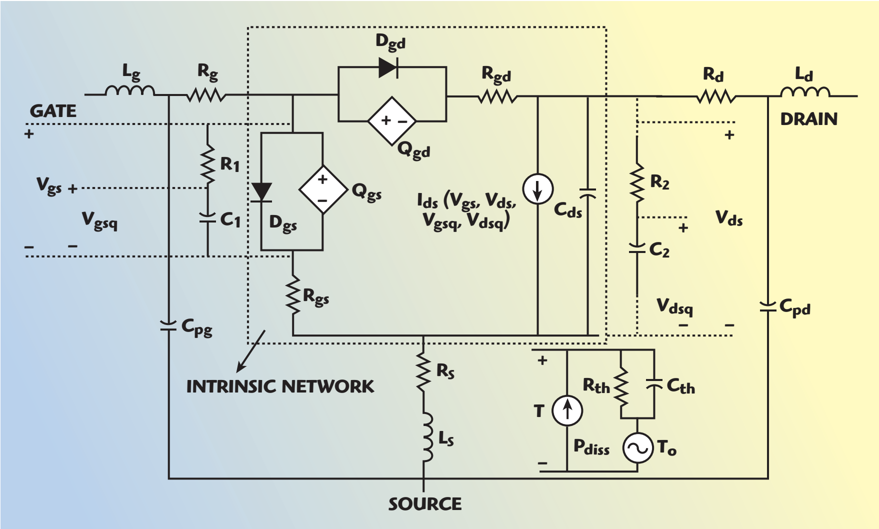
$$V_{pk} = V_{pko} + w_0 V_{ds},\ V_{tail} = V_{tailo} + w_1 V_{ds} \quad (8)$$

As described in the figure, the proposed I-V model consists of two parts: the I_Angelov part maintains the charac-

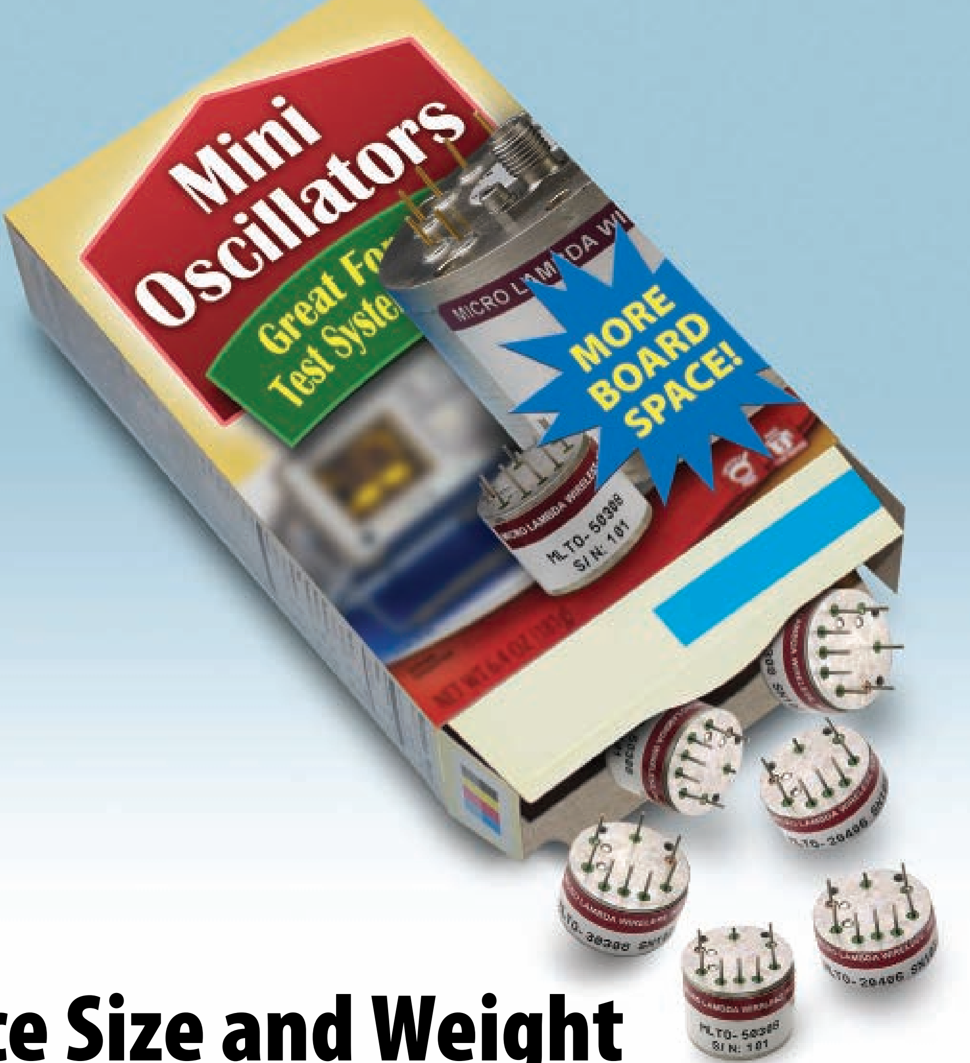
teristics of the Angelov model, where the extraction of the key model parameters, such as the peak G_m coefficient (P_1), gate voltage (V_{pk}) and drain current (I_{pk}) for maximum G_m, is still the same as in the original model. Besides, the tuning parameters in the ph function (P_2 and P_3) now have more freedom to model the G_m expansion when $V_{gs}<V_{pk}$ for the threshold region and the transition from pinch-off to turn-on. The added I_tail part (Equation 3) is to independently model the G_m compression behaviors distinguished by the V_{tail} parameter, the turning point of gate voltage where G_m tail-off begins. This modification with a multiplier term allows the elongation of the bell-shape G_m for $V_{gs}>V_{pk}$.[15]

The restriction of the "symmetrical" behavior of $2I_{pk} = I_{sat}$ in the original Angelov model[3] confines its range of operation.[6] The inclusion of the I_tail current source permits the drain current to increase beyond $2I_{pk}$ as a function of V_{gs} and results in significantly improved accuracy. As a consequence, no trade-offs need to be made for the overall fitting,[4] and the improved I-V model enhances the bias range of operation for which accuracy is maintained, as compared in the figure.

In order to characterize the charge-trapping and self-heating effects[3] found in most GaAs/GaN HEMTs, a four-terminal, large-signal, equivalent-circuit topology with frequency dispersion and thermal sub-circuits has been employed,[11] as shown in ***Figure 2***. The trapping and temperature coefficients as the correction of the model parameters in Equations 1 to 8 are then determined by comparing the pulsed I-V characteristics at different quiescent biasing points and ambient temperatures.[12,13]



▲ *Fig. 2 Complete "four-terminal" large-signal equivalent circuit of HEMTs.*



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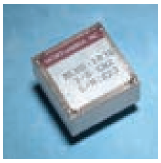

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Gate Charge Q-V Model

After de-embedding the extrinsic elements according to the well-known cold FET method,[14] the multi-bias S-parameter measurements were used to extract the intrinsic bias-dependent gate capacitances C_{gs} and C_{gd}, and then the nonlinear gate capacitances were implemented using the charge-equation-based model as shown below:

$$Q_g(V_{gs}, V_{ds}) = Q_{g\_eehemt} + Q_{g\_peak} \quad (9)$$

$$Q_{g\_eehemt} = p_1(V_p + (1/p_2)\ln(2\cosh(p_2 V_p))) + C_{11off}V_{gs} - C_{12sat}V_{ds} \quad (10)$$

$$Q_{g\_peak} = q_1(1 + \tanh(q_2 V_q)) \quad (11)$$

$$V_p = V_{gs} - V_{inf1}, V_q = V_{gs} - V_{inf2} \quad (12)$$

$$p_1 = p_{1o} + \lambda_{p1}V_{ds} + p_{1t}\Delta T, q_1 = q_{10} + \lambda_{q1}V_{ds} + q_{1t}\Delta T$$

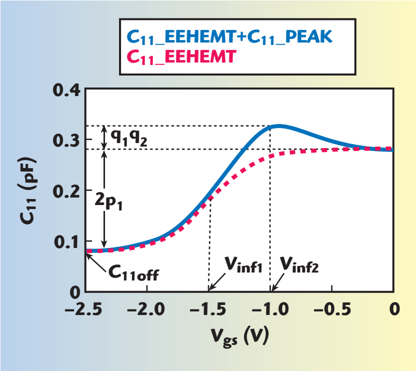
$$V_{inf1} = V_{inf\,1o} + w_{il}V_{ds}, V_{inf2} = V_{inf\,2o} + w_{i2}V_{ds}$$

The unified gate charge modeling equation in Equation 9 satisfies the charge-conservation principle[10] to overcome convergence problem during simulations. Differentiating the gate charge expression with respect to V_{gs} yields the following expression for the gate capacitance C_{11}:

$$C_{11} = \partial Q_g / \partial V_{gs} = C_{11\_eehemt} + C_{11\_peak} \quad (13)$$

$$= p_1(1 + \tanh(p_2 V_p)) + C_{11off} + q_1 q_2 \operatorname{sech}^2(q_2 V_q)$$

Figure 3 describes the operation of the fitting parameters. It can be seen that the additional $C_{11\_peak\ term}$, compared to the EEHEMT charge model, enables the peaking of the gate capacitance C_{11} near cutoff. Besides, the total gate charge Q_g needs to be subdivided between the respective charge sources Q_{gs} and Q_{gd}, so as to be implemented into the proposed large-signal equivalent-circuit model as in Figure 2. Similar bilateral smoothing functions used in the EEHEMT charge model[7] are applied here, as given below:



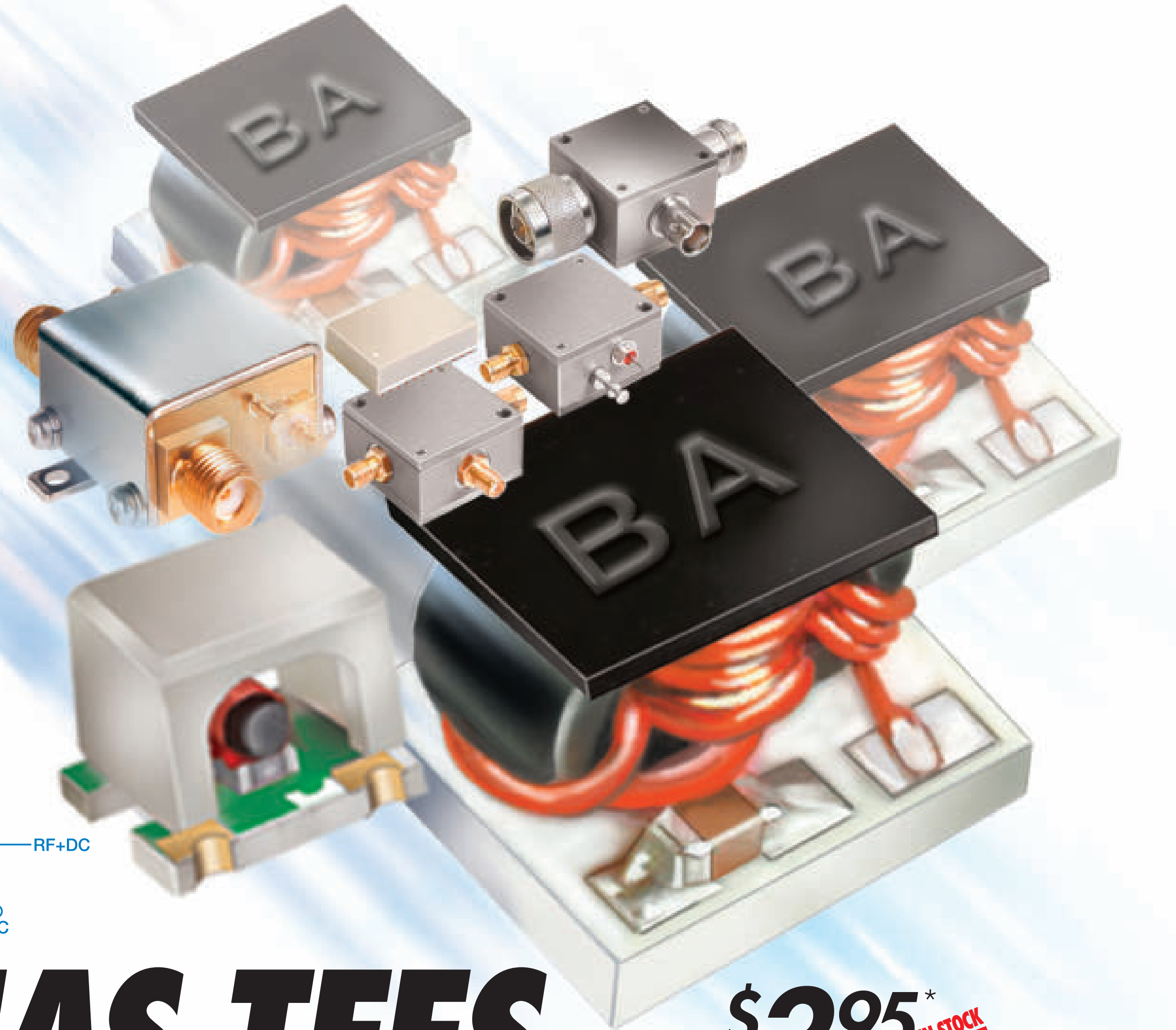
▲ *Fig. 3 Interpretation of the gate charge Q-V model.*

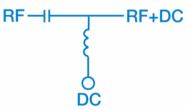
$$V_{do} = \sqrt{V_{ds}^2 + \delta^2} \quad (14)$$

$$V_{go} = 1/2(2V_{gs} - V_{ds} + \sqrt{V_{ds}^2 + \delta^2}) \quad (15)$$

$$f_{1,2} = 1/2(1 \pm \tanh(3/\delta(V_{gs} - V_{gd} - V_{as}))) \quad (16)$$

$$Q_{gs}(V_{gs}, V_{gd}) = (Q_g(V_{go}, V_{do}) - C_{gdsat}V_{gd})f_1 + C_{gdsat}V_{gs}f_2 \quad (17)$$





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$$Q_{gd}(V_{gs}, V_{gd}) = (Q_g(V_{go}, V_{do}) - C_{gdsat}V_{gs})f_2 + C_{gdsat}V_d f_1 \quad (18)$$

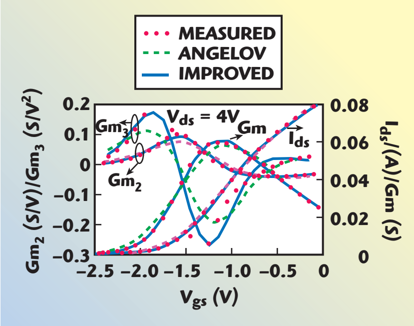
Finally, the gate-source and gate-drain diodes in forward conduction are modeled using the standard Schottky diode equation.[5] The complete large-signal nonlinear model is implemented in Agilent's ADS through Verilog-A coding.

EXPERIMENTAL MODEL VERIFICATION

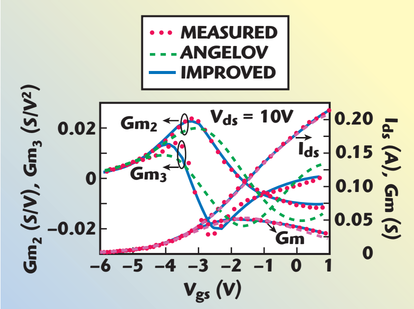
In order to demonstrate the usefulness of the proposed large-signal model, the 0.25 µm gate-lengths on-wafer GaAs double-heterojunction δ-doped PHEMT[9] and the GaN metal-insulator-semiconductor HEMT (MISHEMT) with atomic-layer-deposited (ALD) Al_2O_3 gate insulator[15] have been modeled and validated. As a first step, isothermal pulsed I-V measurements[16] for the 2 × 100 µm gate-widths GaAs and GaN HEMTs have been investigated. The extracted drain current and its first three derivatives (G_m, G_{m2} and G_{m3}) characteristics with respect to gate voltage are compared to measured values at the quiescent biasing point of (V_{gsq}, V_{dsq}) = (0 V, 0 V) in ***Figures 4*** and ***5***, where an excellent fit is obtained for the entire bias range. These curves serve to illustrate the improvements of the derivative reproduction of the modified I-V model over the original Angelov model.

Furthermore, the measured gate capacitance $C_{11} = C_{gs} + C_{gd}$ was evaluated from the intrinsic Y-parameters.[14] The verification of the gate charge model performance (C-V) is shown in ***Figure 6***. It can be seen that the two HEMT devices exhibit gate capacitance peaking characteristics, while the C_{11} of the GaN HEMT is nearly V_{ds} independent.

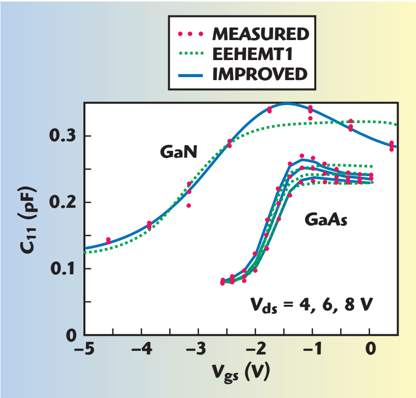
The utility of the power performance of the model is verified by comparing its output predictions with measured power data. The transmitted output power characteristics at the first two harmonics and the power-added-efficiency (PAE) at a particular biasing point in deep Class AB biasing conditions



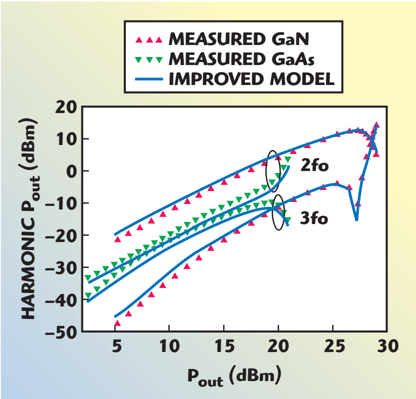
▲ *Fig. 4 Measured (circles) and modeled (lines) pulsed I-V and its first three derivatives (Gm, Gm_2 and Gm_3) characteristics of a GaAs HEMT.*



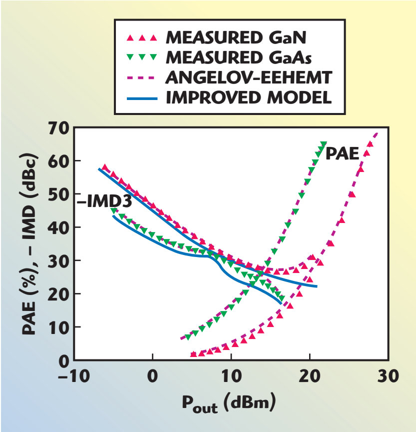
▲ *Fig. 5 Measured (circles) and modeled (lines) pulsed I-V and its first two derivatives (Gm, Gm_2 and Gm_3) characteristics of a GaN HEMT.*



▲ *Fig. 6 Measured (circles) and modeled (lines) C-V results of the GaAs and GaN HEMTs.*



▲ *Fig. 7 Measured (symbols) and modeled (lines) results for the output harmonics power levels.*



▲ *Fig. 8 Measured (symbols) and modeled (lines) single tone PAE and two-tone, third order IMD performance.*

are simulated and compared with measured data, as shown in ***Figures 7*** and ***8***, respectively. For the GaAs HEMT, the frequency was 7.5 GHz and the bias -1.8 and 6.0 V, while for the GaN HEMT, the frequency was 4 GHz and the bias -3.7 V and 20.0 V. The input and output terminating impedances of the device were adjusted for maximum PAE performances. It can be seen that the model provides a very good prediction of the power characteristics. Moreover, the third-order intermodulation distortion (IMD3) has been characterized using two-tone tests (10 MHz spacing) under 50 Ω biasing conditions. According to the data and simulated output shown, the developed nonlinear model is capable of predicting the third-order IMD products more accurately.[17]

CONCLUSION

An improved large-signal model has been presented and validated for HEMTs. Based on the well-known Angelov drain-current I-V and EEHEMT gate-charge Q-V model, two extra drain-current and gate-charge modeling sources have been proposed to independently control the G_m tail-off and C_{gs} peaking characteristics, respectively. The modified nonlinear model has demonstrated the ability to model the I-V and C-V characteristics of the GaAs and GaN HEMTs. In addition, the large-signal model has been

implemented in Agilent's ADS and can accurately predict the large-signal output power performances for the first two harmonics as well as third-order IMD characteristics. This model, developed from the widely-used Angelov and EE-HEMT models, is easy to be extracted, and thus can serve as a useful tool in commercial nonlinear simulators. ■

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Lin-Sheng Liu *received the bachelor's degree (with honors) in electronic engineering from the University of Electronic Science and Technology of China (UESTC), Chengdu, China, in 2005, and is currently working toward his Ph.D. degree in circuits and systems at UESTC. His current research interests include the characterizations/ modeling of III–V compound semiconductor devices and high-efficiency switch-mode PA design.*

DESIGN OF A WIDE STOPBAND BANDPASS FILTER WITH SOURCE-LOAD COUPLING

This article presents a microstrip bandpass filter (BPF) for wireless LAN applications. The BPF offers a wide upper stopband by using two novel slow-wave resonators. Two transmission zeros are generated on both sides of the passband as a result of source-load coupling. The measured results show that this BPF has good characteristics, including a low insertion loss of 1.66 dB at the center frequency of 2.4 GHz and a wide upper stopband up to 7 GHz. Comparison of measured and simulated results shows very good agreement.

With the rapid development of communication technology, there have been increasing demands for advanced radio frequency (RF) filters with small size, wide stopband and high selectivity. To realize better selectivity, the generation of transmission zeros is very important in the synthesis of modern filters. Most of the research efforts are focused on filters where both the source and the load are connected to only one resonator.[1,2] Such filters can generate at most N-2 finite transmission zeros with N-coupled resonators. However, when source/load coupling is involved, N finite transmission zeros from N-coupled resonators can be obtained.[3-6]

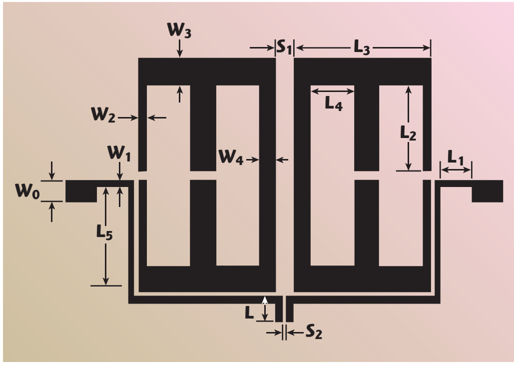


Fig. 1 Layout of the proposed microstrip BPF.

In order to improve the performance of out-of-band rejection, a number of technologies have been widely investigated. For example, utilizing stepped impedance resonators (SIR) or slow-wave resonators is the convenient method to realize wide stopband.[7-9] In addition, a feeding scheme with L-shaped lines has been proposed to suppress the harmonic.[10] Although conventional slow-wave resonators possess the advantages of miniaturization and a wide stopband, these filters suffer from loose coupling between resonator and feeding line, resulting in high external quality factor.

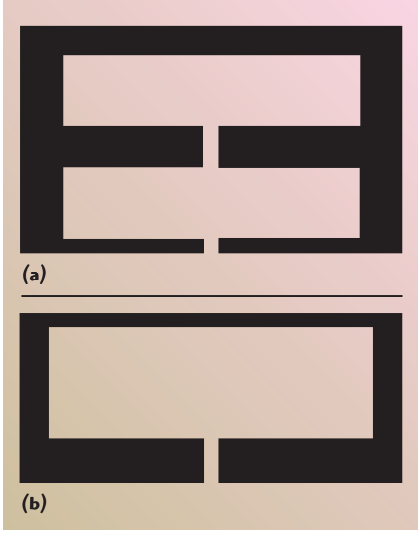
In this article, a two-order filter, operating at 2.4 GHz for application in a wireless local area network (WLAN) system, is proposed. Two slow-wave resonators and corresponding feeding structures are introduced to enhance the tunable range of the external quality factor. Using source/load coupling can realize two controllable transmission zeros. Measured and simulated results show that this filter cannot only obtain high selectivity, but also achieve wide upper stopband as well.

FILTER DESIGN

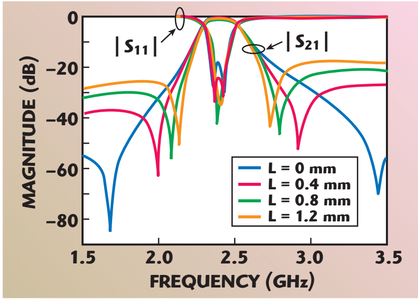
Figure 1 shows the layout of the proposed microstrip BPF using two slow-wave resona-

ZHONG YIN XIAO, SHAN GAO, DE CHEN MA AND LIANG LIANG XIANG
Shanghai University, Shanghai, China

tors. ***Figure 2*** illustrates the structure of the proposed slow-wave resonator. Two opposite open stubs are added inside of the slow-wave resonator to achieve a compact size. Compared with the conventional slow-wave resonator, it results in a smaller external quality factor. The required 2.4 GHz center frequency of the BPF (as specified in the IEEE 802.11a/b standard for WLAN), is obtained by adjusting the size of the resonator and the position of open stubs. In ***Figure 3***, the simulated results show the frequency responses of the proposed BPF under different source/load coupling lengths L. The length L is introduced to provide source/load capacitive coupling. When L increases from 0 to 1.2 mm, the return loss in the passband is reduced, while a pair of transmission zeros is closer to the passband. Thus, sharper fall-off at both passband edges can be achieved.



▲ *Fig. 2 Structure of the slow-wave resonator: (a) novel resonator and (b) conventional resonator.*

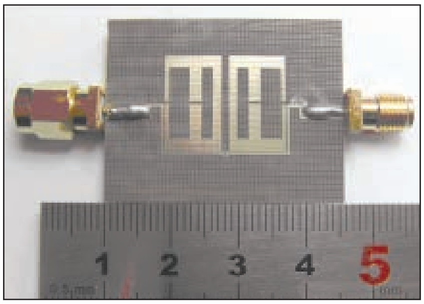


▲ *Fig. 3 Simulated frequency responses of the proposed BPF for different source-lead coupling lengths.*

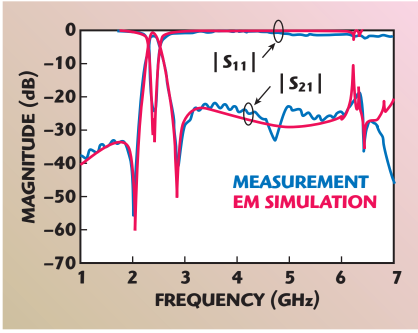
According to the above analysis procedure, the dimensions of the filter are obtained as follows: L = 0.6 mm, L_1 = 1.5 mm, L_2 = 5.2 mm, L_3 = 8.4 mm, L_4 = 1.7 mm, L_5 = 7.2 mm, W_0 = 2.1 mm, W_1 = 0.4 mm, W_2 = 0.6 mm, W_3 = 1.8 mm, W_4 = 1.2 mm, S_1 = 1.2 mm and S_2 = 0.2 mm. The thickness of the substrate used here is 0.8 mm, and its relative dielectric constant is 2.78.

MEASURED RESULTS

A photograph of the fabricated BPF is shown in ***Figure 4***. The S-parameters are measured by using a network analyzer, Agilent 8722ES, and are plotted in ***Figure 5*** together with EM simulat-



▲ *Fig. 4 Photograph of fabricated microstrip bandpass filter.*



▲ *Fig. 5 Comparison of simulated and measured frequency responses.*

ed results. The measured results show a return loss of 24 dB, a minimum insertion loss of 1.66 dB in the passband, FBW of 3.3 percent at 2.4 GHz, and better than -20 dB rejection level in the upper stopband, up to 7 GHz. Two transmission zeros are clearly observed at 2.01 GHz with -56 dB attenuation and 2.88 GHz with -41 dB attenuation. The insertion loss is mainly attributed to the SMA connector and the conductor and dielectric losses. Due to the pair generation of transmission zeros on both sides of the passband, a better selectivity is realized.

CONCLUSION

A novel microstrip bandpass filter, using slow-wave resonators, is presented. The measured results show good characteristics, such as low insertion loss in the passband, a wide upper stopband and high passband selectivity. This performance agrees closely with the simulation. With these features, the proposed BPF is suitable for WLAN applications.

ACKNOWLEDGMENTS

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FAST CALCULATION OF TRANSIMPEDANCE GAIN AND EQUIVALENT INPUT NOISE CURRENT DENSITY FOR HIGH-SPEED OPTICAL PREAMPLIFIER DESIGN

Analytical expressions for the relationships between the transimpedance gain and S-parameters, equivalent input noise current density and noise figure for high-speed optical transimpedance amplifier design are proposed in this article. This technique is based on the signal and noise equivalent circuit models of the optical transimpedance preamplifier. The transimpedance gain and equivalent input noise current density can be obtained directly from measured S-parameters and noise figure, without any additional measurement equipment. A 10 Gb/s high electron mobility transistor (HEMT)-based transimpedance preamplifier has been designed and the measured S-parameters and noise figure have been used to demonstrate this approach.

Optoelectronic integrated circuits (OEIC) have attracted the interest of many researchers because of their important role in the hardware for information technology. The optical receivers have key roles in high-speed optical fiber communications, in high-speed chip-to-chip interconnections in computers, efficient networking between computers and in other diverse areas such as medical imaging. One of the most critical building blocks in an optical link system is the transimpedance amplifier (TIA), which converts the photodiode (PD) current into an amplified voltage. The requirements for a typical TIA are high bandwidth, high transimpedance gain, adequate power gain, low noise, low input impedance, small area and low power consumption for array applications.[1-4]

The major design goals of the TIAs are the transimpedance gain and equivalent input noise current density. The transimpedance gain of the TIAs must be large enough to overcome the noise of the subsequent stage, typically a 50 Ω driver or a limiting amplifier. The equivalent input noise current density determines the minimum input current that yields a given bit error rate, directly impacting the link budget. Unfortunately, the transimpedance gain and equivalent input noise current density cannot be measured directly from microwave and noise equipment, while the S-parameters and

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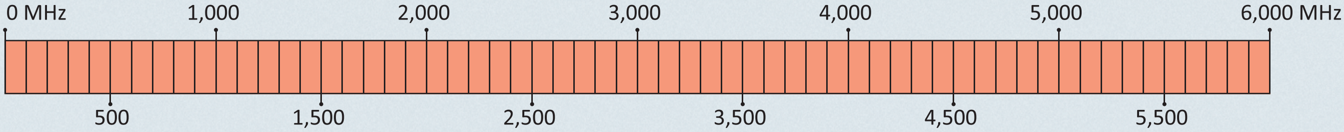

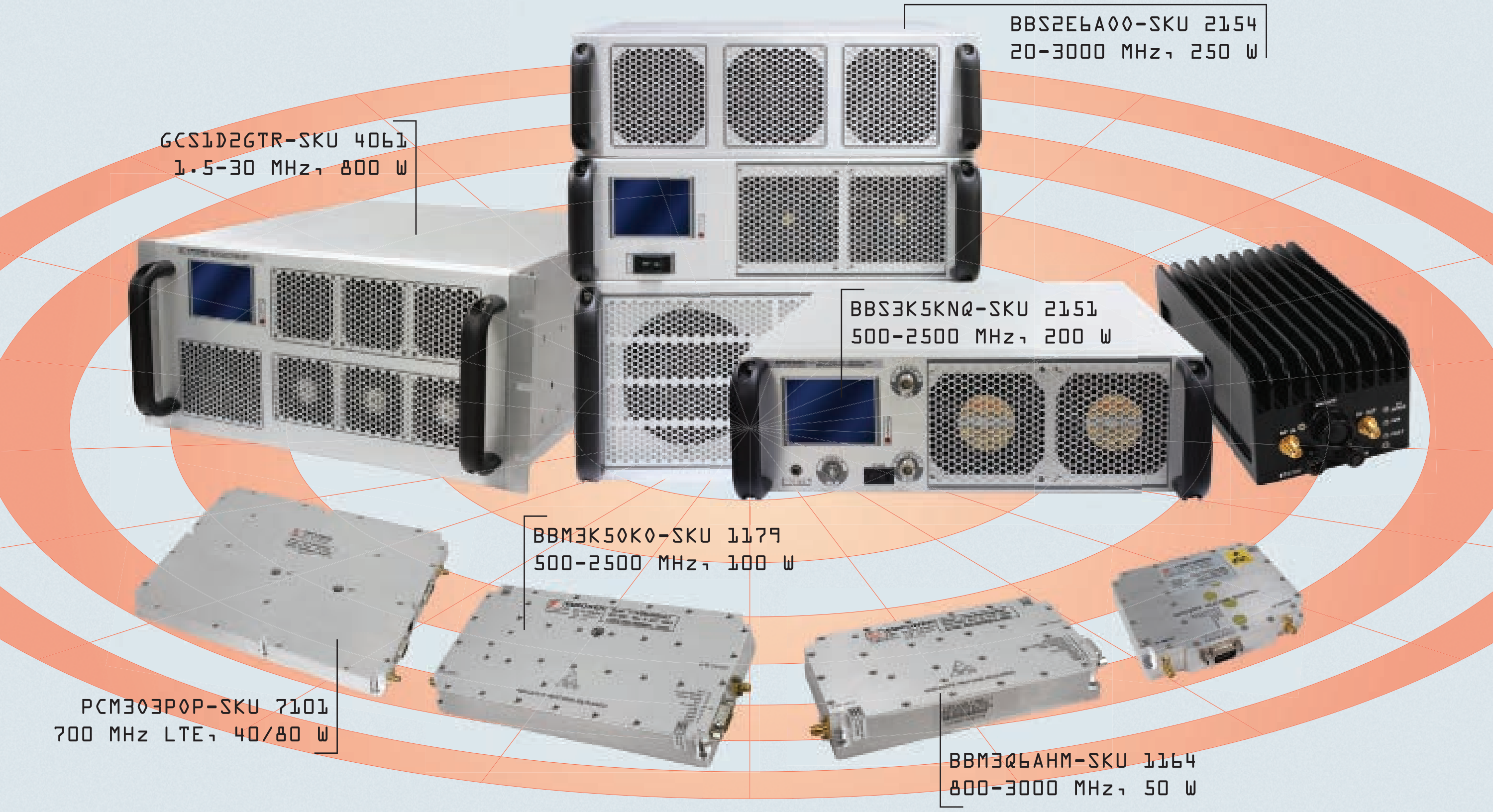

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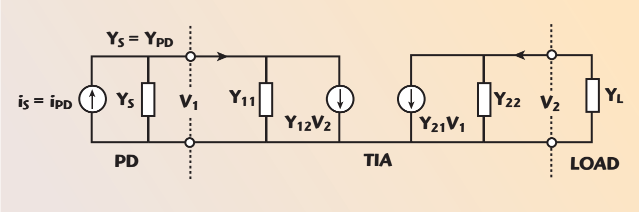

▲ *Fig. 1 Simulated model of the optical receiver front-end.*

noise figure of the TIAs can be measured with a vector network analyzer (VNA) and a noise figure meter in a straightforward manner. Therefore, a fast transformation between S-parameters/noise figure and transimpedance gain/equivalent input noise current density is needed.

Analytical expressions for transimpedance gain and equivalent input noise current of optical receivers have been derived[5] and simple expressions for the relationship between the transimpedance gain and Z-parameters are given.[6-8] However, these expressions are not always valid and the transimpedance gain and equivalent input noise current density cannot be directly and accurately calculated from S-parameters and noise figure measurement data. Based on the author's knowledge, a comprehensive analysis for fast transformation between S-parameters/noise figure and transimpedance gain/equivalent input noise current density has not yet been published.

In this article, a simple but efficient transformation technique for TIAs is proposed and the analytical expressions for the relationships between the transimpedance gain and S-parameters, the equivalent input noise current density and the noise figure for high-speed optical transimpedance preamplifier design are derived. This technique is based on the signal and noise equivalent circuit model of the optical receiver front-end.

In contrast with previous publications,[5-8] this method has the following advantages:

- The transimpedance gain can be directly derived from S-parameters for arbitrary source and load impedances and simplified expressions for two special cases (source impedances are zero and 50 Ω) are also given.
- The equivalent input noise current density can be determined from noise figure measurements without four noise parameters (minimum noise figure, noise resistance and optimum source reflection coefficient) of TIA in 50 Ω and non-50 Ω systems.

THEORETICAL ANALYSIS

Transimpedance Gain

The schematic of the optical receiver front-end circuit is shown in ***Figure 1***, where Y_S is the photodiode (PD) input admittance. Typically this will be that of the PIN/APD and it is almost totally capacitive (that is $Y_S = j\omega C_{pd}$). Y_L is the load admittance, which is generated by the input admittance of the next stage (typically $Y_L = Y_0 = 0.02$ mS).

The transimpedance is defined as the magnitude of the ratio of the output voltage V_2 at a load impedance and the photocurrent through the photo-

diode i_s. Based on the small-signal circuit model analysis for an optical receiver frond-end and applying Kirchhoff's current law, the transimpedance gain of the optical receiver front-end can be expressed as:

$$Z_T = \frac{V_2}{i_s} = -\frac{Y_{21}}{(Y_S + Y_{11})(Y_L + Y_{22}) - Y_{21}Y_{12}} \quad (1)$$

The relationship between the S-parameters and Y-parameters can be expressed as:

$$Y_{11} = Y_o \frac{(1+S_{22})(1-S_{11}) + S_{12}S_{21}}{(1+S_{22})(1+S_{11}) - S_{12}S_{21}} \quad (2)$$

$$Y_{12} = Y_o \frac{-2S_{12}}{(1+S_{22})(1+S_{11}) - S_{12}S_{21}} \quad (3)$$

$$Y_{21} = Y_o \frac{-2S_{21}}{(1+S_{22})(1+S_{11}) - S_{12}S_{21}} \quad (4)$$

$$Y_{22} = Y_o \frac{(1+S_{11})(1-S_{22}) + S_{12}S_{21}}{(1+S_{22})(1+S_{11}) - S_{12}S_{21}} \quad (5)$$

where Y_0 (= 0.02 mS) is the characteristic admittance of the system.

Substituting Equations 2 to 5 into Equation 1:

$$Z_T = \frac{V_2}{i_s} = \frac{2S_{21}}{Y_o A + Y_L B + Y_S C + Y_S Y_L D / Y_o} \quad (6)$$

with

$$A = (1-S_{11})(1-S_{22}) - S_{12}S_{21}$$
$$B = (1-S_{11})(1+S_{22}) + S_{12}S_{21}$$
$$C = (1+S_{11})(1-S_{22}) + S_{12}S_{21}$$
$$D = (1+S_{22})(1+S_{11}) - S_{12}S_{21}$$

If the source impedance is infinite (that is $Y_S = 0$), and the output end of the TIA is connected to a matched load (that is $Y_L = Y_0 = 0.02$ mS), the corresponding transimpedance gain of the receiver front-end can be simplified as follows:

$$Z_T^T = \frac{S_{21}}{Y_o(1-S_{11})} \quad (7)$$

when the TIA is operated in a 50 Ω system ($Y_L = Y_S = Y_0 = 20$ mS), the transimpedance gain can be written as:

$$Z_T^{50} = \frac{S_{21}}{2Y_o} \quad (8)$$

The transimpedance gain and bandwidth versus Y_S and Y_L are summarized in ***Table 1***. It can be observed that the transimpedance 3 dB bandwidth can be determined from the forward transmission coefficient S_{21} only when the input and output ports are terminated in matched loads. The physical meanings of the three transimpedance gains mentioned above are as follows: Z_T is the transimpedance gain of whole optical receiver front-end (PD+TIA); Z_T^T is the transimpedance gain of TIA; and Z_T^{50} is proportional to the power gain S_{21} of the TIA.


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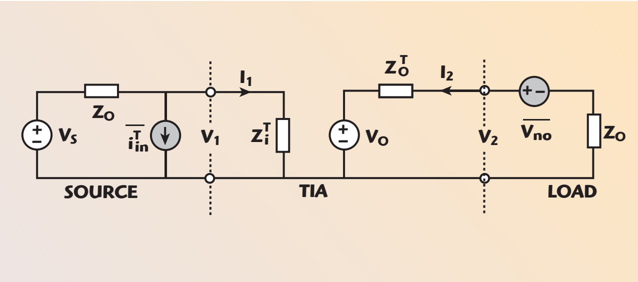
TABLE I
TRANSIMPEDANCE GAIN VERSUS Y_S AND Y_L

Source and Load Impedances	Transimpedance Gain	Physical Meaning
Arbitrary Y_S and Y_L	Z_T	Receiver front-end (PD+TIA)
$Y_L = Y_O$, $Y_S = 0$	Z_T^T	TIA only
$Y_L = Y_S = Y_O$	Z_T^{50}	Power gain S_{21} of TIA



▲ *Fig. 2 Noise model of the 50 Ω noise figure measurement system for an optical preamplifier.*

Equivalent Input Noise Current Density of the TIA

Figure 2 shows the noise model of the noise figure measurement system for an optical preamplifier. It is noted that 50 Ω standard resistances have been used for source and load impedances (Z_S=Z_L=Z_0=50 Ω). Z_i^T and Z_o^T are the input and output impedances of the TIA, respectively. $\overline{v_{no}}$ is the total output noise voltage density, and i_{in}^T is the equivalent input noise current density of the TIA.

The noise figure of the TIA can be expressed as follows:[10]

$$F_{50} = 1 + \frac{\overline{v_{no}^2}}{4kT\left|A_v^2\right|Z_o} \qquad (9)$$

then

$$\overline{v_{no}^2} = 4kT\left|A_v^2\right|Z_o\left(F_{50} - 1\right) \qquad (10)$$

Where A_v is the voltage gain and can be expressed as:

$$A_v = \frac{V_2}{V_s} = \frac{S_{21}}{2} = \frac{Z_T^T}{Z_i^T + Z_o} \qquad (11)$$

Where Z_T^T is the transimpedance of the TIA ($Z_T^T = V_2 / I_1$). The corresponding equivalent input noise current density of the TIA i_{in}^T can be derived as follows:

$$i_{in}^T = \frac{\overline{v_{no}}}{\left|Z_T^T\right|} = \frac{\sqrt{\left(F_{50} - 1\right)4kT_0Z_o}}{\left|Z_o + Z_i^T\right|} \qquad (12)$$

With $Z_i^T = Z_o\frac{1+S_{11}}{1-S_{11}}$ substituted in Equation 12,

$$i_{in}^T = \frac{\overline{v_{no}}}{\left|Z_T^T\right|} = \left|1 - S_{11}\right|\sqrt{\frac{\left(F_{50} - 1\right)kT_0}{Z_o}} \qquad (13)$$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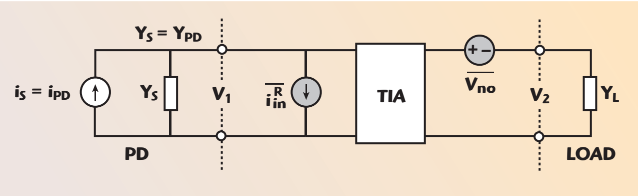
Equivalent Input Noise Current Density of the Optical Receiver Front-end

Figure 3 shows the noise model of a typical optical receiver front-end in a non-50 Ω system, where $\overline{i_{in}^R}$ is the total equivalent input noise current density and $\overline{v_{no}}$ is the total output noise voltage density of the receiver front-end. It is noted that the input port of the TIA is connected to the PD, not the matched load. Therefore, Equation 13 is only valid for TIA design, not for the whole receiver front-end.



▲ *Fig. 3 Noise model of the optical receiver front-end.*

Assuming that the total output noise voltage density $\overline{v_{no}}$ is generated mainly by the TIA (here the noise contribution of the PD is neglected), the equivalent input noise current density of the receiver front-end $\overline{i_{in}^R}$ can be expressed as follows:

$$\overline{i_{in}^R} = \frac{\overline{v_{no}}}{|Z_T|} = \frac{1}{2}\left|Y_oA + Y_LB + Y_sC + Y_SY_LD / Y_o\right| \cdot \sqrt{kT_oZ_o\left(F_{50} - 1\right)} \quad (14)$$

Traditionally, the output end of TIA is connected to a matched load ($Y_l = Y_o$=0.02 mS), then $\overline{i_{in}^R}$ can be written as:

$$\overline{i_{in}^R} = \frac{\overline{v_{no}}}{|Z_T|} = \left|1 - S_{11} + \left(1 + S_{11}\right)Y_s / Y_o\right| \cdot \sqrt{\frac{kT_oZ_o\left(F_{50} - 1\right)}{Z_o}} \quad (15)$$

when the TIA is operated in a 50 Ω system ($Y_L = Y_S = Y_0$ = 20 mS), the equivalent input noise current density can be simplified:

$$\overline{i_{in}^{50}} = 2\sqrt{\frac{kT_o\left(F_{50} - 1\right)}{Z_o}} \quad (16)$$

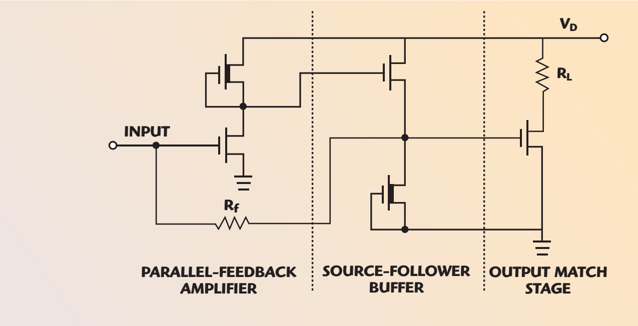
It is noted that Equation 16 is the conventional formula for predicting the equivalent input noise current density for a TIA IC. The $\overline{i_{in}^{50}}$ is dependent on the noise figure only, and independent on the S-parameters of the TIA. The equivalent input noise current density versus Y_S and Y_L is summarized in ***Table 2***.

EXPERIMENTAL ANALYSIS

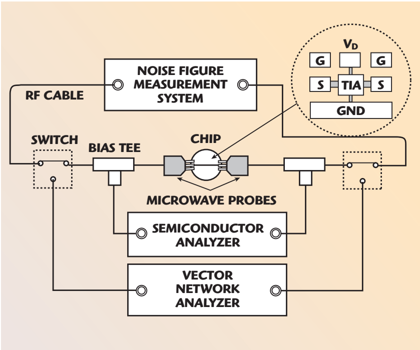
In order to demonstrate the expressions derived in the Theoretical Analysis section for the TIA, a HEMT-based TIA, which operates at 10 Gb/s, has been designed using a 0.2 μm PHEMT process.[11] ***Figure 4*** shows a schematic of the developed TIA IC, using both enhancement- and depletion-mode (E-D) transistors. This IC consists of three parts: a parallel-feedback amplifier core, a source-follower buffer and an output match stage. The

TABLE II
EQUIVALENT INPUT NOISE CURRENT DENSITY VERSUS Y_S AND Y_L

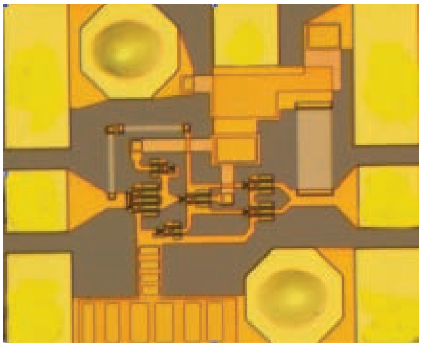
Source and Load Impedances	Input Noise Current Density	Physical Meaning
Arbitrary Y_S and Y_L	$\overline{i^{R}_{in}}$	Receiver front-end (PD+TIA)
$Y_L = Y_O$, $Y_S = 0$	$\overline{i^{T}_{in}}$	TIA only
$Y_L = Y_S = Y_O$	$\overline{i^{50}_{in}}$	Only dependent on noise figure TIA



▲ *Fig. 4 Schematic of the 10 Gb/s HEMT-based TIA IC.*



▲ *Fig. 5 Experimental setup.*



▲ *Fig. 6 Photograph of the 10 Gb/s HEMT TIA chip.*

source-follower buffer improves the flatness of the gain-frequency characteristics by separating the parallel-feedback loop from the large input capacitance of the output buffer (that is eliminating the Miller capacitance loading to the previous stages). The output stage is designed for a 50 Ω output impedance match. ***Figure 5*** shows the experimental setup. All measurements were carried out on-wafer, using Air-Coplanar Probes. The wafer probes were calibrated using the Line-Reflect-Match (LRM) calibration method for S-parameter measurement. The noise parameter measurement method proposed here has been tested on wafer up to 26 GHz. The corresponding chip photograph of the 10 Gb/s HEMT TIA is shown in ***Figure 6***.[11]


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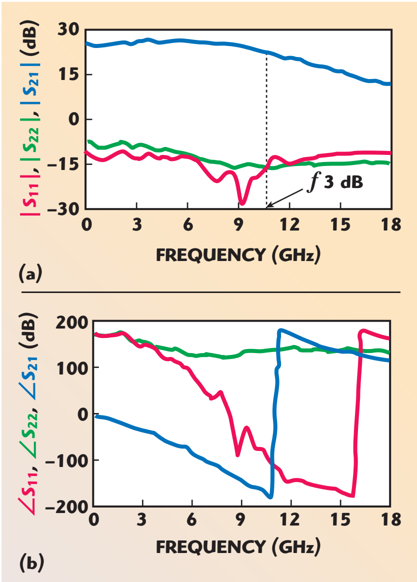
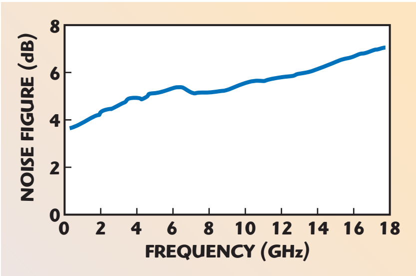
Figure 7 shows the measured magnitudes and phases of the S-parameters of the TIA IC. The high gain $|S_{21}|$ of 25 dB and the broad 3 dB bandwidth over 10.8 GHz have been obtained. Good matching is also achieved, $|S_{11}|$ less than -10 dB and $|S_{22}|$ less than -7 dB for the whole frequency range. The corresponding noise figure versus frequency is shown in ***Figure 8***.

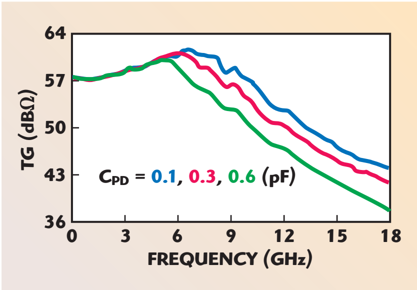
The transimpedance gain (TG) and equivalent input noise current density (EINCD) can be obtained from AC and noise signal analysis by using commercial circuit design tools (such as SPICE). However, it is difficult to measure them directly using conventional microwave signal and noise measurement systems. Alternatively, they can be calculated from S-parameters and noise figure measurements by using the proposed transformation expressions.



▲ *Fig. 7 S-parameters of the 10 Gb/s HEMT-based TIA IC: (a) magnitude and (b) phase.*



▲ *Fig. 8 Measured noise figure of the 10 Gb/s HEMT-based TIA IC.*



▲ *Fig. 9 Transimpedance gain vs. frequency for the 10 Gb/s TIA.*

Figure 9 shows the transimpedance gain, which is derived from the measured S-parameters of the 10 Gb/s TIA; the corresponding 3 dB bandwidth versus capacitance of the PD is shown in ***Figure 10***. It can be found that the 3 dB bandwidth of the TIA transimpedance gain is approximately 11.5 GHz, and the corresponding optical receiver front-end 3 dB bandwidth decreases with the increase of the capacitance of the PD ($Y_S = j\omega C_{pd}$). As long as the capacitance of the PD is kept less than 0.6 pF (3 dB

bandwidth of 8 GHz), the proposed TIA can be operated at a 10 Gb/s bit rate. ***Figure 11*** shows the comparison of the predicted transimpedance gain for the 10 Gb/s TIA obtained from Equations 7 and 8. It is obvious that the gain and bandwidth predicted by Equation 7 is better than that of a TIA operating in a matching system. That means the transimpedance gain will be underestimated using the conventional formula.

Figure 12 shows the EINCD, which is derived from the measured noise figure of 10 Gb/s TIA. The corresponding average values versus capacitance of the PD are shown in ***Figure 13***. It can be found that equivalent input noise current density increases with the increase of capacitance of the PD ($Y_S = j\omega C_{pd}$). As long as the capacitance of the PD is kept less than 0.3 pF, the equivalent input noise current density of the proposed TIA can be less than $20\ \text{pA}/\sqrt{\text{Hz}}$. ***Fig-***

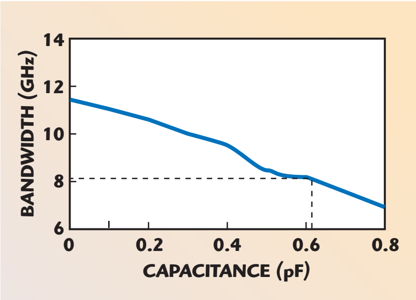


Fig. 10 3 dB bandwidth of the transimpedance gain vs. capacitance of PD.

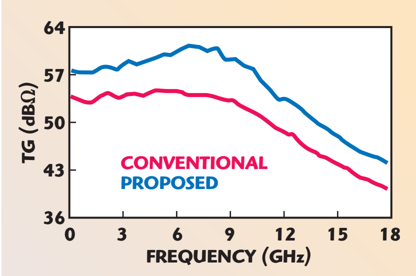


Fig. 11 Comparison of transimpedance gains for 10 Gb/s TIA.

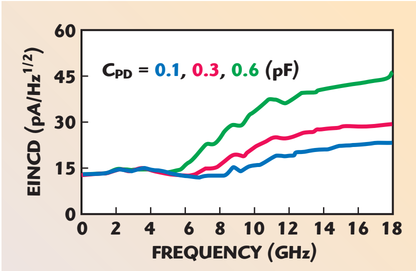


Fig. 12 Equivalent input noise current density (EINCD) vs. frequency for the 10 Gb/s TIA.

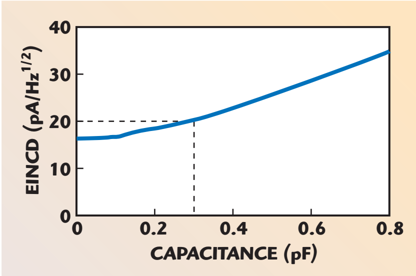


Fig. 13 Equivalent input noise current density (EINCD) vs. capacitance of PD.

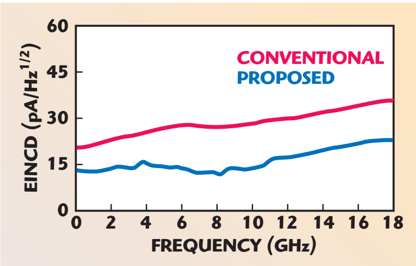


Fig. 14 Comparison of the equivalent input noise current density (EINCD) for the 10 Gb/s TIA.

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ure 14 shows the comparison of predicted equivalent input noise current density for the 10 Gb/s TIA by using the proposed Equation 13 and the conventional Equation 16. It is obvious that the equivalent input noise current density predicted by Equation 13 is better than that predicted by the conventional formula. This means the equivalent input noise current density will be overestimated using the conventional formula.

CONCLUSION

Analytical expressions for the relationships between the transimpedance gain from S-parameters, equivalent input noise current density and noise figure for high-speed optical transimpedance preamplifier design is proposed in this article. The validity of the new approach is proven by using a 10 Gb/s high electron mobility transistor (HEMT)-based transimpedance preamplifier. ■

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Jianjun Gao *received his BEng and PhD degrees from Tsinghua University in 1991 and 1999, respectively, and his MEng degree from the Hebei Semiconductor Research Institute in 1994. From 1999 to 2001, he was a post-doctoral research fellow at the Microelectronics R&D Center, Chinese Academy of Sciences, developing PHEMT optical modulator drivers. In 2001, he joined the school of Electrical and Electronic Engineering, Nanyang Technological University (NTU), Singapore, as a research fellow in semiconductor device modeling and on wafer measurement. In 2003, he joined the Institute for High-Frequency and Semiconductor System Technologies, Berlin University of Technology, Germany, as a research associate working on InP HBT modeling and circuit design for high speed optical communication. In 2004, he joined the Electronics Engineering Department, Carleton University, Canada, as a post-doctoral fellow, working on the semiconductor neural network modeling technique. From 2004 to 2007, he was a full professor in the radio engineering department at Southeast University, Nanjing, China. Since 2007, he has been a full professor in the school of information science and technology, East China Normal University, Shanghai, China. His main areas of research include characterization, modeling and on wafer measurement of microwave semiconductor devices, optoelectronics device and high-speed integrated circuit for radio frequency and optical communication.*

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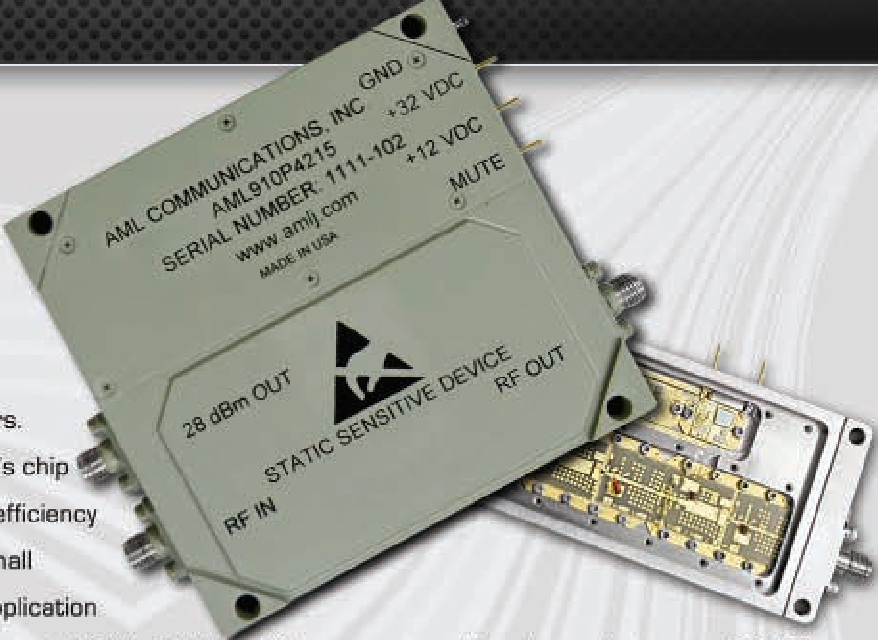

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AML056P4014	0.5 - 6.0	40	37	38	6	28V, 1.0A	20%
AML056P4511	0.5 - 6.0	45	39	40	10	28V, 1.3A	25%
AML056P4512	0.5 - 6.0	45	43	44	25	28V, 2.5A	25%
AML13P5013	1.0 - 3.0	50	46	47	50	28V, 4.8A	25%
AML16P4511	1.5 - 6.0	45	39	40	10	28V, 1.0A	26%
AML16P4512	1.5 - 6.0	45	42	43	20	28V, 2.6A	25%
AML16P4513	1.5 - 6.0	45	44	45	30	28V, 4.8A	25%
AML26P4011	2.0 - 6.0	40	40	41	12	28V, 1.0A	30%
AML26P4012	2.0 - 6.0	45	43	44	25	28V, 2.5A	35%
AML26P4013	2.0 - 6.0	45	46	47	50	28V, 4.8A	35%
AML59P4512	5.5 - 9.0	45	45	46	40	28V, 3.6A	38%
AML59P4513	5.5 - 9.0	45	48	49	80	28V, 7.2A	38%
AML910P4213	9.9 - 10.7	43	37	38	6	32V, 0.5A	30%
AML910P4214	9.9 - 10.7	43	39	40	10	32V, 0.8A	30%
AML910P4215	9.9 - 10.7	46	41.5	42	15	32V, 1.3A	30%
AML910P4216	9.9 - 10.7	46	42	43	20	32V, 1.3A	30%
AML811P5011	7.8 - 11.0	45	43	44	25	28V, 2.6A	30%
AML811P5012	7.8 - 11.0	50	46	47	50	28V, 5.5A	30%
AML811P5013	7.8 - 11.0	50	49	50	100	28V, 11A	30%

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MULTIPACTION DISCHARGE IN COAXIAL COMPONENTS

The development of coaxial microwave components capable of handling high peak power without the presence of multipactor is an important part of component design for space and vacuum environments. Multipactor is a resonance type of discharge that can occur under vacuum conditions.[1] The electric component of the electromagnetic field can have sufficient energy to cause the emission of electrons from the material surface. In a vacuum environment, the electron free path distance is greater than the electrode separation distance. This change in the distance relationship allows free electrons to impact the electrode surface. These collisions create a secondary electron emission from the electrode structure. The synchronization between the secondary electron emissions and the frequency of the electric field alternating polarity will accelerate the electrons back to the source electrode (see ***Figure 1***). Under the appropriate conditions, the number of electrons will increase exponentially up to a saturation point, at which the electron density is large enough to block the electric field. This electron charge build up can cause a resonance type of breakdown in the form of a multipaction discharge.[1] Multipaction discharge itself can also cause an additional saturation mechanism through its interaction with the electrodes.[2]

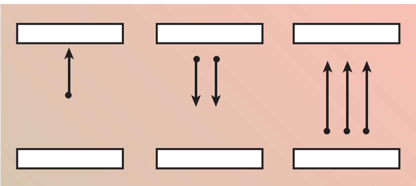

Fig. 1 Multipactor between two planes.

There are two main conditions that must be present for multipactor. First, the one way transit time between the two electrodes is an odd number of half cycles N, where N is an odd positive integer (N = 1, 3, 5 …). Second, the secondary electron emission coefficient of the impact surface must exceed unity.

The multipaction discharge phenomenon is not always undesirable. In the 1930s, American Philo Farnsworth designed an amplifier vacuum tube for television signal transmission, based on the multipactor. This tube was later superseded by Zworykin's Iconoscope.[1] However, Farnsworth first derived the name multipactor from "AC Electron Multiplier,"[2] originally describing hardware rather than the mode of the electron emission itself. Over time, in most space and vacuum applications, the term has come to define the harmonic electron breakdown.

Multipactor creates a sheet like cloud of electrons, which are oscillating between the two electrode surfaces.[1] The discharge will heat the surfaces of the electrodes, increase signal noise, block the electric field and appear as a brief electron current between the

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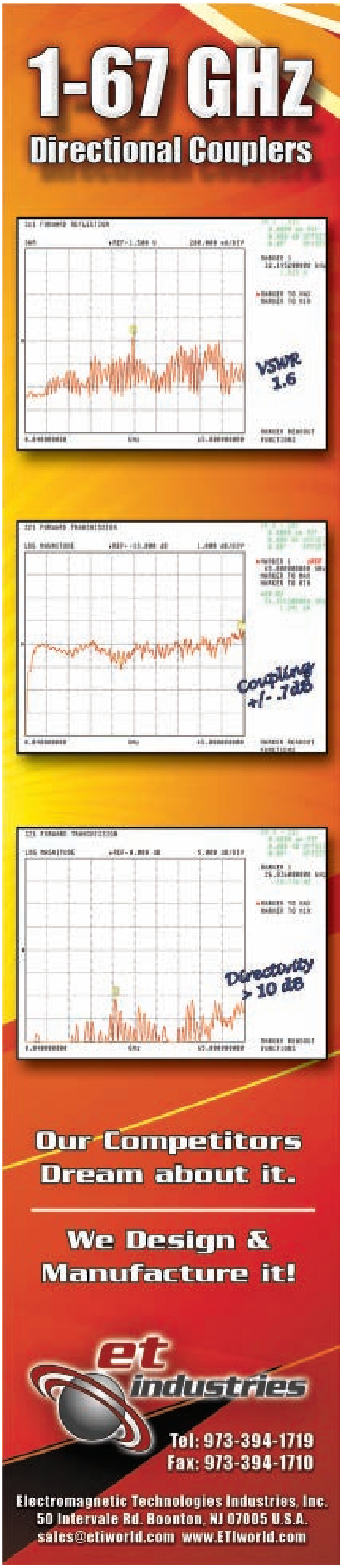


two electrodes. In the case of a high mode (N mode) multipactor, several electron cloud sheets (exactly 2N-1) will oscillate between the surfaces under steady state conditions. Additionally, in some high power tubes, multipactor can emit visible light and X-rays. Single surface multipaction discharge can also occur on dielectric component surfaces, if there is a bias DC field, electric or magnetic, and a high frequency electric field is present parallel to the dielectric surface. This single surface discharge phenomenon on the dielectric surface is not applicable for coaxial lines. For further reading on the history of multipaction discharge analysis, current theory and practical information, see the works of Vaughan,[1] Kishek[2] and Ming Yu.[3]

The focus of Vaughan's work with multipactor was in the field of high and very high power microwave tubes.[1] Vaughan noted that multipactor is essentially a medium power phenomenon.[1] The reason for this statement is that under very high energy, multipactor is not possible. The impact velocity of the emitted electron is of such a magnitude that it penetrates too deep inside the second electrode to cause secondary electron emission from its surface. This type of impact does not meet the second required condition for multipactor, since the secondary electron emission coefficient is less than one.

With regard to coaxial cables and connectors, Vaughan's statement that multipactor as "essentially a medium power phenomenon" is not true in the majority of the cases. Coaxial cables and connectors, inherently, have a limited power handling relative to microwave tubes. In most cases, multipactor in a coaxial line is a high power phenomenon in that it occurs at a power level near the maximum capacity of the component. In fact, the multipaction discharge within a coaxial line is usually not catastrophic in and of itself. However, the discharge can vaporize some of the dielectric material within the coaxial line and create ionized gas particles. If the coaxial line is not properly vented, these collected gas particles can initiate an ionization breakdown within the structure. The ionization breakdown is typically the destructive failure mode.

Extensive research of the multipactor phenomenon has been performed in recent years. The European Space Agency (ESA) has hosted several multipactor workshops for space applications. There are also multiple options for multipactor calculations from Jet Propulsion Laboratories[4] and ESA.[5] However, most of the references describe multipactor in the applications of high power microwave tubes, plasma physics and particle acceleration. Many papers have been published with analysis and applications, yet there are few practical papers that reveal any guidance in designing coaxial components for space applications, where multipactor is a serious concern.

Most early references analyzed the simplest case, that being multipactor between two parallel plates. This application has a uniform field. Coaxial line analysis is much more complicated, because the field is not uniform. However, an examination of two parallel plates is necessary to establish the fundamental factors, which will later be analyzed in the frame of a coaxial system. For further reading on the multipactor analytical study under simplified conditions see the work of Udiljak, et al.[7]

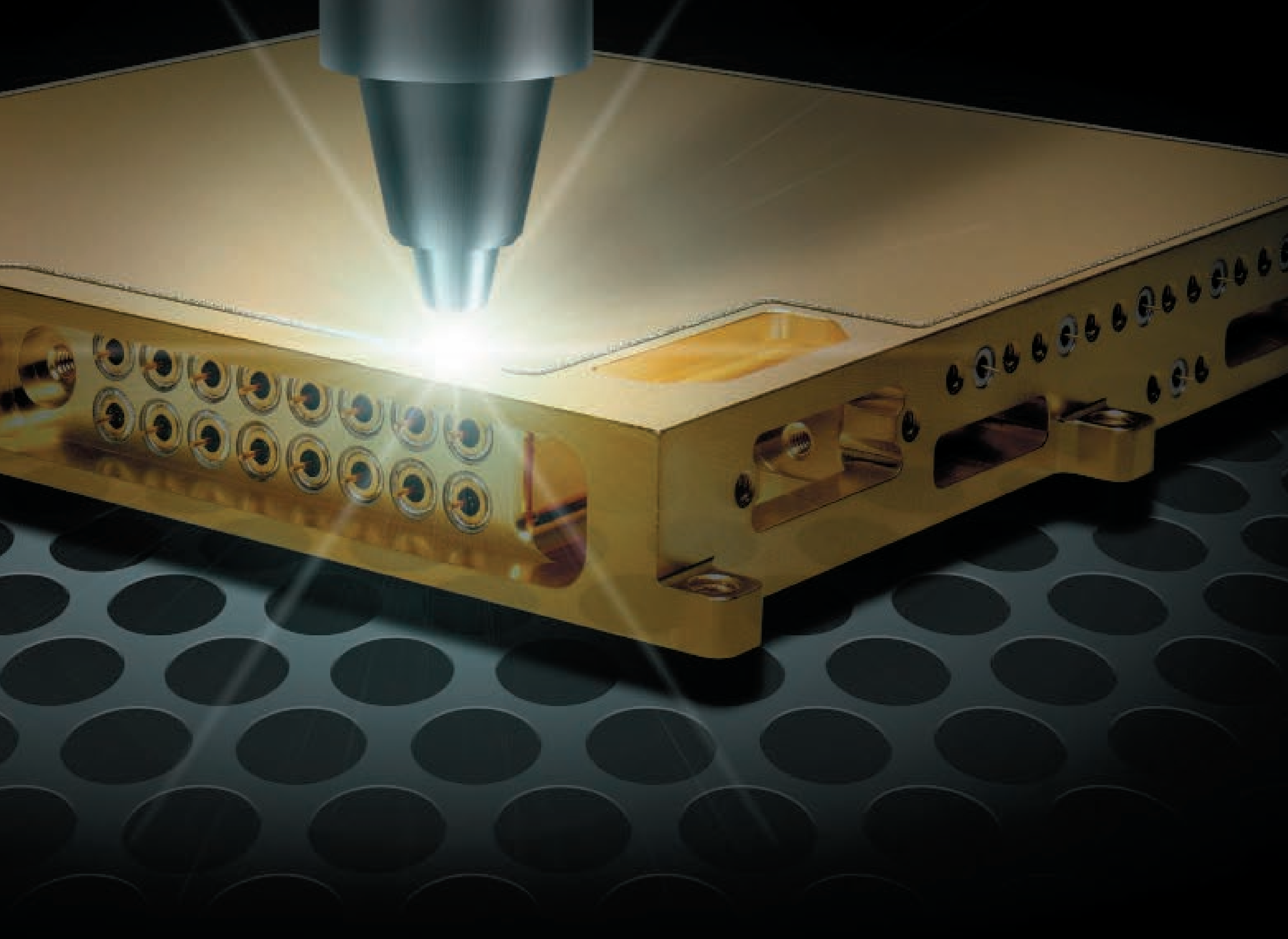
According to Udiljak,[6] the resonance condition for an applied electric harmonic field between two plates is:

$$E_0 = \frac{m\omega\left(\omega d - N\pi\lambda_0\right)}{e\left(N\pi\cos\alpha + 2\sin\alpha\right)} \qquad (1)$$

where m is the mass of an electron (9.1×10^{-31} kg), e is the electron charge (1.6×10^{-19} C), d is the distance between the plates, $\omega = 2\pi f$ and $\omega t = N\pi + \alpha$.

It is possible to calculate the multipactor zones from Equation 1. The multipactor zones are usually depicted in charts, which show the relationship of power (or voltage) versus the frequency-distance product. However, this analysis was done with respect to the electric field only, in the simplified conditions. This is in accordance with most references, which have removed the magnetic field influence because it is assumed to be negligible.

However, according to the Ampere-Maxwell law, the electric field will produce a circulating magnetic field. In a coaxial structure, the magnetic field lines are in concentric circular sweeps around the center conductor circumference.



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The force that describes the electron movement under the influence of both electric and magnetic fields, named the Lorentz Force **F**, is defined as:

$$\mathbf{F} = q\left(\mathbf{E} + \mathbf{V} \times \mathbf{B}\right) \qquad (2)$$

where q is the electron charge, **E** is the electric field, **V** is the electron velocity and **B** is the magnetic field induction. This equation shows that the magnetic field deflects the electron movement from a straight path. This deflection can be important.

At first look, the influence of the magnetic force does indeed look negligible. However, consider a special case. Suppose the first electron is displaced a very small distance in the axial direction. Under multipaction discharge conditions, when secondary electrons are released in a coaxial line, the fields are reversed. However, the vector product **V** × **B** will remain in the same direction because the velocity vector **V** has also changed direction. This means that the secondary electrons will be displaced in the same axial direction over an additional short distance. As the multipactor increases the rate of electron discharge, the space charge axial displacement caused by the cross product of vectors **V** and **B** will grow as well. The axial displacement in the coaxial line will move in the same direction as the incident wave because vectors **V** and **E** are in the same direction, which means that the vector product **V** × **B** is in the same direction as the Poynting vector. Since the typical frequency for a space application is in the gigahertz range, the axial displacement is going to be comparable to the radial gap in a very short time. Modifying Equation 2 and substituting **B** = μ**H** (for vacuum $\mu = \mu_0$) and **H** = **E**/Z_0, Equation 2 can be modified as:

$$\mathbf{F} = q\left(\mathbf{E} + \mathbf{V} \times \mathbf{E}\mu_0/Z_0\right) \qquad (3)$$

Equation 3 shows that the axial displacement is related to the radial acceleration by the factor $V\mu_0/Z_0$. The ratio μ_0/Z_0 (3.33×10^{-9}) is a very small value. However, at microwave frequencies, there will be billions of such cycles per second. Additionally, the electron velocity V will increase at the end of each cycle. The influence of the electron velocity can be more simply shown through the analysis of the two plane multipactor rather than the more complicated structure and field distribution of a coaxial line. According to Vaughan,[1] the electron impact velocity V_i is:

$$V_i = \frac{2\omega d \cos\alpha}{N\pi\cos\alpha + 2\sin\alpha} + V_0 \qquad (4)$$

where $\omega = 2\pi f$ and V_0 is the initial velocity. The multipaction discharge condition is present when $\omega t = N\pi + \alpha$, where α is the initial phase. In the simplest case, for a first order multipactor with zero initial velocity (N = 1, $V_0 = 0$, and α is an integer number of π), Equation 4 can be rewritten as:

$$V_i \approx \frac{2\omega d}{\pi} \qquad (5)$$

Equation 5 presents a very simplified model because, first, the use of a two plane first order multipactor, and second, according to Vaughan, the value of V_0 is unknown because "it is a statistical distribution rather than a single variable value."[1] There are some differences in correlating the phase relations from a two plane structure to that of a coaxial line. Udiljak[6] points out that in a coaxial line, the transmission time is normally longer for electrons emitted from the outer conductor than for electrons emitted from the inner conductor. This means that the phase relations in a coaxial line are less favorable for multipactor, when compared to the simplified model of two planes.

However, Equation 5 shows that, in each cycle, the electron velocity is growing from zero to a very large value because it is linearly proportional to the frequency. The proportional relationship of the impact velocity of the electron to frequency is evident from the fact that, as the frequency increases, the electron velocity must be significantly higher in order to reach the opposite electrode before the polarity reverses. This means that the axial displacement caused by the magnetic field is in fact not negligible and can have substantial effects, particularly at microwave frequencies. From this, it is evident that the velocity dependence on frequency makes the electron axial displacement to increase nonlinearly, as the frequency increases.

From plasma physics, the nonlinear force that a charged particle ex-

periences in an inhomogeneous oscillating electromagnetic field is known as the Ponderomotive or Miller force. The Ponderomotive force influences the particle to drift toward the weak field area. This force is particularly important in the coaxial line because of the inhomogeneous field, which is stronger in the region of the center conductor. However, the axial displacement is different from that of the Ponderomotive force, which depends solely upon the electric field and has a radial influence on the electron position in a coaxial line.

One could say that the axial displacement is not important and that it may have no influence on multipaction. However, as noted before, most references contain data regarding multipactor between two planes. Usually, only a coaxial airline structure is discussed. The airline, however, has little practical interest. Most coaxial transmission lines, particularly for space applications, are fully or partially loaded by a dielectric material. In this case, the axial displacement has a large influence for a partially filled line, which is typical for any cable connector junction. ***Figure 2*** shows a simplified coaxial cable-connector junction that is widely used for high frequency applications. One can see the air gap with height d and width δ. This air gap is a short line of high impedance that improves the electrical match between the cable and connector coaxial line sizes. Typically this air gap is the most susceptible part of the cable assembly to a multipactor event.

According to Udiljak,[6] the rate of electron build up $N_e(t)$ is determined by the following equation:

$$N_e(t) = N_e(0)(\sigma_{se})^{\frac{2ft}{N}} \qquad (6)$$

where $N_e(0)$ is the initial electron quantity and σ_{se} is the secondary electron emission yield. For example, an electron cloud growing from 1 to 10^{14} takes 20 ns at 2 GHz, when the secondary electron emission yield σ_{se} = 1.5. This is close to the same time relationship as shown by Vaughan.[1] This means that electrons can hit the electrode a few dozen times and the overall axial displacement is microscopic, because of the ratio of $\mu_0/Z_0 = 3.33 \times 10^{-9}$ in Equation 3. However, the velocity can reach a significant value, particularly at a high frequency (see Equation 5). Therefore, the multipacting electrons will be displaced in an axial direction to a distance almost equivalent to that between the electrodes (d) in a very short amount of time. However, the electron cloud will hit the dielectric wall under a much smaller displacement (see distance δ) than the distance between electrodes (d).

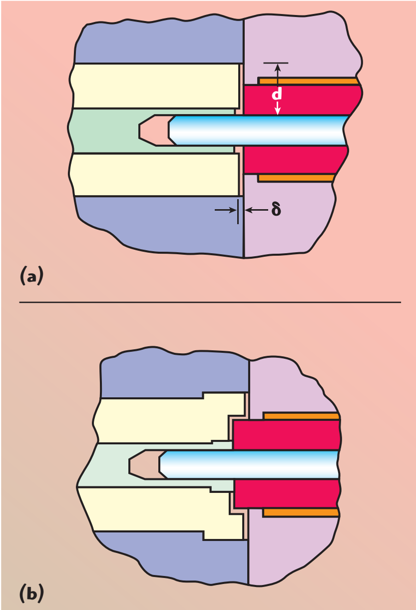

Fig. 2 Cable-connector junction: (a) simplified connector and (b) practical design for high voltage handling.

In most practical cases, the gap width is at least ten times less than the height (d). Apparently, from the moment that the electrons hit the dielectric surface, the phase conditions for multipaction will be violated despite the fact that oblique incidence will increase the secondary emission. The presence of the dielectric wall inhibits the electron build up. This means that multipaction is small or may not exist. The properties of the dielectric barrier can be extended to other dielectric loaded interfaces, for example the junction of two SMA interfaces. Note that the single surface multipactor will have much greater axial displacement because the electron cloud will grow at a much slower rate.

Also note that, statistically, the electron can be located in any spot along the distance δ. This shows that the typical axial displacement required to hit the dielectric surface can be much smaller than δ. Some references[6-8] point out that there are two different types of multipactor in coaxial lines:

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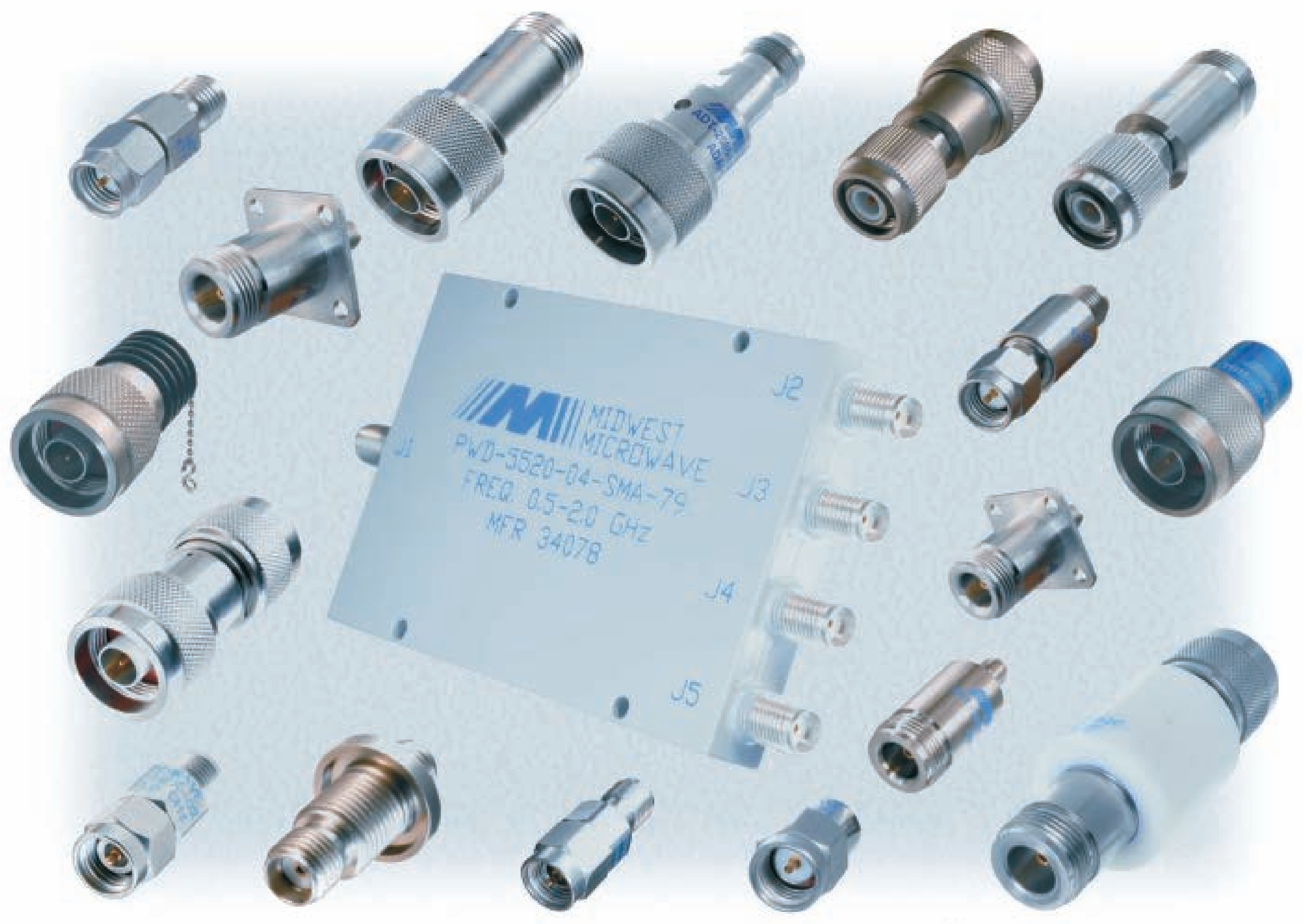

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a two sided discharge between inner and outer conductor and the one sided discharge on the outer conductor only. The main reason for the single surface multipactor is the decreasing electron velocity due to the Ponderomotive force. Therefore, the electron is reversed back before reaching the center conductor. The single-sided multipactor can be present in high impedance lines only. It should be noted that the single surface multipaction was not yet confirmed by experiments as of 2007.

A practical design for high voltage handling is also shown in the figure. Here, the two dielectrics overlap each other, thereby increasing the voltage handling. However, if the overlap is too large, it can compromise the electrical match particularly at high frequencies. Theoretically, multipactor can happen between metal and dielectric surfaces in the gap area. However, the conclusion is the same: the narrower the gap is, the more it will suppress multipactor. According to some space equipment manufacturers, the main danger for such junctions is not multipaction itself, but rather trapped air that can easily create the conditions necessary for ionization breakdown. This breakdown can happen under relatively low power. From Paschen's Law,[12] for every pressure, there is a gap with a low breakdown point. Therefore, it is extremely important to design the connector to provide for positive venting of the junction.

Typical coaxial connectors for high power space applications have a dielectric loaded interface with overlapping surfaces. There are several coaxial connectors that have been specifically designed for space power applications, but they do not comply with the industry connector interface standard MIL-STD-348.[13] The most common, industry standard, coaxial connector interface, for space power applications, is the TNC. The mated TNC connector interface is shown in ***Figure 3***.

One can see that the TNC interface has an overlapped dielectric. There is no line of sight between the inner and outer conductors. There are three main regions, in the connector interface A, B and C, where multipactor can occur. Theoretically, multipactor can occur in region A, between the center conductor and dielectric. However, total breakdown of the TNC line appears to be impossible, because the TEM mode has no axial electric field. Thus, nothing can accelerate electrons in an axial direction within region B. As shown earlier, the Lorentz force equation (Equation 2) reveals that the electron will be deflected in the axial direction. With this knowledge, the TNC interface junction can be evaluated in the same manner as the practical cable-connector junction for high voltage handling. Apparently, if the air gap between mating dielectrics is narrow, it will suppress multipactor in region A because it inhibits electron acceleration. According to some space equipment manufacturers, the TNC interface is highly resistive to multipactor and in many cases it is impossible to initiate a multipactor event under extremely high power levels.

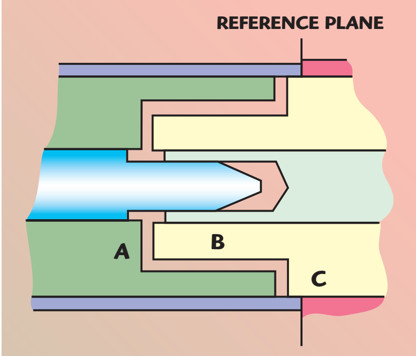

Fig. 3 TNC interface junction.

There are two main references for multipaction calculation: the Woo report and the ESA calculator. The R. Woo[4] report was published in 1967 and is based on JPL NASA experimental data. Another option is the ESA calculator. The ESA calculator was released more recently and is much more convenient to operate. It can be downloaded for free from the ESA website (http://multipactor.esa.int/downloads.html). Particularly impressive are the options available to calculate multipaction for multicarrier signals. The ESA calculator also has the ability to calculate the multipaction handling for standard coaxial connector interfaces. However, when using the ESA calculator, there are some points that must be considered, when evaluating its outputs. It is surprising to find that the calculator gives the same outputs for a TNC connector as for N and 7 mm connectors. The N and 7 mm are both based on a 7 mm air line and both should have

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the same multipactor outputs. However, the TNC interface is based on an overlapped dielectric and it typically can handle much more power. For example, see the comparison in Rosario, et al.[9] Additionally, there is only a single SMA connector option within the ESA calculator. The available connector is specified with a nominal gap of 0.99 mm, which is equivalent to the thick wall SMA plug interface per MIL-STD-348, Figure 310-3.[13] However, this design is not representative of all SMA connectors available. Many SMA plug connectors are designed with a nominal gap of 1.25 mm, which is equivalent to the SMA plug interface per MIL-STD-348, Figure 310-1. This difference should be taken into account when considering the use of an SMA connector in space power applications.

Special attention needs to be given to the determination of an adequate safety margin. ESA recommends a multipaction safety margin of 3 to 4 dB by test and 8 to 12 dB by analysis. An additional safety margin is required for unmatched transmission lines.[11] As was noticed by Ming Yu,[3] the Woo report[4] gives outputs in root mean square (RMS) voltage values, whereas the curves from the ESA calculator[5] gives the output peak voltage. The primary difference between these outputs is that the RMS value already contains a 3 dB margin.

A final and very important issue when evaluating a coaxial connector for space power applications is the presence of cavities and voids within the components. Some manufacturers advocate a policy that avoids any holes or voids in space level components, particularly in coaxial connector junctions. It is practically impossible to design and produce components without any holes or voids. In this case, the air junctions are usually filled with a sealing compound. The common view is that this will help to create a 100 percent multipaction free design. However, solid dielectrics and sealing compounds have a significantly higher thermal resistivity than dielectrics compensated with axial cavities. The difference is particularly noticeable when using a Fluoroloy H (Rulon H) dielectric, which is commonly found in the coaxial connectors for space power applications. Weirback[10] calculates the thermal distribution within coaxial lines using different dielectric materials and geometry. Essentially, this difference indicates that a connector using solid dielectric will handle less average power than a dielectric with cavity compensation.

There are two reasons for such a phenomenon. First, the removed dielectric will reduce the dielectric loss, which is significant for lossy dielectric media such as Fluoroloy H. The increased attenuation dissipates more energy than the increased thermal conductivity of Fluoroloy H can transfer, creating a net increase in dielectric temperature. The second reason is that a drilled out dielectric needs a larger diameter center conductor in order to maintain the same impedance.

Generally speaking, the drilled out dielectric has a higher risk of multipactor, when compared to a solid one, because multipactor is now also possible between the two dielectric surfaces. However, it is possible to reduce the voltage across the holes, which will have two effects. First, this will reduce the risk of multipactor; second, it will improve the average power handing.

Figure 4 shows a possible coaxial line dielectric structure that has good temperature handling and was tested to be multipaction free. The four-hole model and simulated E-field distribution is shown in ***Figure 5***. The simulation was performed using HFSS from Ansoft.[14] The response clearly shows that there is a high density electric field inside the holes. However, the shape of the holes creates an asynchronous phase relationship with the signal frequency that is highly unfavorable for electron cloud build-up. An additional multipactor inhibiting feature of this design is the high primary electron energy, defined in eV, required to create the secondary electron emission. While the secondary electron emission coefficient can

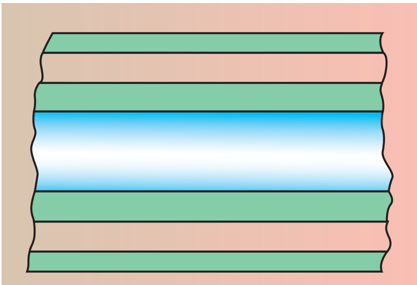
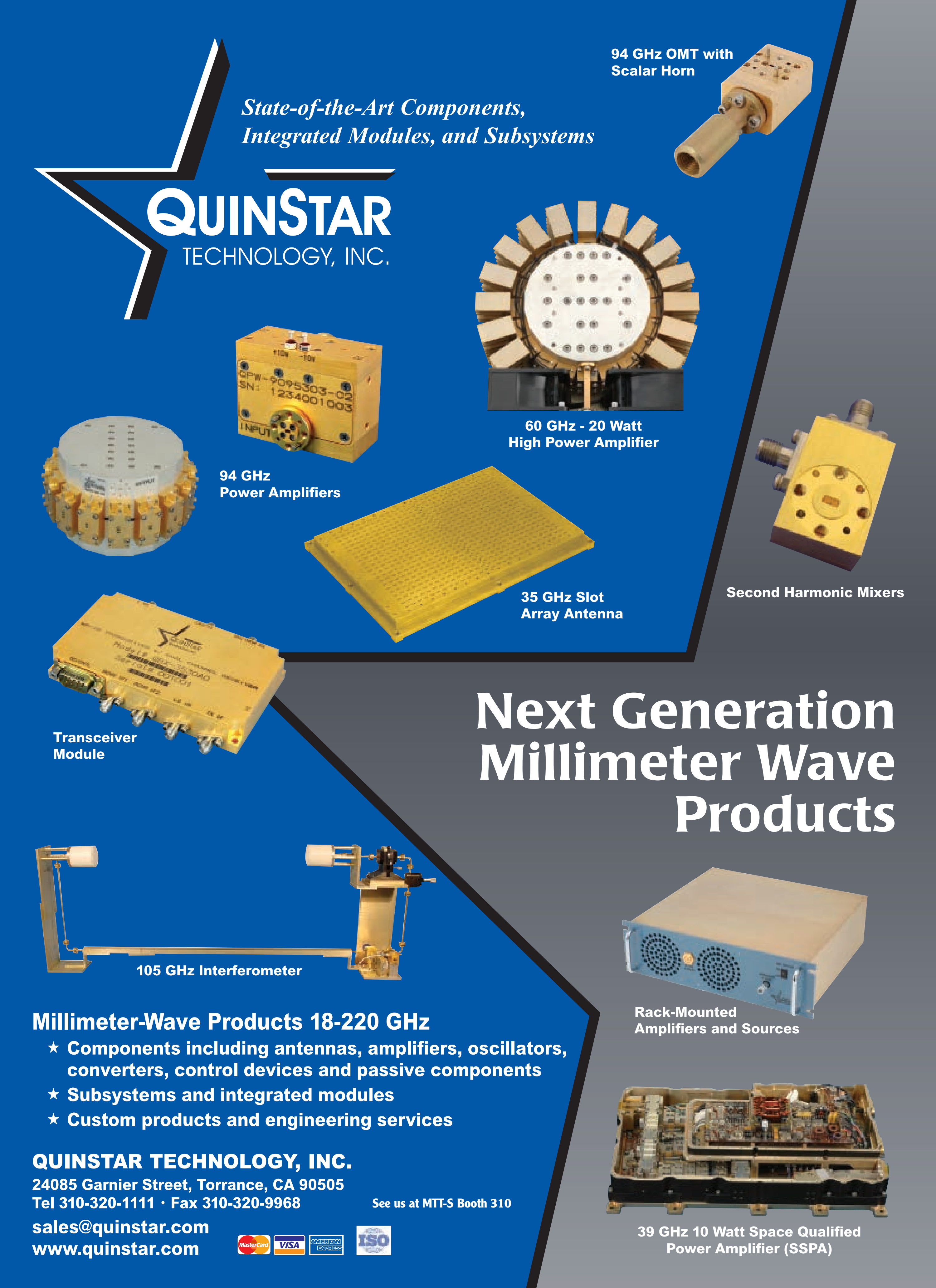


Fig. 4 Coaxial line with drilled-out dielectric.



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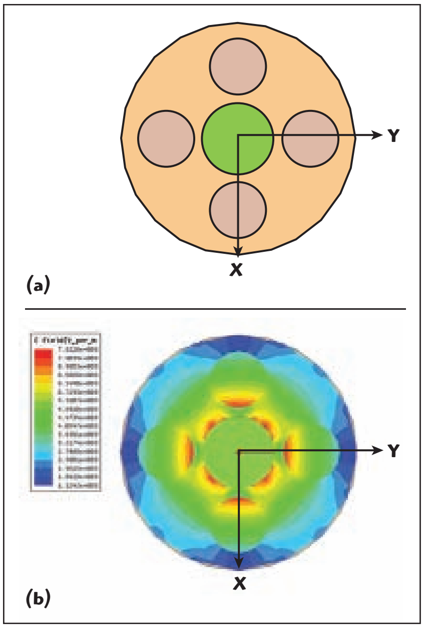
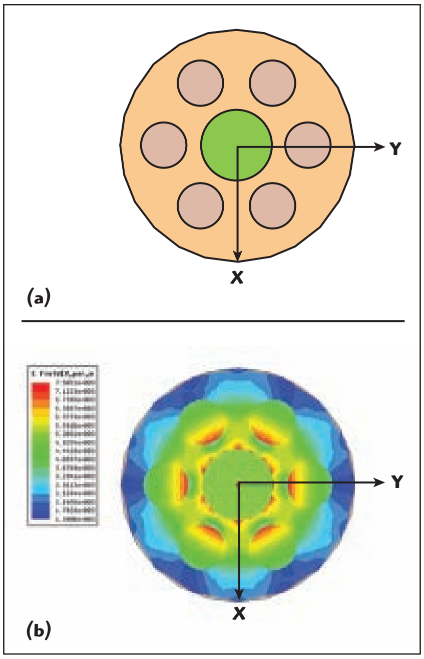


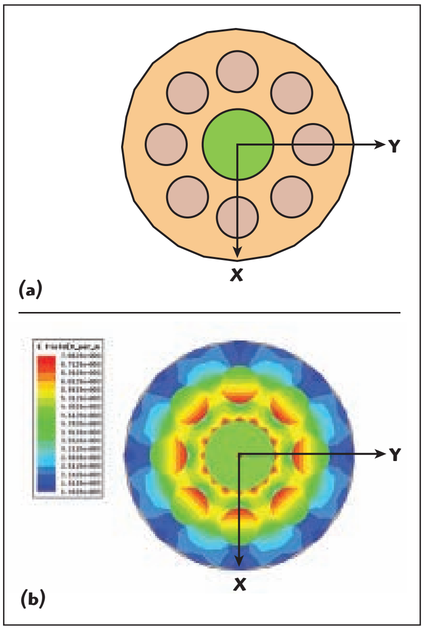
▲ *Fig. 5 Four-airhole structure (a) and electrical field distribution (b).*

be high for some dielectrics (including Teflon), the primary electron energy required to initiate this emission is about three times more for Teflon-based dielectrics than for copper. The voltage drop (Vd) across the holes can be calculated using the field calculator in HFSS. The calculation for the dielectric line showed that in a four-hole structure of Fluoroloy H, this voltage is 83 percent of a total voltage (Vmax) between the inner and outer conductors. This is a substantial value. The inhomogeneous voltage distribution is typical for a partial dielectric structure. The higher voltage is always in the portion of the line with the lower dielectric constant. A six-hole structure, as shown in ***Figure 6***, was analyzed to determine the geometrical impact of hole structure to voltage drop. The six-hole structure needs smaller diameter holes to maintain a 50 Ω impedance. This line geometry showed a better voltage ratio of 71 percent. Following this progression, an eight-hole structure as shown in ***Figure 7*** reduced the voltage ratio to 63 percent.

An additional feature that can be modified is the radial position of the holes. ***Figure 8*** shows the holes moved outwards radially within the dielectric structure, where the electromagnetic field is much weaker. In order to maintain a 50 Ω characteristic impedance, the hole diameter needs to be increased as the holes are



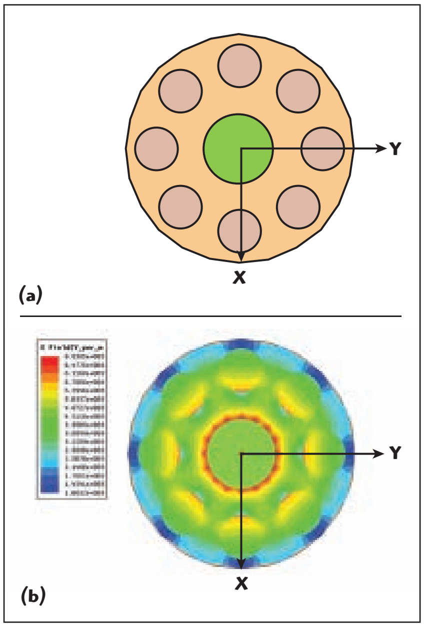
▲ *Fig. 6 Six-airhole structure (a) and electrical field distribution (b).*



▲ *Fig. 7 Eight-airhole structure (a) and electrical field distribution (b).*

moved radially away from the center of the line (compare the larger holes of Figure 8 to those of Figure 7). The results show an additional decrease in the voltage ratio, lowering it to 61 percent. A further advantage of the larger hole diameter is the increase in the frequency-distance product, which makes the component less susceptible to multipactor.

Based upon these analyses, the conclusion can be drawn that the eight-hole structure of Figure 8 ap-



▲ *Fig. 8 Eight displaced air hole structure (a) and electrical field distribution (b).*

pears to be the most reliable design in preventing multipactor. This is due to its lower voltage ratio and increased frequency-distance product. It is important to note that both of these performance improvements are due to the placement of the dielectric voids close to the outer conductor to take advantage of the relatively small field density that is present. In reviewing the models presented in this article, the reader must recognize that ideal dielectric voids were used in forming the basis of these conclusions. The ideal holes do not take into consideration burrs, loose material, or other contamination that may be present in actual machined dielectrics that will have a great influence on multipactor. Connectors must be carefully inspected for the absence of foreign objects and loose particles to ensure their ability to meet the requirements of space power applications.

CONCLUSION

The design of multipaction free coaxial components is a very important part of high power space and vacuum engineering. Here, under the term "coaxial components," the author is primarily referring to practical applications such as the cable to connector junction and coaxial interfaces with overlapped dielectrics. The differences in the flow of electrons and development of multipactor within a partially loaded dielectric coaxial line versus a traditional air line have been presented. It is apparent that the full analysis of practical coaxial components is extremely complicated. Multipaction detection and test methods are separate issues, which are not covered in this article. ■

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Teflon is a registered trademark of Dupont.

Fluoroloy H and Rulon H are trademarks of Saint Gobain Corp.

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CONSIDERATIONS FOR ACCURATELY MEASURING PULSED ACTIVE DEVICES

Understanding device behavior under desired operating conditions is a critical step in the design of any high performance active RF device (e.g., an amplifier or converter). If the component operates in continuous-wave (CW) mode, that characterization can be as simple as measuring its S-parameters using a vector network analyzer (VNA). When it operates in pulsed mode, however, characterization is not so simple. In addition to S-parameters, many other active parameters must be measured in pulse mode. In the case of an amplifier, those parameters include the 1 dB compression (P1dB), intermodulation distortion (IMD) and third-order intercept point (IP3). The amplifier's noise figure, higher-order distortion products and harmonics, among other things, may also be characterized depending on its intended application. Because these active parameters are power-dependent, additional considerations are needed to ensure precise characterization. Understanding the changes required to the VNA to support these measurements is also critical.

To better understand the challenge of accurately measuring pulsed active devices let us first look at the different pulsed operation modes: pulsed-RF and pulsed-bias. The pulsed-RF operation drives a device with a pulse-modulated RF signal and the DC bias is always on. Amplifiers used in receivers in pulse-modulated applications are typically tested under pulsed-RF operation, which requires RF pulse modulators for the stimulus and pulse generators to synchronize (or gate) the VNA receivers to capture the modulated RF signals.

With pulsed-bias operation, the DC bias is switched on and off to generate a pulse-modulated signal. The input is mostly a CW signal. Pulse generators may be needed to turn on and off the DC bias. The VNA receivers are synchronized to measure the output signal when the device is on.

For pulsed-RF network analysis, three types of measurements are performed—average pulse, point-in-pulse and pulse profile—using either wideband or narrowband detection techniques. Wideband detection is used when the pulse width is wide enough for VNA receivers to be able to measure the majority of the pulsed-RF spectrum. When the pulse width is too narrow, narrowband detection is used to measure only the center spectral response by removing all other pulsed-RF spectrum components.

VNA CONSIDERATIONS

When characterizing active devices in pulsed mode using either wideband or narrowband detection, there are a number of considerations that the engineer should keep in mind; namely, required changes to the VNA and techniques for enabling power-dependent active device characterization, including compression and distortion.

Active devices operating under pulsed conditions can be measured with a VNA, but some

HIROYUKI MAEHARA
Agilent Technologies Inc., Santa Clara, CA

hardware modifications are required. For pulsed-RF operation, pulse modulators and generators must be added to the VNA. Pulsed-bias operation may require the addition of pulse generators. One example of an analyzer with integrated pulse generators and modulators is the Agilent Technologies' PNA-X (see ***Figure 1***). The internal pulse modulators and generators enable pulse measurements without external equipment, enabling precise pulse control, synchronization and fine timing resolution. Another required change to the VNA is the addition of a pulse input/output (I/O) port, which provides accessibility to internal pulse generators and modulators, and enables synchronous pulse measurements with external pulse generators or a device-under-test (DUT).

An important consideration that must be taken into account when measuring active devices operating under pulse conditions is pulse system delays (e.g., delays in the pulse system from the pulse trigger to pulse genera-

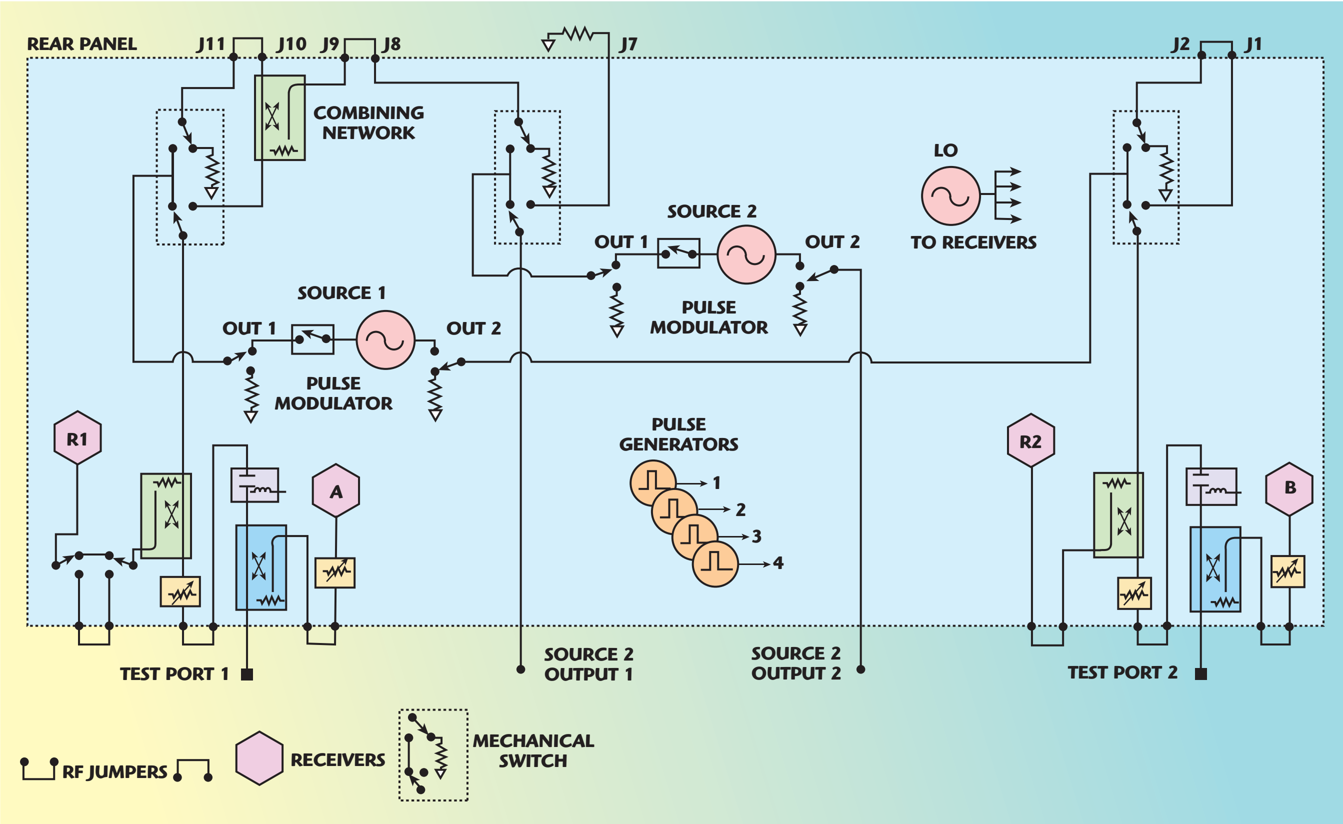

Fig. 1 Agilent's PNA-X is one example of an analyzer with integrated pulse generators and modulators.

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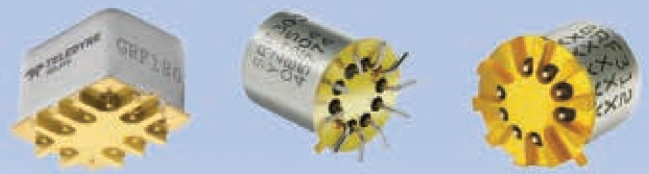

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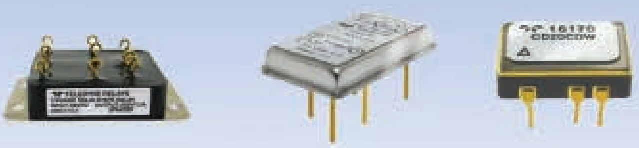

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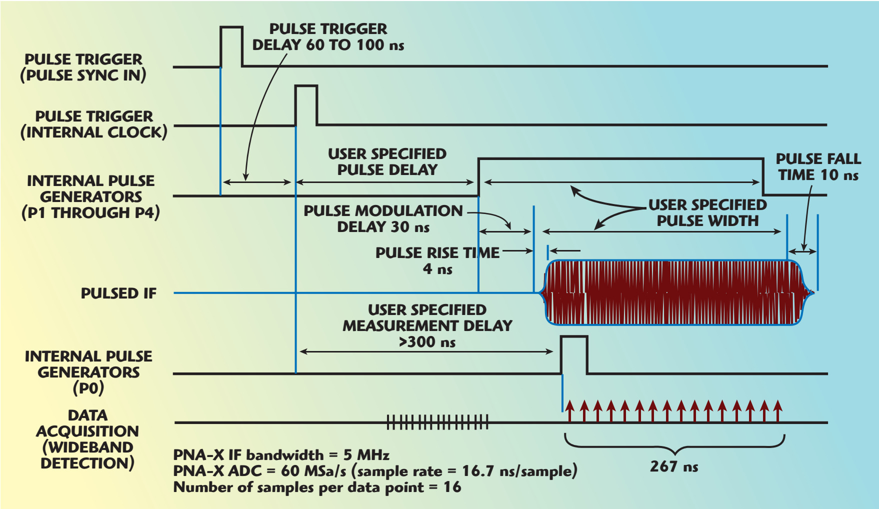
tors, to pulse modulators, and to the ADC for data acquisition). ***Figure 2*** shows a timing diagram with 5 MHz IF bandwidth, from the external pulse trigger through the data acquisition with wideband detection technique. Approximately 60 to 100 ns after the pulse trigger at the PULSE SYNC IN port, the internal pulse generators generate a pulse to drive the pulse modulator and the receiver data acquisition timing. The pulse modulator has about a 30 ns delay to modulate the RF signals. User-specified delays for pulse generators are used to adjust the modulation and measurement timings to account for pulse system delays. If any of the pulse system delays (e.g., pulse trigger and modulation delays), plus other system delays from the test port cables and DUT's electrical length, are relatively long compared to the pulse width and the VNA's receiver data acquisition time, then the timing of each must be carefully adjusted. Additionally, the data acquisition window should be placed at the middle of the pulses (approximately), and a wide enough IF bandwidth chosen to complete the data acquisition in approximately a half of the pulse width. By doing this, most timing errors can be avoided.



▲ *Fig. 2 Timing diagram with 5 MHz BW from the external pulse trigger through the data acquisition.*

POWER-DEPENDENT ACTIVE DEVICE CHARACTERIZATION

Devices that operate under pulsed condition are often discrete active devices or modules that consist of amplifiers and/or mixers. The performance of these devices is typically power-dependent. Therefore, they are characterized in linear and nonlinear operating conditions. Inaccurate stimulus power may introduce considerable measurement errors.

In some VNAs, the stimulus power is factory calibrated. This provides a reasonably accurate stimulus power level at the test ports, even without source power calibration. When accurate stimulus power is required at the device input (typically at the end of the test port cable), source power calibration is performed. The calibration compensates for the path loss and corrects errors, which in turn, enables the stimulus power accuracy to be set to a specified tolerance level from the power sensor accuracy. For pulsed-RF measurements, this simple calibration becomes problematic. Because most power sensors measure average RF power, the sensor readings are 10log(duty cycle) lower than the peak pulse power during source power calibration in pulse mode. Two approaches may be employed to overcome this source power calibration problem.

Source Power Calibration Using Power Sensor Loss

This technique is used to calibrate the stimulus with the pulse modulation on. To successfully perform a source power calibration, the power sensor loss feature must be used to ensure the VNA's source does not go unleveled as it tries to bring the test port power to the desired calibrated power level. The pulse desensitization effect due to the pulse duty cycle ap-

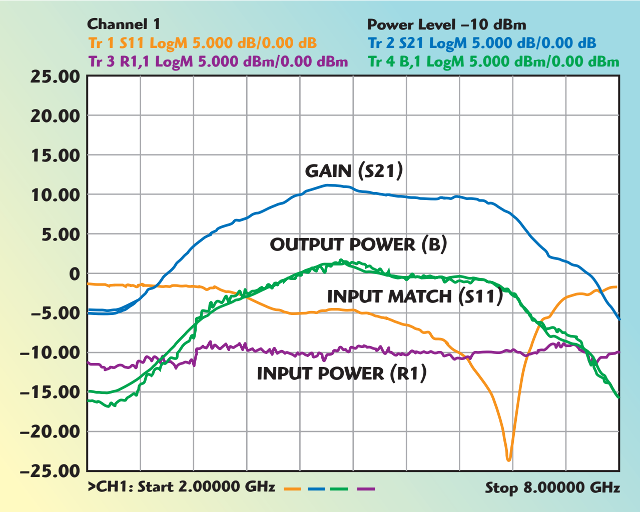
pears as attenuation, thus the power offset is always negative. For example, the power offset value for a pulsed-RF stimulus with 5 percent duty cycle is 10log(0.05) = -13 dB.

Accurate Pulse Stimulus Using Receiver Leveling

The VNA receiver is used to monitor the pulsed-RF power and correct the source power level for every measurement sweep in receiver leveling mode. Once the receiver leveling is selected, the source level is adjusted with the receiver readings and the source power correction coefficients are ignored (source power calibration is not used even if it is turned on). Reference receivers are typically used for receiver leveling, although any receiver or even a power sensor (if added as a receiver to the VNA) can be used. The source level accuracy in receiver leveling mode depends on the receiver's absolute power measurement accuracy, making receiver calibration essential.

Reference receivers can be calibrated by performing receiver calibration independently or as part of a source power calibration, although the latter is recommended. During calibration, the leveling mode must be open loop with the same source chain settings as the measurements, and the pulse modulation must be turned off. Also, the receiver setting must be the same between the receiver calibration and the pulsed measurements.

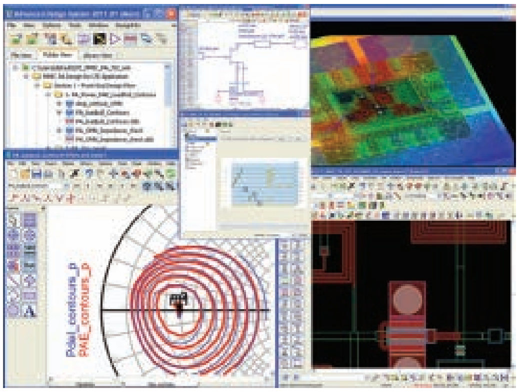
Once calibrated, the receiver can accurately measure the peak pulse power in wideband detection and adjust the source power until it is either in the specified tolerance or reaches the maximum number of iterations before the measurement sweep. In narrowband detection mode, the receiver measures the power lower than the peak pulse power by 20log(duty cycle). The power offset may be used with receiver leveling in narrowband pulse measurements.



▲ *Fig. 3 Calibrated wideband pulsed S-parameters and absolute power measurements with a comparison between open loop and receiver leveling modes.*

Note that for S-parameter measurements, where the DUT is in linear operation, power is not a concern and open loop leveling is suitable. When making absolute power and/or power-dependent performance measurements, the pulsed stimulus power matters greatly and must be accurately leveled. In this case (wideband detection), receiver leveling is recommended (see ***Figure 3***). The difference in memory traces is very small in the input match and gain measurements, but is larger in the absolute power measurements. It can be used with both wideband and narrowband detection and applied to swept-power measurements, as well as compression and two-tone IMD measurements.

Accurately measuring pulsed active devices can be a difficult task, especially when those measurements are power dependent. Receiver leveling offers one means of addressing this issue. Another consideration the engineer must be aware of when characterizing active devices is selecting a VNA that supports pulse generators and modulators. Employing the right solution and appropriate techniques for accurately leveling the pulsed stimulus power are critical for enabling both S-parameter measurements and accurate power-dependent active device characterization, including compression and distortion. ■



ADS 2011 USHERS IN A NEW ERA IN RF/MICROWAVE DESIGN

Advanced Design System (ADS) 2011 from Agilent Technologies represents the most significant release of the ADS product in over a decade. With improvements to virtually all areas of the platform, it offers something for anyone doing RF/microwave design, whether of a monolithic microwave integrated circuit (MMIC), module or printed circuit board (PCB). What really sets ADS 2011 apart is its ability to design and verify multiple technologies concurrently.

ADDRESSING THE CHALLENGE OF MULTI-TECHNOLOGY DESIGN

Today's RF design industry is in the midst of a transformation. For evidence, look no further than the commercial wireless and aerospace/defense industries where trends like increasing complexity and integration have become commonplace. Today's products are no longer single MMICs put into a package. Instead, multiple chips are now combined into packages or modules, and this increased product integration brings circuit elements closer together, within and across technology boundaries. As a consequence, engineers can no longer ignore the interactions between these different technologies. To achieve success requires a platform that works in a multi-technology design space. ADS 2011 meets the challenge with a comprehensive multi-technology design platform.

Existing design tools generally work only in a single technology space. More often than not, the tool used to design the IC is different than the one used to design the module that it goes in or the PCB, making it difficult or even impossible to take into account the important interactions between the technologies. With ADS 2011, not only can engineers design ICs, modules and PCBs all in the same environment, they can also easily assemble these multiple technologies with complete access to

AGILENT TECHNOLOGIES INC.
Santa Clara, CA

all the analysis and design technology within the ADS flow.

MULTI-TECHNOLOGY DESIGN IN ACTION

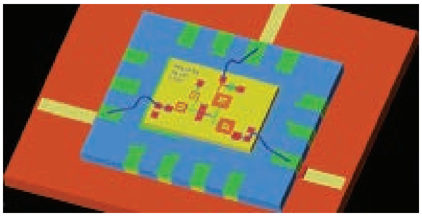
As an example of the ADS 2011 multi-technology design capabilities, consider the design of a 10 GHz local oscillator amplifier (see ***Figure 1***). Here is an IC mounted in a package that is then placed on a PCB. The design encompasses three different technologies. With ADS 2011, one can assemble this multi-technology design without making any changes to the individual designs. There are no worries about any conflicts between component names, PDKs, physical layer definitions, or other aspects of the technology definition. Once assembled, one can perform circuit simulation on the entire structure, ensuring that the entire design will perform to the original specifications.

In addition to circuit simulation, EM simulation can be performed on this multi-technology structure using either the Momentum 3D Planar simulator, or the 3D Finite Element simulator (see ***Figure 2***). This enables engineers to discover EM coupling effects, even across technology boundaries. By resolving these issues prior to fabrication, engineers can avoid expensive manufacturing re-spins and keep product delivery on schedule.

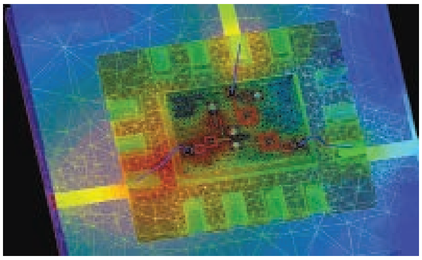
PUTTING EM TECHNOLOGY WITHIN EVERY ENGINEER'S REACH

Historically, EM tools have been restricted to experts, and therefore only used sparingly. In today's world of smaller form factors and physical complexity, EM analysis has become a necessity in order to achieve design success. Over the last few years, ADS has brought together a suite of EM technologies including 3D Planar and FEM solvers in a single integrated platform. With ADS 2011, significant strides have been made to make EM analysis accessible to a broader community of engineers.

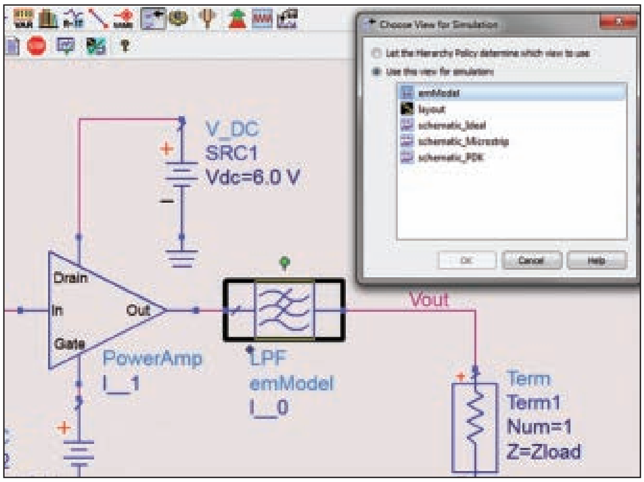
To start, ADS 2011 features a unified, graphical layer definition editor that makes it easy to define the substrate technology (dielectric, metal, vias and material properties). To set up and run a simulation, multiple dialogs have been consolidated into a single dialog that is used for both the Momentum and FEM simulators.



▲ *Fig. 1 A multi-technology 10 GHz amplifier.*



▲ *Fig. 2 Performing multi-technology EM analysis.*



▲ *Fig. 3 Multiple data views in ADS 2011.*

Once the simulation setup has been done, it can be saved and re-used for other designs and even shared with other engineers. In addition, the underlying technology has been improved with the capacity and performance required to solve much larger problems than were possible even a few years ago. Finally, parameterized 3D solid models can be imported as components to ADS 2011 from Electromagnetic Professional (EMPro), Agilent's 3D EM modeling and simulation platform. These components can then be combined with the circuit layout and simulated as an integrated physical structure.

NEW FLEXIBILITY AND PRODUCTIVITY FOR DESIGN AND SIMULATION

A key improvement for ADS 2011 is the new organization of the design data. Each sub-circuit or component in the design is now a cell that can have a variety of views, which represent different models (e.g., circuit, behavioral and EM), or even design variations (see ***Figure 3***). This makes it easier to explore the design space, make trade-offs between simulation speed and accuracy, and keep the schematic cleaner and better organized. Additionally, a new load-pull controller simplifies data import and shortens the time to design and simulation. Other new features include a Multi-level Hemispherical Model that more accurately models surface roughness for transmission line and Momentum simulations and improved Smith Chart graphing.

ADS 2011 also boasts significant improvements for layout, not the least of which is a new, industry standard database that provides improvements in performance and capacity. Editing "handles" added to all basic layout objects make layout editing more efficient. Bond wires are now easier to create and edit, and can be modeled directly by Momentum. Further improvements to designer efficiency come from a new command line editor with dozens of common functions and a new layout toolbar.

A FOUNDATION FOR TODAY'S CHALLENGES AND BEYOND

With the introduction of ADS 2011, the ADS platform becomes the first RF/microwave design tool that is built directly on the industry standard Open Access database (supported by Si2, an organization of nearly 100 industry-

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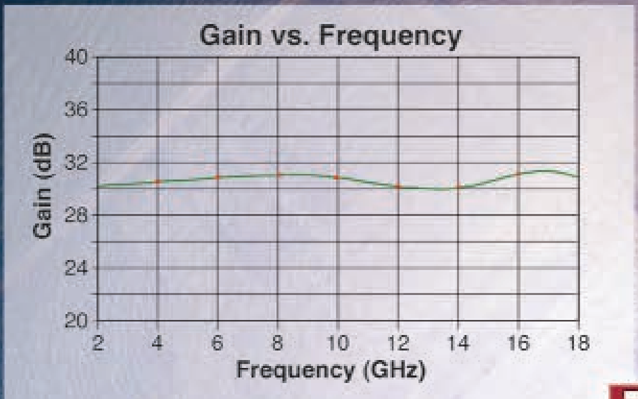

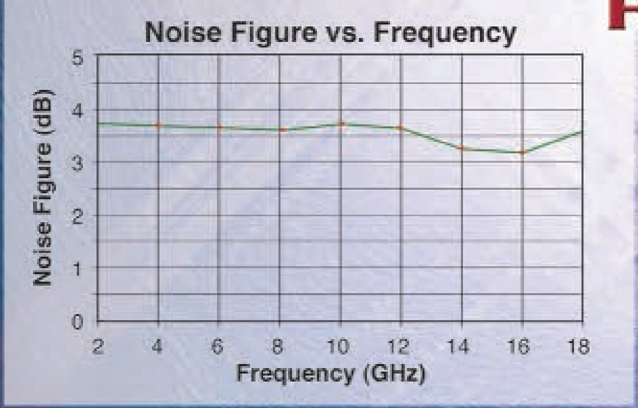

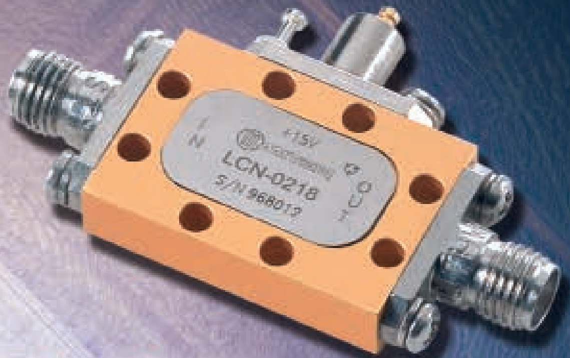

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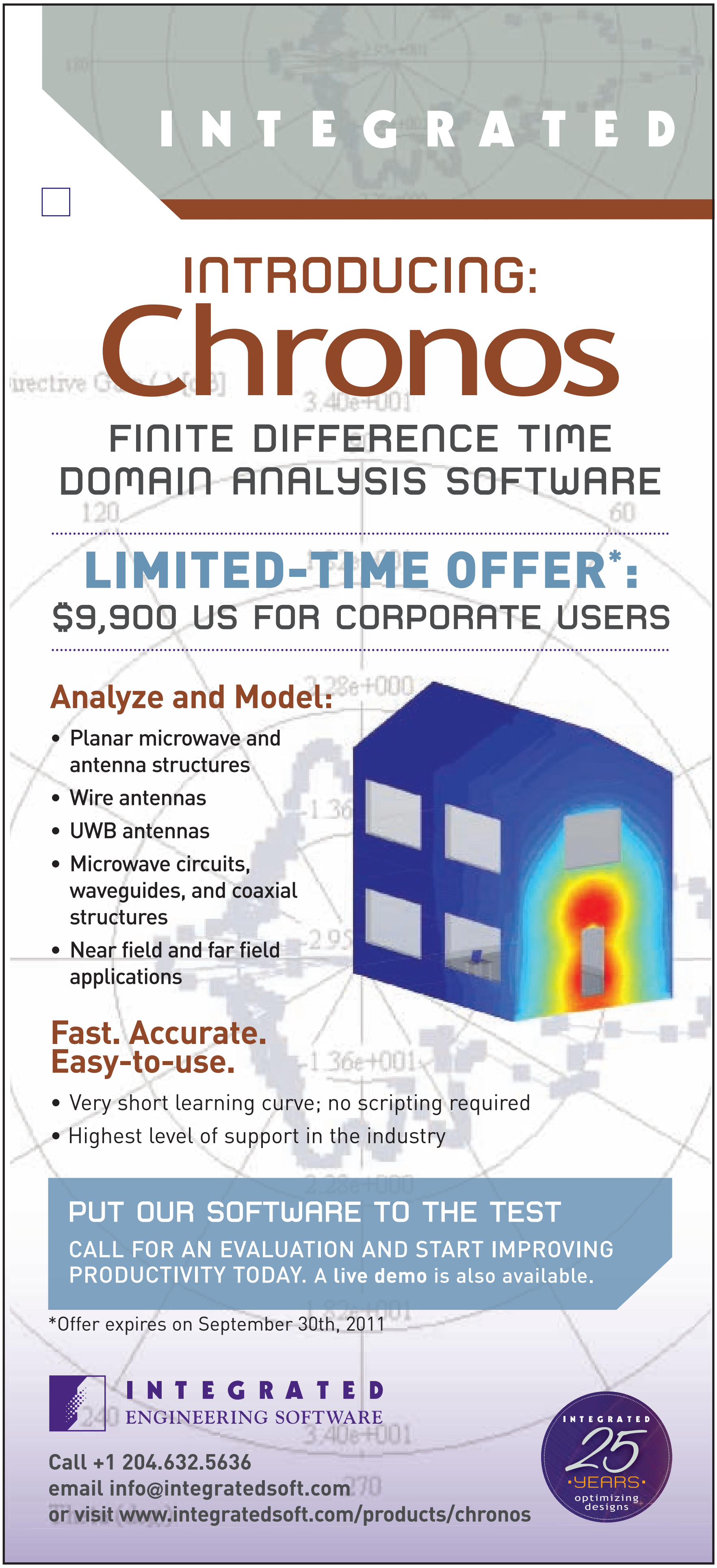

leading companies). This proven design database provides the capacity and performance to address not only single technology design, but also the increased demands of a native, multi-technology design platform. Unlike the proprietary databases found in other RF/microwave tools today, the OpenAccess database has been engineered for industry-wide interoperability, and a variety of other leading EDA tools are currently built on OpenAccess.

With the rapid evolution of RF/microwave design, today's tools need to keep pace with the critical circuit and EM simulation technologies required to address conventional single-technology design. However, this alone is no longer sufficient to deal with the interactions between multiple technologies being combined into complex systems. What is needed is a true multi-technology design platform that combines the necessary database capabilities and capacity with the advanced simulation technologies needed to find and resolve issues across technology boundaries before going to manufacturing. ADS 2011 provides a comprehensive design environment to address these multi-technology design challenges in a single integrated design platform.

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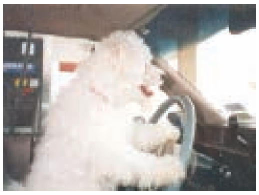

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NEW NETWORK ANALYZER GENERATION SETS THE PACE

The new R&S ZNB family of network analyzers stands out due to its wide dynamic range of up to 140 dB (at 10 Hz IF bandwidth), its low trace noise of 0.004 dB (RMS) (at 10 kHz IF bandwidth) and its high output power of up to +13 dBm that can be varied electronically in a range of more than 90 dB. The state-of-the-art operating concept of these network analyzers makes configuration, measurement and analysis simple.

All basic and frequently used functions can be controlled via keys, and functions needed for the individual test sequences are available via context-sensitive menus on the touch screen. Working with diagrams and traces, setting up markers for analysis, and zooming in on details—all it takes is a simple movement of the finger on the large, high-resolution 12.1-inch screen. Due to their shallow depth, the compact two-port and four-port analyzers leave plenty of space on the workbench for the measurement application.

Operation is extremely low-noise thanks to low power consumption and an elaborate cooling concept. With the available frequency ranges of 9 kHz to 4.5 GHz and 9 kHz to 8.5 GHz, the network analyzers are primarily intended for use in the mobile radio and wireless communications and electronic goods industries. The R&S ZNB is suitable for developing, producing and servicing RF components such as amplifiers, mixers, filters or cables, which are often used in large quantities by manufacturers of base stations and mobile terminal equipment.

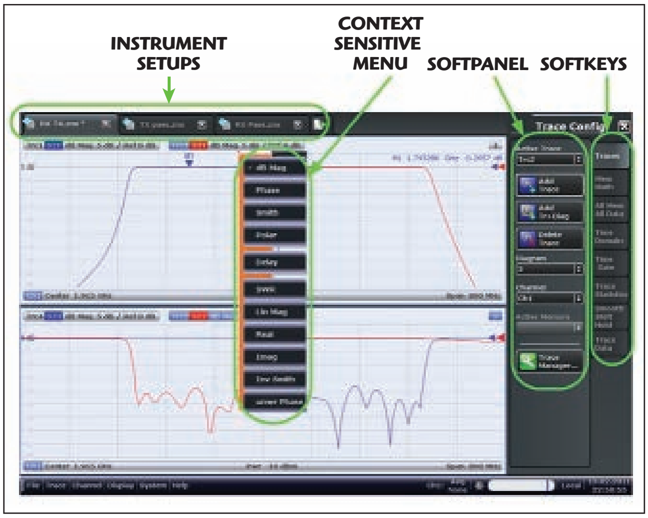
THREE OPERATING STEPS

The R&S ZNB does away with side and submenus and, in addition to hard keys and soft keys, it includes a soft panel as a new control element. The soft panel not only displays control functions that may be needed for a measurement, but also supports all instrument functions at the press of a maximum of three keys. The analyzers of the R&S ZNB family offer tangible network analysis as they allow users—simply by touching the screen—to shift traces between diagrams, position markers on traces, move scaling reference lines, or change test parameters via context-sensitive menus right at the point where the parameters are displayed.

Measurement tasks such as characterizing amplifiers and RF modules, which involve a large number of test parameters, can be split up and assigned to several clearly arranged

ROHDE & SCHWARZ
Munich, Germany

instrument setups with just a few traces. All instrument setups are available at a finger's touch, and because there are no submenus, each step that needs to be performed is clearly accessible on the touch screen. This straightforward operating concept (shown in ***Figure 1***) not only benefits untrained or infrequent users, but also makes operation easier for experienced users and increases measurement efficiency.



▲ *Fig. 1 R&S ZNB control elements.*

The R&S ZNB offers users a wide choice of options when it comes to displaying results. Traces can be freely assigned to diagrams and channels, and assignments can be changed at any time during the measurement. To maximize the display area, which may be a useful option during manual adjustments, the soft panel can be hidden to make the entire screen area available for displaying results. Recognizing that solving a wide variety of tasks is easiest in one's mother tongue, the new network analyzers offer a large range of language options, including English, Chinese, Japanese, French and Russian (see ***Figure 2***).

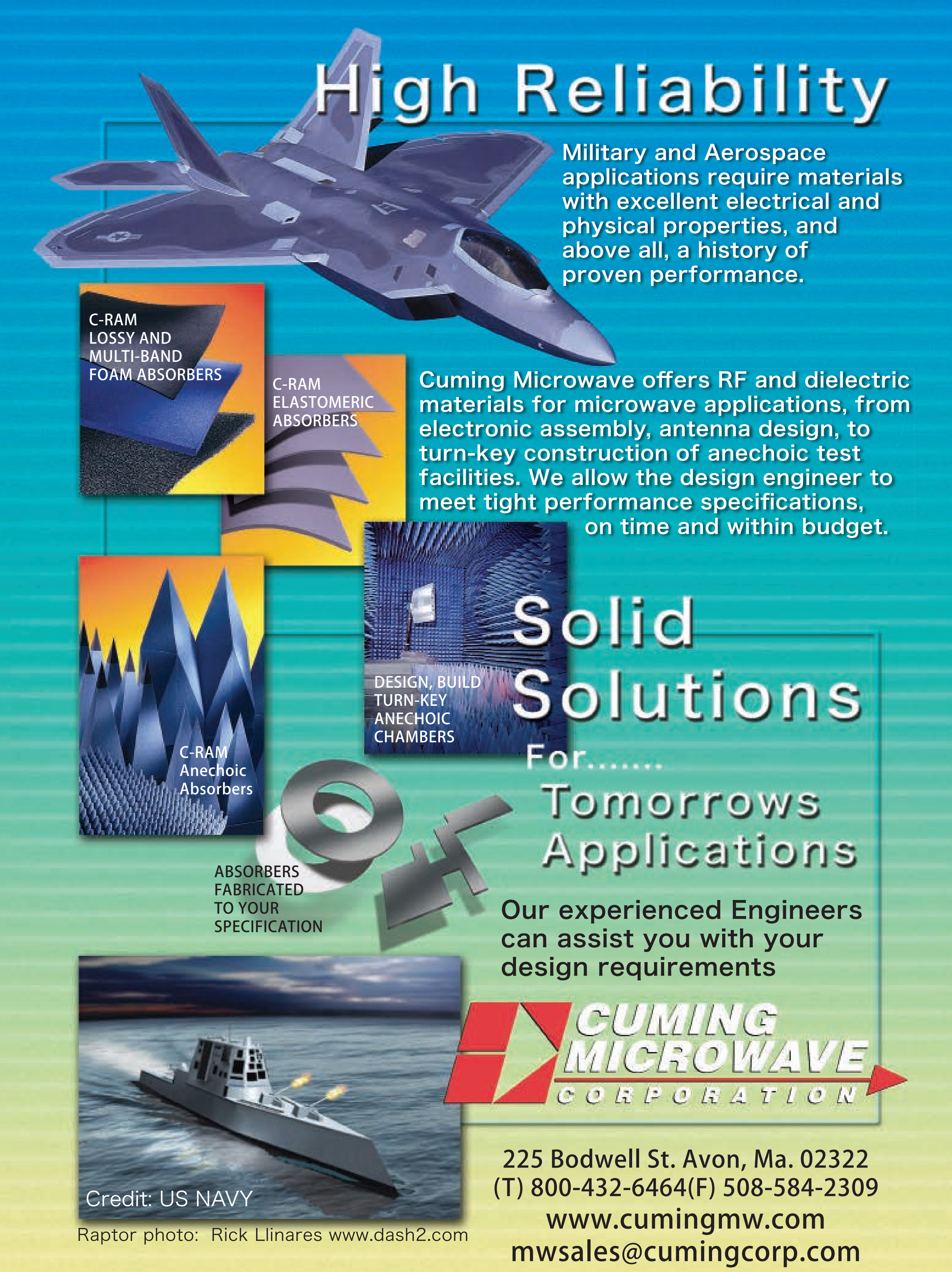
Fast or accurate? This is often a question faced by users in a production mode. However, with the R&S ZNB there is no longer the need to trade off speed against accuracy as the network analyzer combines a fast synthesizer with high sensitivity and a wide dynamic range.

WIDE DYNAMIC RANGE

The speed of measurements involving high attenuation—for example in the stopband of a base station duplex filter—is determined by the required dynamic range and the corresponding IF bandwidth. Reducing the IF bandwidth by a factor of 10 will increase the dynamic range by 10 dB. In the case of narrower IF bandwidths, the measurement time per point is approximately 1/IF bandwidth. The larger the IF bandwidth, the shorter the measurement time.

▲ *Fig. 2 R&S ZNB language selection.*

A 10 dB increase in dynamic range will boost measurement speed by a factor of 10. The R&S ZNB offers a dynamic range of up to 140 dB at 10 Hz IF bandwidth. At a dynamic range of 120 dB, the measurement time per point is therefore 1 ms. In addition to



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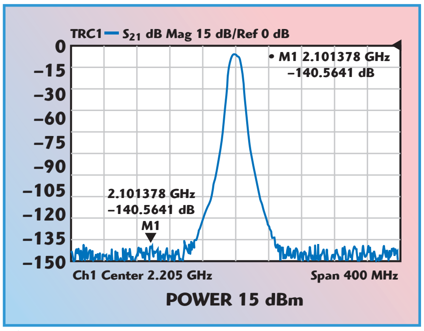
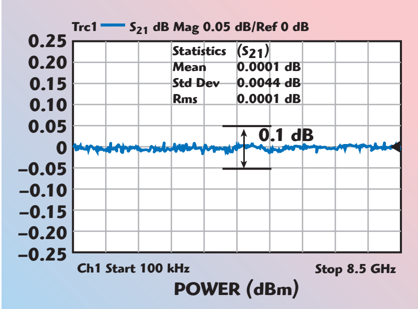


▲ *Fig. 3 Filter measurement at 10 Hz IF bandwidth.*



▲ *Fig. 4 Trace noise at 10 MHz IF bandwidth is less than 0.1 dB.*

high measurement speed, this also offers a signal-to-noise ratio (SNR) sufficient to provide high measurement accuracy. ***Figure 3*** shows filter measurements at 10 Hz IF bandwidth.

MEASUREMENTS WITH LOW ATTENUATION

Measurements involving low attenuation—for example in the passband of a base station duplex filter—can be carried out at maximum IF bandwidth. Measurement time is not determined by the IF bandwidth, but by the speed of the synthesizer. At an IF bandwidth of 1 MHz, the R&S ZNB requires no more than 4 ms for a sweep with 401 points. The measurement error is virtually negligible even at this high IF bandwidth due to the low trace noise. ***Figure 4*** shows the trace noise at 10 MHz IF bandwidth 0.1 dB.

CALIBRATION KITS

The R&S ZNB supports a variety of different calibration methods. The Un-known Through, Open, Short, Match (UOSM) calibration method deserves a special mention as it supports simple calibration kits that do not contain a Through standard. Calibration with such kits is carried out using a simple adapter not known to the vector network analyzer instead of a high-quality Through standard.

While such adapters are inexpensive, they lead to measurement uncertainties of up to a few tenths of a dB with calibration methods requiring Through, Open, Short and Match standards. When using the UOSM method, the adapter's characteristics are irrelevant, and accuracy after calibration is comparable to that achieved with a high-quality Through calibration standard.

For applications calling for speedy calibration, e.g. in production, the R&S ZNB supports automatic calibration units. Controlled via USB, these units carry out full calibration within 30 sec of the press of a key. This affords an enormous speed advantage and minimizes the risk of operator errors over manual calibration especially when full four-port calibration is performed, e.g. on balanced two-port components. ***Figure 5*** shows the R&S ZV-Z51 calibration unit.

▲ *Fig. 5 Calibration unit for the R&S ZNB.*

Careful calibration increases measurement accuracy, but interrupts the development or production process. As temperature and long-term stability determine the calibration interval, the R&S ZNB hardware has been developed with these factors in mind. Good raw data is also crucial to stability. This data indicates a network analyzer's accuracy when no internal error correction is active and no user calibration has been performed. The new network analyzers offer raw test port match of up to 25 dB and directivity of up to 35 dB.

AMPLIFIER MEASUREMENT

The R&S ZNB offers a wealth of functions for measuring amplifiers. In addition to S-parameters, it determines output power, stability factors, power consumption, impedances and Z-parameters as a function of frequency or power. The high output power of up to +13 dBm and the wide electronic power sweep range of over 90 dB enable fast and wear-free amplifier measurements under different stimulus conditions.

The electronic receiver attenuators are designed for input powers of up to +27 dBm, enabling the network analyzer to perform compression-free measurements even on amplifiers with high output powers. Amplifier characterization also includes determining the RF to DC transfer characteristics of power-monitoring level detectors and measuring power consumption to determine efficiency. For this purpose, the R&S ZNB offers four DC inputs with a voltage range of ±10 V and sensitivity of 10 µV. With future proofing in mind, the R&S ZNB supports the remote control command sets of other Rohde & Schwarz network analyzers and those of other manufacturers' instruments.

Productivity redefined—the new R&S ZNB network analyzers feature simple operation, flexible analyses, long-term stability, high IF bandwidths and a dynamic range previously found only in high-end instruments. Whether in production or development, they offer enhanced measurement speed and reliable accuracy at reduced calibration effort and support users in optimally organizing their measurement processes. The two-port model is available with four-port models coming online in September 2011.

VENDORVIEW

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SECOND GENERATION RF LINEARIZER TARGETS 4G SMALL CELL DEPLOYMENTS

Cellular service providers are struggling to keep up with the surging demand for data services. As this demand continues to outstrip the available infrastructure capacity, operators are recognizing the need for heterogeneous network deployments. This trend, from voice-centric macro base stations to lower power, wider bandwidth small cell, distributed antenna, and MIMO architectures increases the requirement for more linearity out of power amplifiers at lower output power levels.

Deployment of these heterogeneous network base stations with smaller coverage areas and low power transmit architectures will significantly increase the volume of transmitters as well as necessitate lowered equipment and deployment costs. Furthermore, the worldwide trend to reduce carbon emissions is also driving operators to seek solutions that are highly energy efficient. Prior to Scintera, no commercially available solution existed that could cost-effectively linearize PAs from 50 W down to 250 mW (average output power at the antenna) while also meeting operator's and OEM's stringent performance and system requirements.

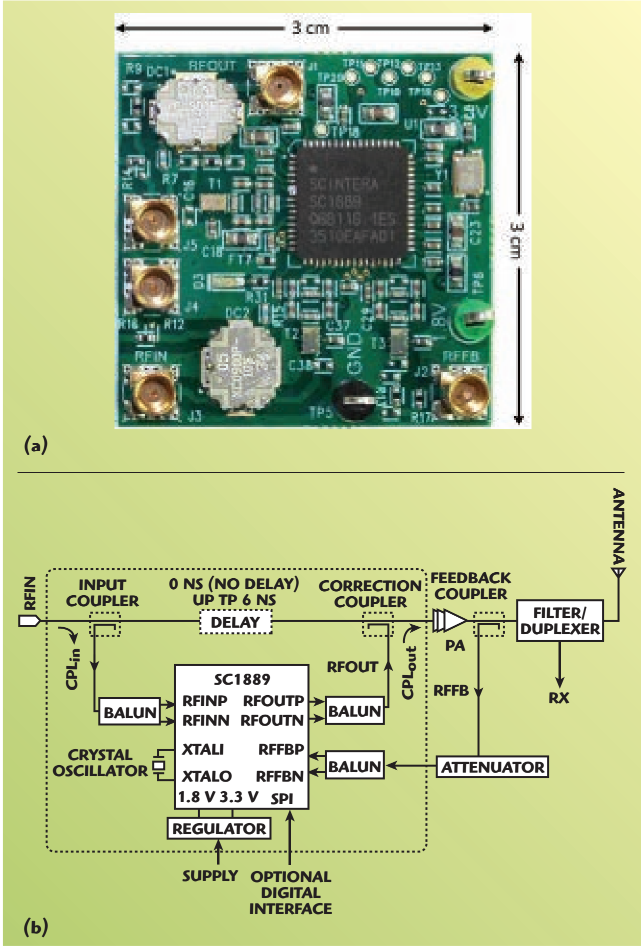
Scintera's SC1889 is a second generation RF PA linearizer (RFPAL) and, as can be seen in ***Figure 1***, features a compact footprint and low external BOM. The SC1889 consumes minimal power while providing excellent correction performance across static signals including CDMA and W-CDMA, and dynamic signals including WiMAX and LTE. The SC1889 represents one of the key enabling technologies for the successful deployment of small cells for heterogeneous networks. The SC1889 can increase system efficiency of lower power base station PAs (10 W average power at antenna and lower) by up to 2×, if linearizing Class A/B amplifiers, and up to 4× by enabling the use of more efficient Doherty amplifiers. In either configuration, Scintera's SC1889 will cut capital and operation/energy costs by an amount proportional to the efficiency improvement.

ACTIVE AND PASSIVE LINEARIZATION

The two legacy linearization solutions deployed include digital predistortion (DPD) and operating the PA in backoff. While DPD is an active linearization solution, the most popular linearization method by far is passive linearization that requires reducing (backing off) the PA output power until achieving the desired linearity. This method typically requires doubling the size of the RF power devices compared to active linearization.

SCINTERA
Sunnyvale, CA

Due to cost, complexity and system power consumption considerations, RFPAL is one of the best linearization solutions to effectively displace passive linearization in small cell applications with average output power levels (at the antenna) of 5 W down to 500 mW. It is important to note that with advanced communication protocols with wide signal bandwidth requirements like LTE, or in wideband multicarrier/multiprotocol systems, backing off the PA output power may not be an option as the PA may never reach the desired linearity at any power level. In these systems, Scintera's RFPAL represents a practical linearization solution for small cell network deployments.



▲ *Fig. 1 Scintera's complete standalone linearization solution in a 3 × 3 cm footprint on a PCB (a) and block diagram (b).*

RF PREDISTORTION VS DIGITAL PREDISTORTION

Scintera's RF predistortion technology shares similarities with DPD in that both compensate for AM-AM and AM-PM distortion, intermodulations and PA memory effects and utilizes adaptive feedback. The similarities end with their circuit and system implementations.

Scintera takes a new approach to RF power amplifier linearization by repartitioning portions of the predistortion algorithm from the digital to the analog/RF domain. Additionally, the entire adaptive feedback path including the analog to digital converters (ADC) is integrated within the RFPAL. The result is an elegant, single chip and highly integrated solution that maintains the flexibility of digital approaches while offering the simplicity and power consumption of analog approaches.

BENEFITS

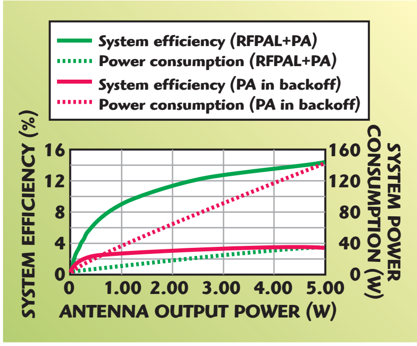
Many factors determine the system performance of any linearization solution. Comparing RFPAL against solutions operating in backoff, customers can realize the greatest performance benefits. As highlighted in ***Table 1***, for a given average output power level at the antenna, by "spending" 0.8 W on active linearization, customers can realize up to a 4× improvement in efficiency, thus enabling proportional decreases in the system power consumption. Additionally, linearization enables operation of the PA closer to its PSAT operation point and typically can cut the power transistor size and cost in half. A direct benefit of the improved power consumption is a reduced yearly operating cost (electricity) which, at higher antenna power levels, can offset the initial cost of the RFPAL system in a relatively short time. The system power consumption and system efficiency can be seen in ***Figure 2***.

An often overlooked benefit is the

TABLE I
CALCULATION FOR SYSTEM POWER CONSUMPTION, SYSTEM EFFICIENCY AND YEARLY OPERATING COST

Parameter	RFPAL (Doherty Amplifier)	Back Off (Class A/B amplifier)	Unit
Desired max antenna Pout (avg)	37	37	dBm
Component IL between PA and antenna	3.5	3.5	dB
PA output power (max antenna power - IL)	40.5	40.5	dBm
PA efficiency at 40.5 dBm (avg)	35.0%	8.0%	
Linearization power consumption	0.8	0	W
Pre-amp + driver power consumption	2	2	W
Total power consumption (w/o final stage PA)	2.8	2	W
System efficiency at max antenna Pout = 37 dBm	14.4%	3.5%	
System power consumption at max antenna Pout = 37 dBm	34.9	142.3	W
Cost of energy (cost per kWhour)	$0.05	$0.05	
Yearly cost of operation per system	$15.28	$62.35	
Added yearly cost of operation compared to RFPAL		$47.07	

INDICATES ENTERED VALUES



▲ *Fig. 2 Graph of system power consumption and system efficiency against antenna output power.*

dramatic reduction in size/volume and cost associated with the power supplies and cooling elements (heat-sinks, fans, etc.). The power supply savings can be proportionally higher than the improvement in efficiency due to power supply cost increasing faster than supply capacity. At the same time, the RFPAL will deliver similar or better ACLR (distortion) performance than when the PA was operated in backoff (a simplified version of the calculator is available online at www.scintera.com/RF-PA-linearization-predistortion-efficiency-calculator).

Finally, Scintera's RFPAL lends itself to fast system design times and requires no expertise in predistortion algorithms. The RFPAL offers stand-alone operation that is very nearly "plug and play," thus accelerating time to market and enabling any company, large or small, to enjoy the benefits of active linearization. Typically, linearization results are achieved within a half day of opening the evaluation kit.

RELIABILITY

Replacing a system operating in backoff with RFPAL provides an improvement in device and system reliability. By improving the efficiency of the device and thus lowering its operational case temperature leads to a decrease in the failures in time (FIT) rate. With more than 50,000 systems based on Scintera's first generation RFPAL, the SC1887, deployed in the field with no failures or returns, Scintera's RFPAL clearly demonstrates the robustness and ruggedness required to meet even the most stringent operator requirements.

Based on field-proven technology, Scintera's SC1889 represents a new alternative to existing linearizing solutions. It is an elegant and compact solution that reduces development costs and speeds time to market. Applicable across a broad range of signals, including 2G, 3G, 4G wireless and other modulation types. The SC1889 solves some of the key challenges faced by operators trying to deploy data services and will continue to play a key role in the transition to 4G and beyond.

Scintera,
Sunnyvale, CA (408) 636-2600,
www.scintera.com.

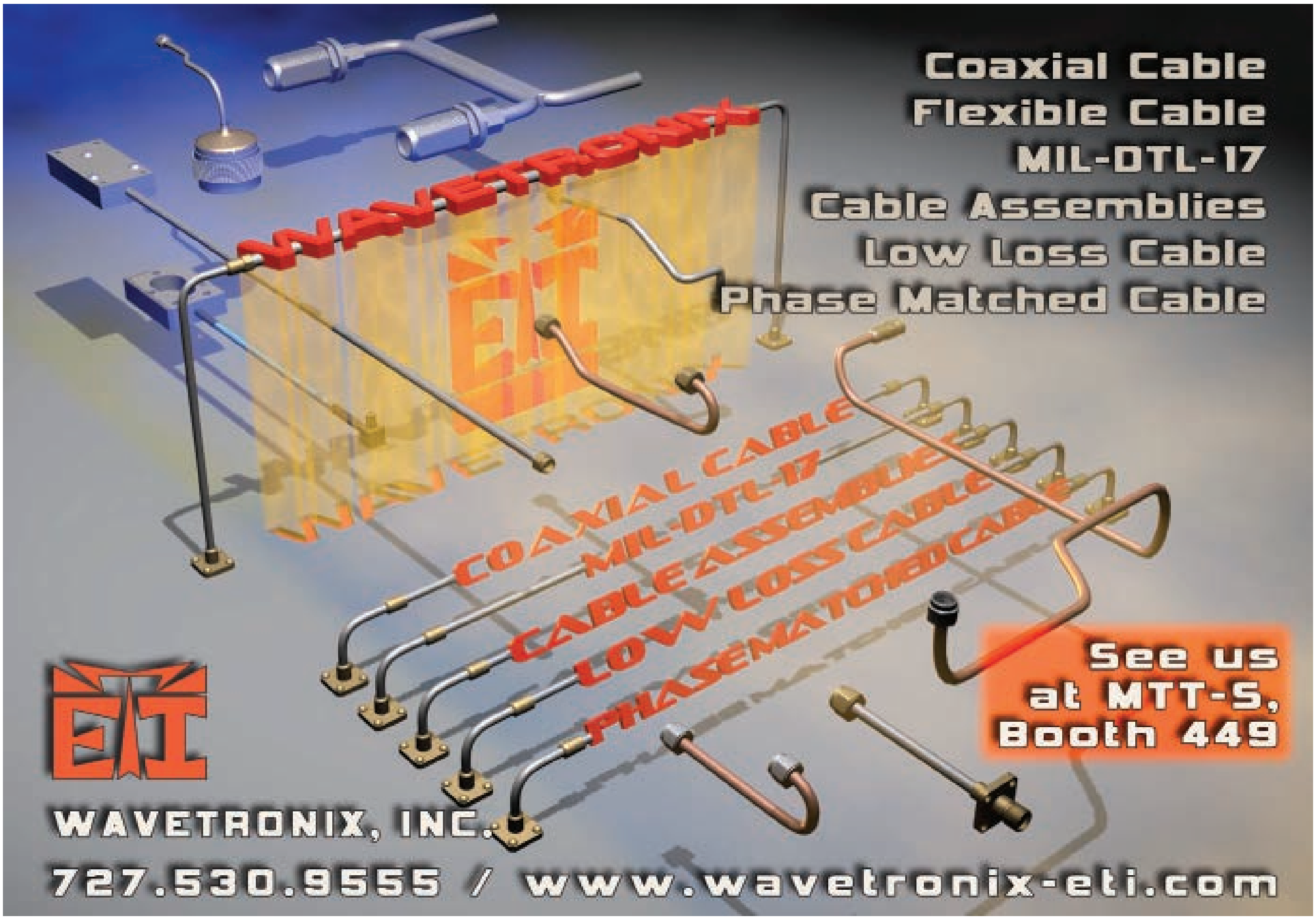
RES-NET MICROWAVE, INC.
P.O. Box 1260
Clearwater, FL 33757
Ph: 727.530.9555
Fx: 727.531.8215
www.res-netmicrowave.com

"THINKING AT A HIGHER FREQUENCY"

Res-net has both thick-film and thin-film SMT terminations, resistors, and attenuators available in DC to 40 GHz. Res-net also has high power passives to 6 GHz with power up to 2KW. Our enhanced thick-film process allows for custom circuit layouts on Alumina, Aluminum Nitride, and Beryllium Oxide. Res-net is currently developing new products so go online to www.res-netmicrowave.com to see what is new.

- Frequency to 40 GHz
- Power to 2,000 watts
- 50 ohm impedance
- Operating temperature from -55°C to +150°C
- RoHS compliant
- Low VSWR

See us at MTT-S, Booth 449



ULTRA LOW NOISE, HIGH IP3 MONOLITHIC AMPLIFIER

The Mini-Circuits PMA2-162LN+ is an ultra low noise MMIC amplifier covering 0.7 to 1.6 GHz with a unique combination of low noise and high IP3 making it ideal for sensitive receiver applications. The design operates on a single 4 V supply and is internally matched to 50 ohms. It offers high dynamic range in addition to good input and output return loss without the need for external components. It is packaged in a 2 × 2 × 0.55 mm (MCLP) leadless surface-mount package with very good thermal performance.

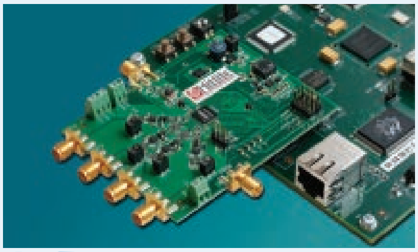
Parameter	Typical Value at 1 GHz (dB)
Noise figure	0.47
Gain	22.7
Input return loss	20.4
Output return loss	18.9
Pout P1dB	19.9
Output IP3	29.9

The PMA2-162LN+ has a low noise figure of 0.5 dB and high IP3 of 30 dBm typical at 1 GHz. The gain is 22.7 dB typical and output power P1dB of 20 dBm typical at 1 GHz. The operating temperature is -40° to +85°C with high reliability due to the low, small-signal operating current of 80 mA nominal, which maintains the junction temperatures typically below 100°C at a ground lead temperature of 85°C. It has a Class 1B HBM ESD rating (500 V). Typical applications include base station infrastructure, portable wireless, LTE, GPS, GSM and airborne radar.

VENDORVIEW

Mini-Circuits,
Brooklyn, NY,
(718) 934-4500,
www.minicircuits.com.

High Speed Analog-to-Digital Converter Family



Hittite Microwave Corp. has introduced a new high speed analog-to-digital converter (ADC) product line that exhibits ultra-low power dissipation and high cost efficiency while maintaining high performance.

The HMCAD1520, HMCAD1511 and HMCAD1510 are multi-mode ADCs with integrated crosspoint switches (Mux Array). HMCAD1520 offers 12-bit resolution up to 640 MSPS in high speed mode, and 14-bits up to 105 MSPS in precision mode. The HMCAD1520 is ideal for communication applications, including diversity receivers and digital pre-distortion loops, as well as test & measurement applications such as spectrum analyzers and precision oscilloscopes. The HMCAD1510 and HMCAD1511 offer 8-bit resolution up to 500 and 1000 MSPS respectively, which enables significant power savings and unique functionality in test & measurement applications such as digital oscilloscopes. HMCAD1511 is also an excellent choice for satellite receivers. The HMCAD1520 can be combined with HMC960LPE DC to 100 MHz dual DVGA and the HMC900LP5E 50 MHz dual baseband low pass filter to provide a complete direct conversion line-up. HMCAD1520, HMCAD1511 and HMCAD1510 offer an integrated clock divider that provides a flexible and easy to implement clock path without sacrificing performance.

The HMCAD1060 is a versatile, Quad 14-bit ADC running up to 105 MSPS with optional power saving modes. The different reduced power dissipation modes can be selected during operation to trade off power dissipation against accuracy. Low switching times between the modes enables the system to continuously keep power dissipation and performance at optimum levels. This makes the HMCAD1060 ideal for communication applications such as certain types of low power software-defined radios and diversity receivers where low power dissipation is a critical parameter.

The HMCAD1102, HMCAD1101 and HMCAD1100 are Octal 12- and 13-bit ADCs that operate up to 80 MSPS and are ideal for medical ultrasound and non-destructive testing. The HMCAD1102 is the only discrete Octal 12-bit ADC offering an 80 MSPS sample rate, and is an excellent choice in diversity base band receivers.

The dual HMCAD1050-40/80 and single HMCAD1051-40/80 are 13-bit ADCs, while the dual HMCAD1040-40/80 and single HMCAD1041-40/80 are 10-bit ADCs operating up to 80 MSPS. These ADCs offer the industry's best SNR performance for the lowest power consumption. These ADCs are ideal choices in power critical applications requiring 10- to 13-bit analog-to-digital conversion at input frequencies up to 50 MHz.

VENDORVIEW

Hittite Microwave Corp.,
Chelmsford, MA,
sales@hittite.com, www.hittite.com

600 W UHF Power Transistor

NXP Semiconductors has introduced an ultra high frequency (UHF) 600 W RF power transistor that is a LDMOS device for broadcast transmitters and industrial applications. The BLF888A is the most powerful LDMOS broadcast transistor in the market to date. For a DVB-T signal over the full UHF band from 470 to 860 MHz, the transistor can deliver 120 W average DVB-T signal power with efficiencies greater than 31 percent. Featuring excellent linearity, high gain of 21 dB and ruggedness corresponding to VSWR greater than 40:1, the BLF888A is ideal for advanced digital transmitter applications.

The performance of the BLF888A is enabled by NXP's 50 V high voltage LDMOS process technology in combination with advanced thermal concepts, resulting in high power density and thermal resistance as low as 0.15 K/W. As a result, the BLF888A allows broadcast equipment manufacturers to optimize existing or new transmitter installations for performance and total cost of ownership. For complete power amplifier line-ups, the BLF888A combines optimally with the BLF881 driver transistor. The transistor is available in two versions: BLF888A, a bolt-down package and BLF888AS, an earless package, which enables a more compact PCB design. The BLF888AS can be soldered to achieve a further decrease in junction temperature.

NXP Semiconductors, Eindhoven, The Netherlands, www.nxp.com.

Visit NXP Semiconductors in Booth #420 at this year's IEEE MTT-S International Microwave Symposium being held June 5-10, 2011 in Baltimore, MD.

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Featuring VENDORVIEW Storefronts

The following booth numbers are complete as of April 8, 2011.

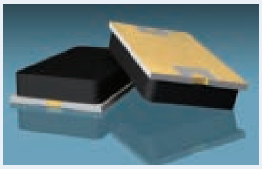
26.5 GHz SMPM Attenuator

Aeroflex/Inmet introduced a 26.5 GHz fixed attenuator that incorporates the SMPM connector. The self-aligning push-on connector is a miniature version of its SMP attenuator and provides reliable high performance, excellent RF characteristics and mates non-destructively with GPPO™ connectors. Designed for use in tight quarters whether the requirement is in manufacturing or semiconductor chip test applications, this new 2 W device offers standard attenuation values of 3, 6, 10, 20 and 30 dB all under 0.75" in length. Non-standard attenuation values are available.

Aeroflex/Inmet,
Ann Arbor, MI (734) 426-5553,
www.aeroflex.com.

Booth 2212

Drop-in, Surface-mount Limiters



This LM series of surface-mount limiters is designed for receiver protection applications through 8 GHz. These RoHS-compliant devices provide high power protection at levels to 100 W CW and 2 kW peak power in surface-mount technology (SMT) packages measuring only 8 × 5 × 2.5 mm. Ideal for receiver protection applications at L-band (1 to 2 GHz), S-band (2 to 4 GHz) and C-band (4 to 8 GHz) frequencies. LM series limiters provide considerably higher thermal capacity than silicon and GaAs MMIC solutions. The limiters' small size and excellent thermal conductivity supports low-profile circuit designs without sacrificing protection for sensitive receiver front-end components.

Aeroflex/Metelics,
Londonderry, NH (888) 641-7364,
www.aeroflex.com/metelics.

Booth 2212

Digital Attenuator

VENDORVIEW

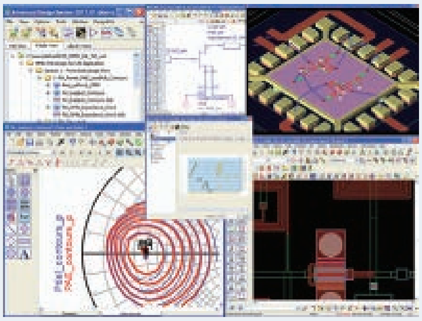
Aeroflex/Weinschel's new model 4202-63 is a digital attenuator that operates over the 0.4 to 6 GHz frequency range and provides an attenuation range from 0 to 63 dB in 1 dB increments. This attenuator offers excellent repeatability and performance; SMA female connectors; built-in TTL Interface and ruggedized construction. Custom configurations are available upon request.

Aeroflex/Weinschel Inc.
Frederick, MD (301) 846-9222,
www.aeroflex.com/weinschel.

Booth 2212

Design and Simulation Platform

VENDORVIEW



Agilent Technologies announced shipment of the latest version of its RF and microwave design and simulation platform, Advanced Design System 2011 (ADS). ADS 2011 delivers new features for new and existing Advanced Design System users, including electromagnetic technologies for faster, more accurate simulations; a new use model that makes electromagnetic simulation easy for all engineers; and layout improvements for easier physical design. Advanced Design System 2011 also features dozens of new capabilities and improvements designed to enhance the platform's functionality and usability.

Agilent Technologies Inc.,
Santa Clara, CA (800) 829-4444,
www.agilent.com.

Booth 813

PXA Signal Analyzer

VENDORVIEW

This PXA signal analyzer is a high performance millimeter-wave signal analyzer that operates in a frequency range up to 50 GHz. With external mixing, it can cover 325 GHz and beyond. The result is easier, more accurate millimeter-wave measurements. The PXA delivers a level of performance at millimeter-wave frequencies that is unmatched by competing solutions, offering accurate, sensitive and frequency-stable signal analysis. Its ability to measure small signals in the presence of very large signals is unparalleled and enables customers to develop the most advanced radar, surveillance and wireless communications systems.

Agilent Technologies Inc.,
Santa Clara, CA (800) 829-4444,
www.agilent.com.

Booth 813

Switch Matrix on a Substrate

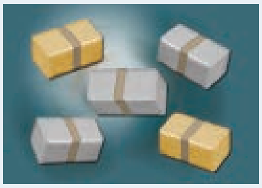
VENDORVIEW

AMC brings microwave integrated circuit technology to the solid-state switch matrix resulting in a hybrid switch matrix on a single substrate. Using a multilayer substrate, AMC is able to design for SMT production various configurations of RF/microwave switches with custom driver/logic circuitry and custom mechanical requirements. With two sides for discrete components, AMC can integrate a variety of other components including filters, amplifiers, combiners/splitters, bias Ts and fault circuits.

American Microwave Corp. (AMC),
Frederick, MD (301) 662-4700,
www.americanmic.com.

Booth 4319

Ultra-broadband Capacitor



ATC's new 550L ultra-broadband capacitor (UBC) has been designed and manufactured with the highest quality materials to provide reliable and repeatable ultra-broadband performance from 16 kHz through 40+ GHz. Now available with gold terminations, this unique component provides ultra-low insertion loss, flat frequency response and an excellent match over multiple octaves of frequency spectrum. The 550L has been engineered in a one piece orientation-insensitive 0402 SMT package, making it fully compatible with high speed automated pick-and-place manufacturing operations. Its superior broadband performance and reliability make it ideal for the requirements of the most stringent ultra-broadband applications.

American Technical Ceramics,
Huntington Station, NY
(631) 622-4700, www.atceramics.com.

Booth 1906

15 W GaN Amplifier

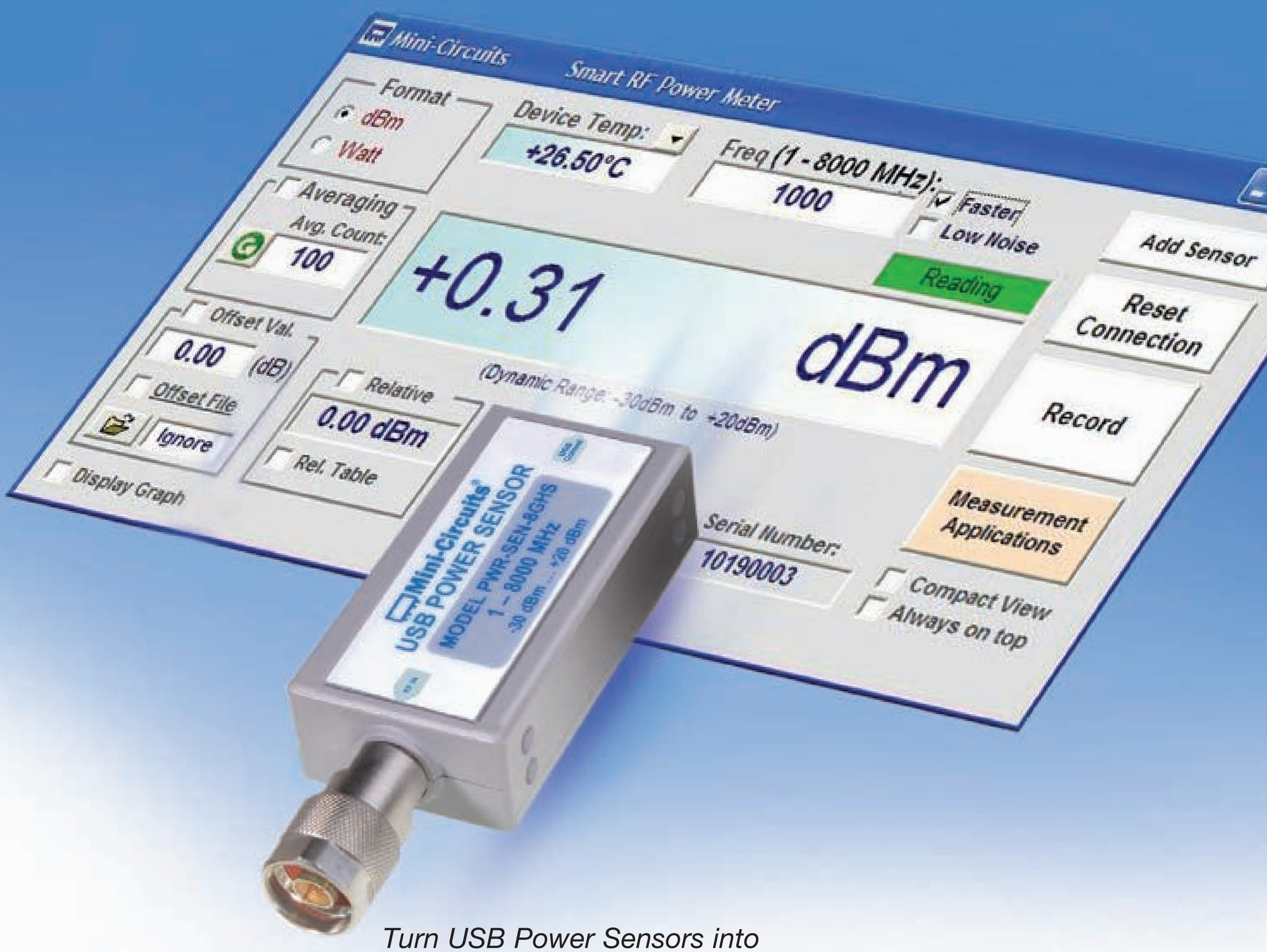
AML910P4215 is a 15 W, X-band, GaN amplifier that delivers minimum 30 percent power added efficiency. AML910P4215 operates over 9.9 to 10.7 GHz. Amplifier requires operating voltages of +32 V and +12 V DC. This amplifier has an integrated isolator at the output; TTL controlled muting function with 1 µs on/off speed; and a second output coupled from the main line with +28 dBm power. Package dimensions are 3.6" × 3.4" × 0.67". Operating temperature range is -30° to +60°C.

AML Communications Inc.,
Camarillo, CA (805) 388-1345,
www.amlj.com.

Booth 2024

Microwave Signal Generator

Anapico's APSIN20G is a 10 MHz to 20 GHz fast-switching microwave signal generator with excellent -108 dBc/Hz SSB phase noise at 10 GHz and a


Mini-Circuits
Smart RF Power Meter
Format
dBm
Watt
Device Temp:
+26.50°C
Freq (1 - 8000 MHz):
1000
Faster
Low Noise
Averaging
Avg. Count:
100
+0.31
dBm
Reading
Add Sensor
Reset Connection
Record
Offset Val.
0.00
(dB)
Offset File
Ignore
Relative
0.00 dBm
Rel. Table
Display Graph
(Dynamic Range: -30dBm to +20dBm)
Serial Number:
10190003
Measurement Applications
Compact View
Always on top
Mini-Circuits
USB POWER SENSOR
MODEL PWR-SEN-8GHS
1 - 8000 MHz
-30 dBm ... +20 dBm

New Waves

wide range of modulation capabilities including DCFM and fast pulse-modulation. The versatile, fan-less instrument is available in a compact and robust design. The APPH6000 is an ultra-low noise floor signal source analyzer from 10 to 6.2 GHz. Available with dual-channel cross-correlator, the residual noise floor is as low as -190 dBc/Hz. The APPH6000 features fast measurement speeds and is highly automated with easy-to-use remote control through LAN VXI-11 or USB port.

AnaPico AG,
Zurich, Switzerland +41 44 440 00 51,
www.anapico.com.

Booth 2323

Cavity Filters for 700 MHz LTE

VENDORVIEW

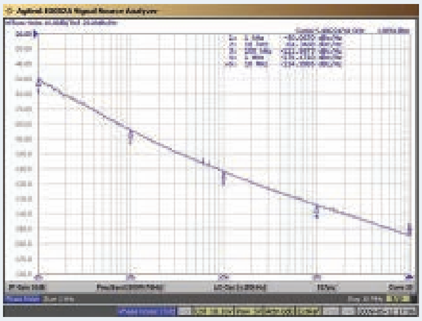
Anatech Electronics will feature its cavity bandpass filters designed for 700 MHz deployments

of LTE systems, with models available for all uplink and downlink bands. The filters have very high rejection (at least 40 dB at 700 kHz from passband edges), low loss and high return loss. They also meet the need for extremely low passive intermodulation distortion (PIM), with levels of -150 dBc or better, and are available for both indoor and outdoor installations.

Anatech Electronics,
Garfield, NJ (973) 772-4242,
www.anatechelectronics.com,
www.amcrf.com (Web store).

Booth 4507

Voltage-controlled Oscillators



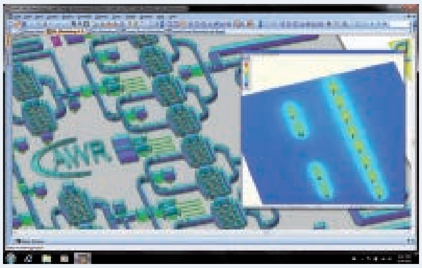
APA Wireless introduces a new line of voltage-controlled oscillators (4254SM5 and 5362SM5) that operate independently of ground-plane and load impedance. These VCOs will drive a short circuit, open circuit, or anything in between regardless of ground plane over the industrial temperature range. Excellent phase noise and linearity in the four to six GHz range, these devices provide exceptional performance in a variety of phase-locked and free running applications.

APA Wireless,
Oakland Park, FL (954) 563-8833,
www.apawireless.com.

Booth 317

HIgh Frequency EDA

VENDORVIEW



Visit AWR Corp. in booth #1618 for a demonstration of the company's 2011 release including Microwave Office's new electrical-thermal MMIC co-simulation design flow, simulation-state management technology, and yield analysis/optimization via a graphical shape-based manipulation approach; Visual System Simulator's new envelope simulator; as well as AXIEM's asynchronous electromagnetic (EM) simulation support. Last but not least, catch a sneak preview of AWR's new 3D FEM EM analysis technology.

AWR Corp.,
El Segundo, CA (310) 726-3000,
www.awrcorp.com.

Booth 1618

Solid-state Amplifier

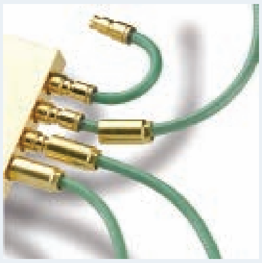
VENDORVIEW

The new solid-state microwave amplifier, model 175S1G4 operates in a frequency range from 0.8 to 4.2 GHz and has a power output of 175 W. This amplifier employs a new design that delivers more than twice the power of older models. The new, more efficient design consumes less power and incorporates both USB and Ethernet interfaces in addition to the standard IEEE and RS-232 interfaces. With these improvements, AR has maintained the superior rugged design for load tolerance and excellent linearity.

AR RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181,
www.arworld.us.

Booth 1103

Open Source Connector

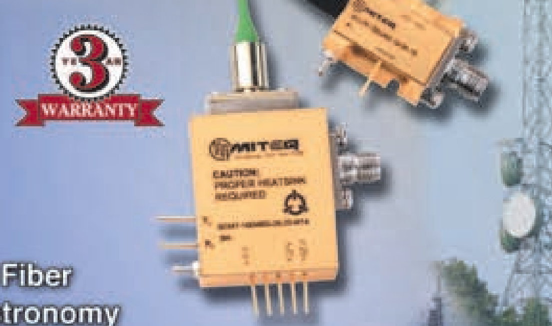


The SMPM-T is the smallest threaded open source connector on the market offering centerline-to-centerline spacing of just 0.20 inches. Its innovative combination of a MIL-STD-348 SMPM Female interface connector with a retractable threaded Nut provides unprecedented electrical and mechanical stability in even the harshest operating environments. The SMPM-T connector is space qualified and available along with Astrolab's microbend™ "Bend-To-The-End" technology. AS 9100 and ISO 9001 certified.

Astrolab,
Warren, NJ (732) 560-3800,
www.astrolab.com.

Booth 931

DIRECT MODULATION MICROWAVE
FIBER OPTIC LINKS
To 20 GHz



FEATURES:

- Low Noise Figure
- Low Signal Loss (Typ. RF Loss: 0.4 dB/km)
- Small Size And Low Power Consumption
- No External Control Circuits Required
- Variable Gain Control Option In Receiver
- Low Maintenance And Simple Installation
- Custom Configurations Available
- Backed By A 3-Year Warranty*

WIDE RANGE Of APPLICATIONS:

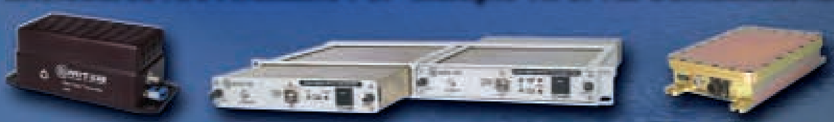
- EMC Testing · Antenna Remoting · Radio Over Fiber
- Interfacility RF Communication Link · Radio Astronomy
- Radar Applications · Aircraft And Shipboard Applications
- SATCOM Applications · Links For Satellite Ground Stations
- ELINT, EW And EMC Applications · Tactical Common Data Links

Electrical Specifications (1 Meter of Fiber)

Series	Frequency	Gain (dB)	Noise Figure (dB)	Input Power @ P1dB (dBm, Min.)	Spurious Free Dynamic Range (dB/Hz, Typ.)	Phase Noise (dBc, Typ.)	Group Delay (ns)	VSWR (In/Out)	Available Wavelengths Standard (nm)	Available Wavelengths Optional Wavelengths
Transmitters and Receivers										
SLL	5 kHz - 2.5 GHz	12	18	-14	103	>100	0.2	2:1	1550/1310	18 CWDM Ch
	100 MHz - 2.5 GHz	12	18	-14	103	>100	0.2	2:1	1550/1310	18 CWDM Ch
LBL	50 KHz - 3 GHz	15	11	-14	106	>100	0.2	2:1	1550/1310	18 CWDM Ch, 45 DWDM Ch
	50 KHz - 4.5 GHz	15	11	-14	106	>100	0.2	2:1	1550/1310	18 CWDM Ch, 45 DWDM Ch
	10 MHz - 3 GHz	15	11	-14	106	>100	0.2	2:1	1550/1310	18 CWDM Ch, 45 DWDM Ch
	10 MHz - 4.5 GHz	15	11	-14	106	>100	0.2	2:1	1550/1310	18 CWDM Ch, 45 DWDM Ch
LBL-HD	950 MHz - 2.5 GHz	0	22	7	114	>100	0.2	2:1	1550/1310	18 CWDM Ch
SCML	50 kHz - 6 GHz	15	15	-14	103	>100	0.2	2:1	1550	1310/1490 nm
	100 MHz - 6 GHz	15	15	-14	103	>100	0.2	2:1	1550	1310/1490 nm
	100 MHz -11 GHz	15	15	-14	103	>100	0.2	2:1	1550	1310/1490 nm
	100 MHz -13 GHz	15	15	-14	103	>100	0.2	2:1	1550	1310/1490 nm
	100 MHz -15 GHz	15	15	-14	103	>100	0.2	2:1	1550	1310/1490 nm
	100 MHz - 18 GHz	15	15	-14	103	>100	0.2	2:1	1550	1310/1490 nm
	10 MHz - 18 GHz	15	15	-14	103	>100	0.2	2:1	1550	1310/1490 nm
High Gain Broadband Receivers										
DR-125G-A	30 KHz -12.5 GHz	35 O/E (or TIG = 2800 ohms)						2:1		1280-1580
SCMR-100K20G	100 KHz - 20 GHz	32 O/E (or TIG = 2000 ohms)						2:1		1280-1580

CWDM: Course Wavelength Division Multiplexing, DWDM: Dense Wavelength Division Multiplexing

Enclosures Are Available For Multiple Tx or Rx Combinations



For additional information or technical support, please contact our Sales Department at (631) 439-9220 or e-mail components@miteq.com

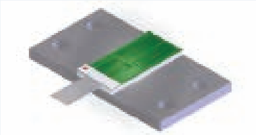
MITEQ
100 Davids Drive · Hauppauge, NY 11788
TEL.: (631) 436-7400 · FAX: (631) 436-7430
www.miteq.com

*3-year warranty applies to rack-mounted and indoor equipment

See us at MTT-S Booth 1909

New Waves

High Power Flanged Termination

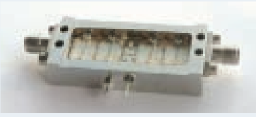


Barry Industries Inc. announced its new 1000 W high power flanged termination. This RoHS compliant 50 ohm termination has an input power rating of 1000 W, continuous wave. It offers a frequency range of DC to 1 GHz, and has an excellent input return loss of 28.5 dB, 1.10:1. For a datasheet, contact michellef@barryind.com and request part number T50R0-1000-3X. Barry also offers a full line of low and high power custom resistors, terminations and attenuators in a variety of substrate and metallization options.

Barry Industries Inc.,
Attleboro, MA (508) 226-3350,
www.barryind.com.

Booth 726

Ultra-low Noise Amplifiers



Ciao Wireless introduced its ultra-low noise amplifiers with noise figures as low as 0.30 dB. Designs are offered over most 300 MHz bandwidths between 0.5 and 2.9 GHz. Gain levels offered between 30 and 60 dB. Delivery in one to two weeks ARO with competitive pricing offered.

Ciao Wireless,
Camarillo, CA (805) 389-3224,
www.ciaowireless.com.

Booth 3609

L-band Switch Matrix System

This L-band switch matrix system is designed for demanding SATCOM ground station installations. The matrix has a base configuration of 12×48 (down-converter to modem) and is expandable to 24×192 ports. The system is configured with separate receive and transmit paths and cabinets. Each is separately controllable, covering the range of 1 to 2 GHz and providing an output IP3 of +34 dBm minimum. This system is an outstanding choice for demanding multi-carrier applications.

Crane Aerospace & Electronics,
Beverly, MA (978) 524-7200,
www.craneae.com/mw.

Booth 1822

RF Coaxial Cable Assembly

These LL335 series cable assemblies are a new addition to the company's line of low-loss RF coaxial cables. Designed to operate up to 18 GHz, the CCSMA-MM-LL335 cable assemblies boast extremely low loss, with attenuation ratings of 0.03 dB/ft at 500 MHz, and 0.20 dB/ft at 18 GHz. Crystek LL335 cables offer a minimum bend radius of 1.5 in. and are available in-stock in 36-, 48- and 60-inch lengths. The cables are supplied with high frequency SMA or N-Type connectors, featuring rugged stainless-steel solder-clamp construction and heavy-duty strain relief with a neoprene jacket.

Crystek Corp.,
Fort Myers, FL (239) 561-3311,
www.crystek.com.

Booth 325

6 to 18 GHz Power Amplifier

CTT announced a new, compact, solid-state power amplifier (SSPA) that operates in a frequency range from 6 to 18 GHz for a wide variety of RF and microwave applications. This amplifier design provides good efficiency, high operating temperature range and small size. CTT's latest compact SSPA is a GaN-based MMIC design that offers 40 W of output power in a compact package. Additional specifications include a minimum of +46 dB of gain, maximum, gain flatness of ±2.5 dB and noise figure of 8.0 dB. Power saturation (Psat) performance is +44.5 dBm, minimum and +46.0 dBm, typical. The compact package measures 4.14" × 3.0" × 0.68".

CTT Inc.,
Sunnyvale, CA (408) 541-0596,
www.cttinc.com.

Booth 2302

6 to 18 GHz Low Noise Amplifier

Custom MMIC Design Services announced the release of the CMD157, a 6 to 18 GHz low noise PHEMT amplifier in a plastic encapsulated, 3 mm QFN package. The CMD157 has a gain of 27 dB, a noise figure of 1.5 dB and a bias requirement of 53 mA at 3 V. With applications including microwave communication and phased array systems, the CMD157 offers exceptional performance. The CMD157 is part of a broad line of plastic encapsulated amplifiers being introduced by CMDS this month.

Custom MMIC Design Services Inc.,
Westford, MA (978) 467-4290,
www.custommmic.com.

Booth 650

Full-band Amplifiers

Ducommun RF Product Group has released a new line of full-band amplifier products. These full-band amplifiers will cover the frequency ranges starting at Ka-band up to W-band amplifiers. These full-band amplifiers will be available in three configurations: high power, low noise and general purpose. Features include: broadband performance across entire band; compact size and weight; single DC power supply/internal regulated sequential biasing and variable I/O options.

Ducommun Technologies Inc.,
Carson, CA (310) 513-7256,
www.ducommun.com.

Booth 404

Connectorized Clock Oscillators

The PLXO series of phase-locked crystal oscillators are designed to operate at select custom frequencies from 5 to 500 MHz as reference clocks in military and commercial RF/microwave systems. Locked to an external frequency reference (or optional internal reference), the PLXO units feature low RMS jitter (< 0.05 pSec, typical), excellent phase noise (Fout = 233 MHz, < -120 dBc/Hz at 1 KHz, typical) and low power consumption at +3.3, +5, +8 or +12 V DC. Housed in a miniature connectorized package (1.50" × 1.50" × 0.6") to withstand harsh environments, the PLXO units also feature no sub-harmonics and operate over an optional wide temperature range (-40° to +85°C).

EM Research Inc.,
Reno, NV
(775) 345-2411,
www.emresearch.com.

Booth 1149

65:1 VSWR Power Transistors

VENDORVIEW

Freescale and Richardson RFPD have partnered to build a microsite dedicated to the new Freescale 50 V LDMOS rugged RF transistors. These transistors are able to withstand a 65:1 VSWR mismatch and continue to deliver full output power of 1.25 kW, 600 W and 300 W, respectively. Due to the number of customers redesigning circuits, Richardson RFPD and Freescale Semiconductor partnered to create this one-stop shop for RF design engineers.

Freescale,
www.rell.com/RuggedLDMOS.

Booth 1028

Microwave Power Amplifiers

Giga-tronics has introduced the GT-1020A and GT-1040A instrument-grade broadband microwave power amplifiers that cover 100 MHz to 20 GHz and 10 MHz to 40 GHz respectively, with flat frequency response, low noise figure and low harmonics. Designed using broadband MMIC technology, these amplifiers typically provide ½ W (+27 dBm) at 20 GHz and ¼ W (+24 dBm) at 40 GHz with > 25 dB gain and < 6 dB noise figure. Gain flatness is typically ±2.5 dB over the full frequency range.

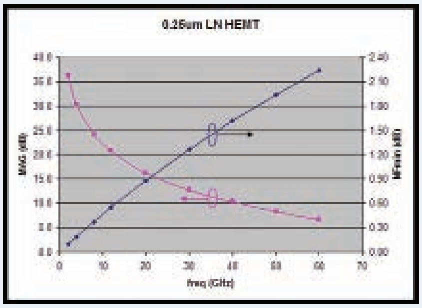
Giga-tronics Inc.,
San Ramon, CA
(925) 328-4650,
www.gigatronics.com.

Booth 1409

New Waves

Low Noise PHEMT

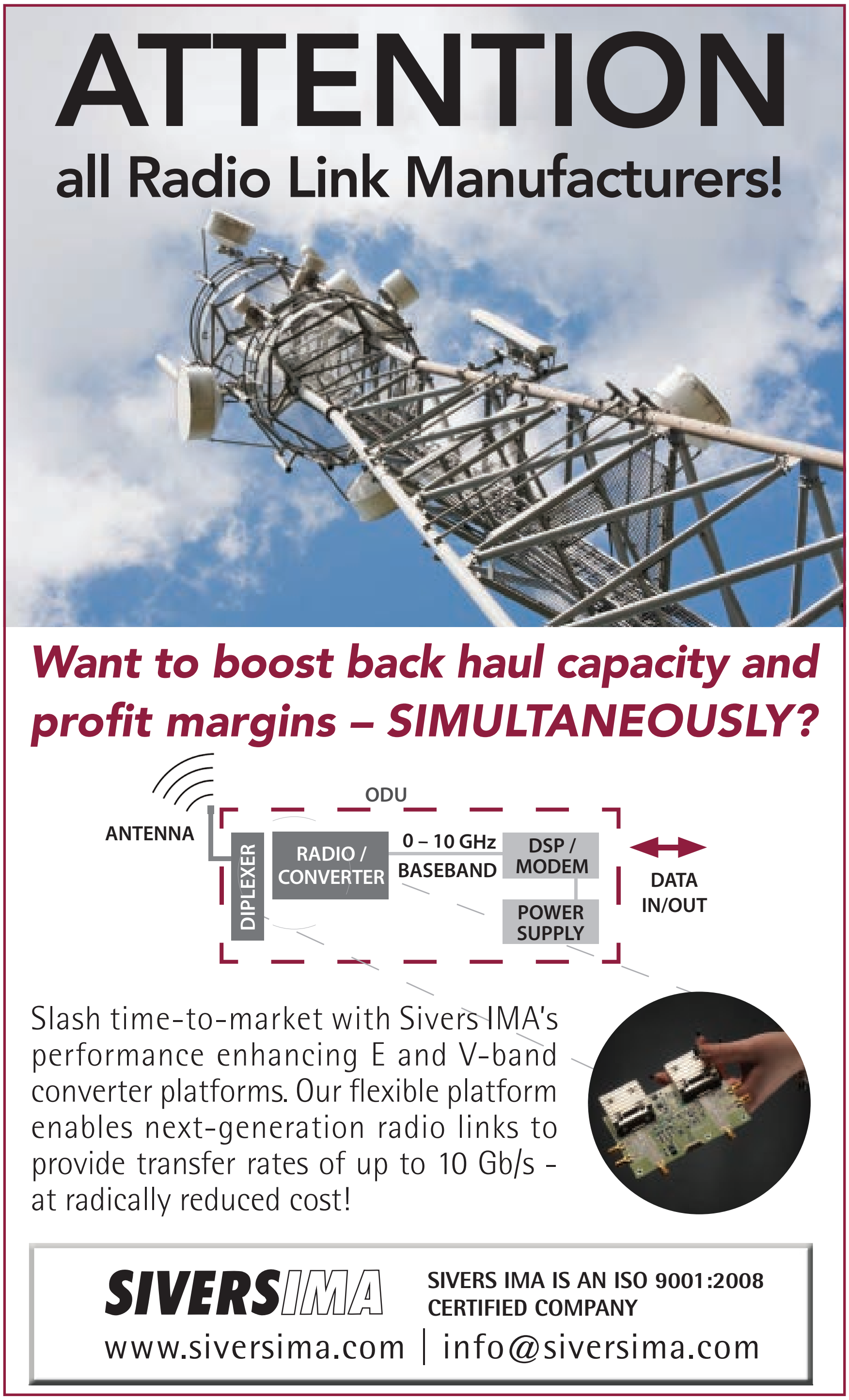
GCS has developed a low noise PHEMT technology with an optical 0.25 μm gate, $f_T > 80$ GHz and $f_{max} > 150$ GHz. The technology achieves a noise figure minimum of < 0.6 dB with a gain > 15 dB at 12 GHz. A 6 to 18 GHz balanced LNA fabricated with this technology has shown better noise and gain performance than NEC33200. This process is fully qualified with a MTTF > 8×10^7 hours at channel



temperature = 125°C. GCS is offering this process to all foundry customers.

Global Communication Semiconductors LLC, Torrance, CA (310) 530-7274, www.gcsincorp.com.

Booth 2504



Broadband Conical Inductors

These new conical inductors respond to market demand for more standard and custom conical design options for microwave applications. Gowanda's "C" series includes standard flying lead and SMT designs with up to 150 W power capability, excellent coplanarity, robust construction and typical operation from 40 MHz to 40 GHz. The company's custom capabilities – already well-established for Gowanda's RF and power inductors – have been enhanced to provide conicals with application-specific core configurations, electrical parameters, footprints, frequencies, wattage and wiring options (copper, gold plate, specialty).

Gowanda Electronics, Gowanda, NY (716) 532-2234, www.gowanda.com.

Booth 730

Analog-to-Digital Converter

VENDORVIEW

Hittite Microwave Corp. has introduced a new high speed analog-to-digital converter (ADC) product line. Hittite's multi-funtion ADC products are easy-to-use, exhibit ultra-low power dissipation and superior cost efficiency while maintaining high performance and complementing Hittite's existing RF, microwave and mixed-signal IC product lines. The new ADC product line significantly expands Hittite's product offering in communications, test & measurement, military, industrial and medical applications.

Hittite Microwave Corp., Chelmsford, MA (978) 250-3343, www.hittite.com.

Booth 2009

Phase Noise Analyzers

Holzworth Instrumentation will showcase the HA7000 series phase noise analyzers at IMS 2011. The advanced cross correlation engine delivers fast data acquisition speeds to low levels (example: -180 dBc/Hz < 20 sec). Holzworth's self-calibrating, integrated architecture makes for quick setups while eliminating the need for on-site troubleshooting support. These designs offer a highly intuitive interface, coupled with price points that truly support ease of implementation. The HA7400 series analyzers deliver on what's expected of the industry's next generation test instruments.

Holzworth Instrumentation, Boulder, CO (303) 325-3473, www.holzworth.com.

Booth 2419

High Performance Interconnects

HSI LLC designs and manufactures high performance interconnects for use by OEMs in

NEW WAVES

Mil-Aero, instrumentation, industrial, medical and other industries. HSI specializes in microwave cable assemblies to 70 GHz as well as micro-miniature coaxial structures as small as 50 awg. HSI has over 150 man-years in experience with these products/industries. Current customers include leading OEMs in military communications systems, UAVs, test instrumentation and other critical, leading-edge apps. The company provides solutions to OEMs demanding mechanical/electrical/environmental requirements, including superior signal integrity and low weight, high density packaging.

High Speed Interconnections LLC (HSI), Scottsdale, AZ (888) 565-7878.

Booth 340

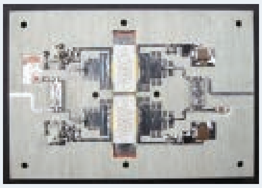
RF Probe with Integrated Attenuator

The HFS-835: RF probe with integrated attenuator is especially suitable for assembly in test fixtures with space restrictions or to prevent shearing forces to the probe, which can occur when an externally connected attenuator is directly connected with the input interface of a conventional RF probe. It is available with nominal attenuation values of: 3, 6, 10 and 20 dB. It is designed for use up to 3 GHz at an impedance of 50 Ω and its flange design allows easy integration with a fixture or mounting.

INGUN Prüfmittelbau GmbH, Konstanz, Germany +49 7531 8105-0, www.ingun.de.

Booth 3804

Radar Pallet Amplifier

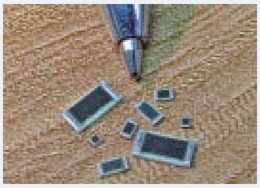


Integra Technologies announced an S-band radar pallet that will significantly reduce cycle time in your next high powered design. Part number ILP2731M260 is a 50 ohm matched high power pulsed radar pallet amplifier for S-band radar systems produced for drop-in manufacturability. The pallet amplifier supplies a minimum of 260 W of peak pulse power under the conditions of 300 us pulse width and 10 percent duty cycle operating over the instantaneous bandwidth of 2.70 to 3.10 GHz. The unit operates in class AB mode with 32 V drain bias optimizing the gain and efficiency parameters.

Integra Technologies Inc., El Segundo, CA (310) 606-0855, www.integratech.com.

Booth 4015

Surface-mount Chip Resistors



The HVI series of chip resistors is especially suited for high voltage applications. The HVI series is offered in sizes 0402 to 2512, values to 1 Gohm and tolerances to 1 percent. These resistors feature a nickel barrier layer for excellent solder leach resistance and proprietary thick film architecture allowing the 2512 size to withstand a continuous 3 kV and overload of 4 kV. Applications for the HVI series high voltage chip resistors include but are not limited to power supplies, power converters, defibrillators, sensors, detectors, pacemakers and power meters. Samples are available.

International Manufacturing Services Inc., Portsmouth, RI (401) 683-9700, www.ims-resistors.com.

Booth 2106

Phase-locked Outdoor Block Converters

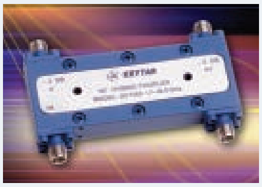
Jersey Microwave's KABUC-ODU series is offered in Ka-bands up to 1500 MHz bandwidth. Standard or custom specifications are available. IF from 950 to 2450 MHz, RF band segments up to 38 GHz. Typical performance includes 5 to 20 dB gain with

NEW WAVES

< 1.0 dB flatness over the RF frequency band, ±0.2 dB over any 40 MHz segment. Low spurious and superior phase noise performance. Internal or external reference is available. Remote M&C functionality.
Jersey Microwave LLC,
Flanders, NJ (908) 684-2390, www.jerseymicrowave.com.

Booth 630

Quadrature Hybrid Coupler



This 90 degree quadrature hybrid coupler offers high performance over the broadband frequency range of 1.7 to 36 GHz in a single compact and lightweight package. Model 3017360 is a multi-purpose, quadrature hybrid stripline design that exhibits excellent amplitude balance with ultra-broadband quadrature phasing between the output ports. KRYTAR's technological advances has extended the frequency range of this four-port unit from 1.7 to 36 GHz with coupling loss of 3 dB, greater than 12 dB isolation, ±1.7 dB amplitude imbalance and ±12 degrees of phase imbalance. Size: 2.6" (L) × 0.625" (W) × 0.50" (H).
KRYTAR Inc.,
Sunnyvale, CA (408) 734-5999, www.krytar.com.

Booth 1712

Microwave Power Modules

These microwave power modules (MPM) are designed for Ku- and Ka-band communication applications. The new modules are geared for use in airborne, naval or ground communication applications and are specifically designed in a weight-balanced, split-package configuration intended for direct antenna mounts. Available in either Ku- or Ka-band configurations, L-3's new MPM designs significantly reduce conventional RF system losses, enhancing overall efficiency while also improving problematic pointing and position stabilization issues. At just 1.1 inches high, this compact two-piece set weighs in at a balanced 5.2 pounds and is MIL-STD-461E compliant.
L-3 Electron Devices,
San Carlos, CA (650) 486-5594,
www.l-3com.com.

Booth 502, 602

Hall Effect Measurement System

Lake Shore Cryotronics Inc., in collaboration with Toyo Corp. of Japan, introduced the new 8400 series Hall effect measurement system (HMS). Available in September 2011, the 8400 series HMS with optional AC field measurement capability allows you to measure hall mobilities down to 0.001 cm²/Vs—lower than ever possible using traditional DC field Hall measurement techniques.
Lake Shore Cryotronics Inc.,
Westerville, OH (614) 891-2244,
www.lakeshore.com.

Booth 3603

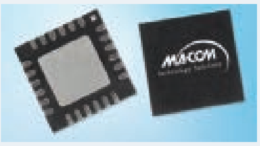
Circuit Board Prototyping

LPKF Laser & Electronics continues its efforts in circuit board prototyping with the redesign of the ProtoMat® S-Series. Each system features improved functions, a higher level of automation and upgrade options. The entry-level ProtoMat S43 is a milling machine that provides a great introduction into the world of professional rapid PCB prototyping. For those with an occasional use and/or limited budget, the ProtoMat S43 has the precision and capacity for drilling, depaneling and structuring printed circuit boards and engraving front panels. It comes equipped with a 40,000 RPM spindle motor, a working area of 9" × 12", and has the ability to produce multiple design iterations in the same day.
LPKF Laser and Electronics,
Tualatin, OR (503) 454-4232,
www.lpkfusa.com.

Booth 2202

Six-bit Digital Attenuator

VENDORVIEW



M/A-COM Technology Solutions Inc. introduced the MAAD-008866, a six-bit, 0.5 dB step digital attenuator for 75 Ohm systems operating up to 1 GHz. This attenuator is ideal when high accuracy, low power consumption (4 microAmps typical at 5 V, steady state) and low intermodulation products are required. The MAAD-008866 includes an integrated TTL/CMOS compatible driver and offers parallel and serial control with a power-up state function. The device achieves an insertion loss of 1.4 dB with a typical input return loss of 18 dB from 5 to 1,000 MHz. Attenuation accuracy is plus/minus 0.15 dB plus 4 percent of attenuation setting.
M/A-COM Technology Solutions,
Lowell, MA (978) 656-2500,
www.macomtech.com.

Booth 1418

Harmonic Load Pull Solutions

Maury Microwave Corp. will showcase two state-of-the-art active and hybrid-active harmonic load-pull solutions: VNA-based vector-receiver load-pull and mixed-signal active load-pull. The vector-receiver system is based upon Maury's IVCAD measurement and modeling device characterization software and its single-, double- and triple-frequency tuning solutions. The MT2000 series turnkey mixed-signal system stands alone

New Waves

in offering wideband impedance control for modulated PAs. In addition, Maury will showcase its pulsed IV, pulsed S-parameter and noise parameter measurement solutions.

Maury Microwave Corp.,
Ontario, CA (909) 987-4715,
www.maurymw.com.

Booth 1016

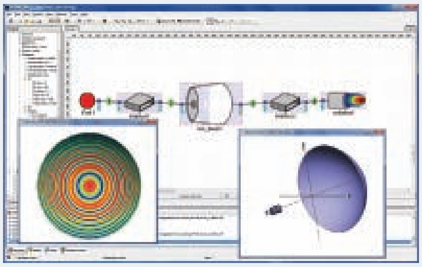
EZ-Mate Connectors

MegaPhase's EZ-Mate™ connectors assist in making quick and reliable connections without finger wear. Engineering personnel who connect and disconnect cables tens and hundreds of times in a day can now easily connect using the MegaPhase EZ-Mate. To assure connectors can be easily and reliably mated, MegaPhase has designed and now offers EZ-Mate Type N, TNC and SMA connectors. Engineers can easily manipulate the half knurled, half hex shaped stainless steel connector. EZ-Mate's benefits are particularly critical when working in tight spaces. The unique design of the EZ-Mate also allows test professionals the option to use a torque wrench in lieu of easy finger operation.

MegaPhase LLC,
Stroudsburg, PA (570) 424-8400,
www.megaphase.com.

Booth 4202

Analysis and Optimization Tool



μWave Wizard™'s radiation module now includes a reflector antenna analysis and optimization tool. The incident EM-field on the reflector is calculated by using the spherical wave expansion of the radiated horn antenna field. The calculation of the farfield of basic reflectors such as parabol, hyperbol and ellipsoid is being perfomed by physical optics approximation. The radiated reflector field is also available as spherical-wave-expansion, which can be applied as a feeding system in other reflectors. The definition of the reflector geometry is completed by just a few parameters and includes an automatic mesh generation. Any optimization of the antenna performance parameters including the reflector is supported.

Mician GmbH,
Bremen, Germany
+49 421 168 993 56,
www.mician.com.

Booth 740

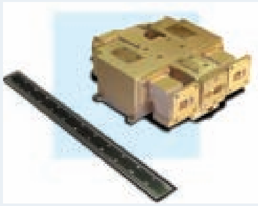
Ka-band SATCOM Preamplifier

Microsemi RF Integrated Solutions has a new addition to its JCA Amplifier™ product line, specifically targeted for SATCOM applications. The MSC2931-50-15 is a preamplifier with gain flatness of ±0.5 dB and up to 50 dB of gain over the 29.5 to 31.0 GHz frequency range. Variable attenuators can be added to optimize gain and phase expansion for your application. The amplifier is designed to operate over the full military temperature range of -40° to 85°C and has a P1dB of 15 dBm minimum. Current, for a typical two attenuator configuration, is 750 mA from a single DC supply of +12 V. The amplifier is supplied with field replaceable K-type connectors and is RoHS compliant.

Microsemi Corp.,
Irvine, CA (800) 713-4113,
www.microsemi.com.

Booth 722

High Isolation Waveguide Switch



This X-band high isolation waveguide switch cascades MAG's successful single element switch, providing high isolation (> 50 dB), and handling moderate peak (50 kW) and average (200 W) power in a compact, economical construction. This switch provides 1 dB nominal insertion loss over a bandwidth in excess of 10 percent. Tandem rotators operate in opposition or summation, driving the horizontal or vertical arm of an orthomode transducer, providing 25 microsecond switching time. MAG is also developing this architecture at other frequency bands.

Microwave Applications Group (MAG),
Santa Maria, CA (805) 928-5711,
www.magsmx.com.

Booth 326

RF Frequency Counter

VENDORVIEW

Mini-Circuits' UFC-6000 (RoHS compliant) is a small, light weight frequency counter operating over the frequency range 1 to 6000 MHz. The counter is cased in a rugged shielded case (size: 6.16" × 3.68" × 1.38") with a 16×2 character LCD screen, a reference input BNC(F) port and a signal input SMA(F) port. Using the USB interface allows remote display of measured frequencies, and eliminates the need for an additional power supply. The counter can also operate independently using an external power supply. The UFC-6000 is supplied along with a software CD containing a graphical user interface program featuring an API DLL com object. Also included are a 2.7 ft. USB cable and a power adaptor suitable for both US and EU power systems with a USB A female connector. Price: $495.00 (Qty. 1-4).

Mini-Circuits,

Brooklyn, NY (718) 934-4500,
www.minicircuits.com.

Booth 1031

X-Parameter Modeling Services

Modelithics now offers its customers nonlinear X-parameter measurement and modeling services. This state-of-the-art technology is enabled through use of Agilent Technologies' PNA-X series nonlinear vector network analyzer (NVNA) and provides circuit board designers with mathematically correct extensions of S-parameters for large-signal conditions for devices such as amplifiers, mixers and RFIC/MMIC functional blocks. Additionally, this technology characterizes the amplitudes and relative phase of harmonics, characterizes impedance mismatches, and can be applied to transistor modeling as an alternative to traditional compact equivalent modeling.

Modelithics Inc.,
Tampa, FL (813) 866-6335,
www.modelithics.com.

Booth 713

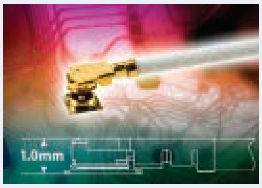
DIN Valve Connectors

Molex Inc. has released the next generation of Brad® mPm® DIN valve connectors featuring the addition of Form C and Form Micro housings. Combining IP67 sealing properties with an external-thread design, the mPm DIN valve connector range provides superior cable retention for increased performance and reliability. mPm DIN valve connectors simplify the manufacturing process and reduce overall applied costs for hydraulic, pneumatic and electromagnetic drive systems. The external nut on the Molex mPm DIN valve connector provides greater and consistent torque, which ensures cable retention and high reliability.

Molex Inc.,
Lisle, IL (800) 786-6539
www.molex.com.

Booth 2102

RF Micro Coaxial Connectors



The JSC series of low profile RF micro coaxial connectors offer a maximum profile of just 1.0 mm, making it ideal for high-tech wireless products. The low profile is possible through advanced manufacturing techniques used for both the board mounted connector and the micro coaxial cable. The JSC series comprises of board mounted receptacle (MM5829-2700) that mates with a RF cable (MXJA01xxxxxx) that has a diameter of 0.81 mm. The receptacle measures 2 × 1.8 × 0.5 mm and the mated height of both the receptacle and cable plug is 1.0 mm maximum. The part is designed to withstand up to 30 mating cycles and emits an audible click on connecting. The connector and cable structure is optimized to ensure excellent RF performance up to 12 GHz.

Murata Electronics North America,
Smyrna, GA (800) 241-6574,
www.murata-northamerica.com.

Booth 1607

IMA Technology

VENDORVIEW

This integrated microwave assembly (IMA) product uses the company's new proprietary microwave multi-layer circuits (MMC) technology with digital signal processing. These IMA products allow for extremely compact, densely populated modules, consistent with SWaP goals. Embedded microprocessors and FPGA devices make possible adaptive adjustments that compensate for system dynamics and environmental extremes. Narda's IMA products are offered in frequency ranges from DC to 60 GHz for applications in EW, MILSATCOM, radar, missile, UAV and related markets. In addition, IMA products and capabilities from its San Diego Tech Center have been added to the Narda portfolio and will be on display as well.

Narda Microwave - East,
an L-3 Communications Co.,
Hauppauge, NY
(631) 231-1700,
www.nardamicrowave.com.

Booth 502, 602

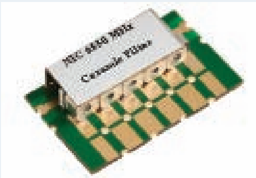
2016 Size TCXO

This TCXO offers two outputs of the same reference clock frequency. The need for a TCXO that can provide reference clock signal to both of the two functions has increased amidst the ambivalent two needs: miniaturization and multifunction. In order to meet these market needs, NDK has developed a TCXO with two outputs of the same frequency. This TCXO can provide reference clock signal to both of the two functions via independent outputs. Its enable/disable function offers more efficient power management, leading to lower power consumption. This TCXO alone can provide the reference clock signal to both of the two functions. This will help downsize the circuit boards in mobile information terminals. Size: 2.0 × 1.6 × 0.7 mm.

NDK America Inc.,
Belvidere, IL (815) 544-7900,
www.ndk.com.

Booth 710

6550 MHz Ceramic Filter



NIC's 6550 MHz ceramic filter is a high frequency ceramic filter built for use in C-band applications. The features include low insertion loss of < 2.5 dB at center frequency, rejection of > 50 dB at 6000 MHz and > 40 dB at 7200 MHz, built in a small package size of 0.83" × 0.51" × 0.19". Custom designs are available up to C-band.

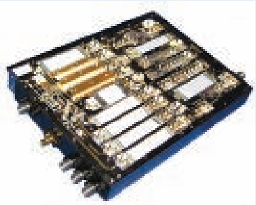
Networks International Corp.,
Overland Park, KS
(913) 685-3400,
www.nickc.com.

Booth 733

NEW WAVES

0.5 to 18 GHz ELINT Receiver

VENDORVIEW



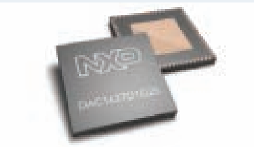
Norden Millimeter has developed a 0.5 to 18 GHz ELINT receiver with a proprietary frequency plan to reduce unwanted spurious. This receiver features an RF frequency range of 0.5 to 18 GHz; IF frequency of 1 GHz ±200 MHz; conversion gain of 8.75 to 12.75 dB; noise figure of 14.5 dB maximum; image rejection of 80 dBc; LO re-radiation at RF port of -90 dBm maximum; mixer spurs and harmonics of 60 dBc with 50 percent of input band and 50 dBc at 100 percent of input band.

Norden Millimeter Inc.,
Placerville, CA (530) 642-9123,
www.nordengroup.com.

Booth 635

Digital-to-analog Converters

NXP Semiconductors has recently introduced the DAC1627D1G25, a high-speed 16-bit dual channel digital-to-analog converter (DAC) with selectable 2×, 4× and 8× interpolating filters optimized for multi-carrier and broadband wireless transmitters at sample rate up to 1.25 Gsps. Supplied from a 3.3 V and a 1.8 V source, the DAC1627D1G25 integrates a differential scalable output current up to 30 mA. Digital on-chip modulation up-converts the complex I and Q inputs from baseband to IF. The mixer frequency is set by a high resolution 40 bit numerically controlled oscillator (NCO). High resolution internal gain, phase and offset control provide outstanding image and LO rejection at the system analog modulator output.



NXP Semiconductors,
High Speed Converters,
San Jose, CA, www.nxp.com.

Booth 420

2.45 GHz ISM Band Market

The growing popularity of the 2.45 GHz ISM band requires an optimized set of RF power products. NXP meets this need with a family of products running on a 28 V supply and delivers 10 to 140 W of power. The BLF2425ML(S)-140 is the most powerful device with 140 W and a gain of 17 dB and 52 percent efficiency.

NXP Semiconductors, RF Power,
San Jose, CA,
www.nxp.com.

Booth 420

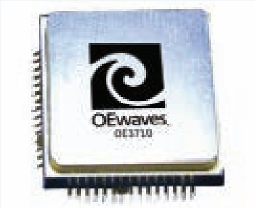
Ku-band Downconverters

The TFF101xHN is a family of Ku-band downconverters that includes an integrated mixer, PLL/VCO and IF gain stage, all within a leadless 16-pin package. The devices operate from 10.7 to 12.75 GHz and require only seven external passive components, including the 25 MHz crystal. The downconverters are completely RF tested devices and achieve OIP3 of 13 dBm at only 54 mA, conversion gain up to 45 dB, and excellent integrated phase noise of less than 1.8° RMS.

NXP Semiconductors,
RF Small Signal, San Jose, CA,
www.nxp.com.

Booth 420

Opto-electronic Oscillator



OEwaves Inc. has achieved unprecedented phase noise performance in a microchip package based on proprietary ultra-high quality factor (Q) crystalline optical resonators and the opto-electronic oscillator architecture. Capable of microwave frequencies beyond 100 GHz, such high performance microwave photonic oscillator chip revolutionizes communication system performances required by the next generation military/defense and commercial microwave applications. With significantly lower phase noise/jitter than conventional oscillator technology in comparable form factor, the system's spectral purity can be significantly improved without compromising size weight and power (SWaP).

OEwaves Inc.,
Pasadena, CA (626) 449-5000,
www.oewaves.com.

Booth 324

Four-way Power Divider

This model is a Wilkinson type four-way power divider that operates in a frequency range suited for communication satellite system and other Ku-band projects. The low price, compact designed divider has SMA-jack connectors. This power divider offers dimensions of 54 × 38.2 × 13.5 mm (excluding connectors). The four-way power divider operates in a frequency range from 12 to 15 GHz, VSWR of < 1.5, loss of < 0.60 dB and isolation of < 20 dB. Other custom designed dividers can be provided upon request.

Orient Microwave Corp.,
Shiga, Japan +81-749-45-8121,
www.orient-microwave.com.

Booth 1732

18 GHz Coaxial Adapters

P1dB introduces precision stainless steel SMA to SMA ($9.95 each) and N to SMA ($13.95 each) 18 GHz coaxial adapters for the most demanding test bench and production test applications. The SMA adapters are available in Male to Male, Female to Female and Male to Female with maximum VSWR of 1.20:1 at 18 GHz. The N to SMA adapters are available in Male to Male, Female to Female and Male to Female with maximum VSWR of 1.25:1 at 18 GHz.

P1dB Exclusive Stocking Distributor,
RFMW Ltd., San Jose, CA (408) 414-1450,
www.rfmw.com.

Booth 2507

Hi Q/Low ESR Capacitors

Passive Plus Inc. now offers an extended working voltage capability for the company's core Hi Q/low ESR capacitor line. Available in six case sizes: 0.055" × 0.055" extended up to 300 W VDC; 0.110" × 0.110" extended up to 1,500 W VDC; 0.220" × 0.250" extended up to 5,000 W VDC; 0.380" × 0.380" extended up to 7,200 W VDC; 0.600" × 0.400" extended up to 8,000 W VDC; and 0.760" × 0.760" extended up to 10,000 W VDC. All product lines are available in P90 or NPO dielectrics with a variety of terminations and lead styles. All products are also available in non-magnetic termination styles. Delivery: stock to two weeks.

Passive Plus Inc.,
Huntington Station, NY
(631) 425-0938,
www.passiveplus.com.

Booth 2404

Digitally Tunable Capacitors

Peregrine's PE64904 (SPI) and PE64905 (I^2C) DTCs are solid-state, digitally-controlled variable capacitors targeting 100 MHz to 3 GHz. These unprecedented UltraCMOS™ RFICs enable frequency agile tunable matching networks, increasing radiated power and improving antenna performance. Utilizing DuNE digitally tunable capacitors (DTC), monolithic tunable filters can also replace antiquated switchable filter banks, reducing radio complexity and cost. Featuring capacitance of 1.05 to 5.1 pF; 131 fF step size; Q~40 for lowest Cap state at high frequency; 2 kV HBM ESD; fast 10 µs switching time and low-power operation.

Peregrine Semiconductor Corp.,
San Diego, CA
ww(858) 731-9400,
http://dtc.psemi.com.

Booth 1626

Phase-locked Oscillator

The PLS-11600-P100I is a high performance, low noise, 11.6 GHz phase-locked oscillator (PLO) with a 100 MHz OCXO internal reference. The design of this PLO's primary source consists of a low-noise, fundamental bipolar-silicon-transistor oscillator. In addition, a buffer amplifier in the output path provides the desired power output and load isolation. Power output is 13 dBm minimum into a 50 ohm load. Phase noise at 10 kHz and 100 kHz offsets is typically

New Waves

better than -117 dBc/Hz. The PLS-11600-P100I is housed in a compact (2.25" × 2.25" × 0.92") connectorized package.
Phase Matrix Inc.,
San Jose, CA (408) 428-1000,
www.phasematrix.com.
Booth 4418

Detector Log Video Amplifier

VENDORVIEW

PMI model SDLVA-218-71-70MV is a CW immune, extended range detection log video amplifier (ERDLVA) that offers 71 dB dynamic range over the frequency range of 2 to 18 GHz.

This model offers a maximum rise time of 35 nsec and a recovery time of less than 350 nsec. CW immunity is provided for signal levels up to -40 dBm. The unit is temperature compensated such that log linearity over temperature remains less than ±1.5 dB over the full operating temperature range of -20° to +85°C. This model is supplied in a compact housing measuring only 3.5" × 2.5" × 0.5". Optional frequency ranges covering 100 MHz to 26.5 GHz are available.
Planar Monolithics Industries Inc.,
Frederick, MD (301) 662-5019,
www.pmi-rf.com.
Booth 2304

Precision Connectors

This line of precision connectors is designed exclusively for Dynawave Cable's Dynaflex DF218, DF118 and DF126 cable. Both straight and right angle Male connectors are offered for SMA (18/26 GHz), TNCA (18 GHz) and Type N (18 GHz) series. The connectors feature solder/clamp terminations and fully captive soldered center contacts for better connector retention. Female connectors are also available in straight and bulkhead configurations. These connectors are designed for minimum VSWR and insertion loss over the specified frequency range.
Precision Connector Inc.,
Franklin, IN (317) 346-0029,
www.precisionconnector.com.
Booth 4818

Solid-state Power Amplifiers

QuinStar has developed millimeter-wave high power solid-state power amplifiers covering 25 to 100 GHz with unprecedented power output. Standard and customized models are offered for applications from instrumentation to space systems. Output power

for standardized amplifiers ranges from 25 W at 35 GHz to 2 W at 94 GHz. Application-specific amplifiers with higher power, unique performance and environmental or mechanical requirements could be offered at economical prices and short lead-time.
QuinStar Technology Inc.,
Torrance, CA (310) 320-1111,
www.quinstar.com.
Booth 310

Small Form Factor Filters

VENDORVIEW

Reactel will feature a line of small form factor filters that are suitable for densely populated boards, portable systems or any application where size is at a premium. These tiny units are available in discrete component, ceramic, cavity or combline designs. With profiles as low as 1/8" these robust units pack all of the performance of their larger counterparts into a much smaller package. They are available across a frequency range of 100 MHz to 20 GHz with bandwidths of 5 to 100 percent and are available in 4-12 sections.
Reactel Inc.,
Gaithersburg, MD (301) 519-3660,
www.reactel.com.
Booth 3915

Coupler Cable

VENDORVIEW

Response Microwave announced the availability of its new drop-in or connectorized hybrid couplers suitable for use as a directional coupler or 90° quadrature hybrid. The new RMCL series offers average power handling options between 60 and 1400 W average and nominal coupling options from 2.8 through 52 dB. Typical electrical performance includes insertion loss of 0.3 dB, VSWR of 1.20:1 and isolation of 20 dB. Units can be cascaded to obtain broadband widths and are ideal for use in military power amplifier combine/divide stages or antenna feed networks.
Response Microwave Inc.,
Devens, MA (978) 772-3767,
www.responsemicrowave.com.
Booth 4414

SMA Test Grade Adapters

These precision SMA test grade adapters feature passivated stainless steel construction for long life in environments where repetitive attachment to test equipment is required. All adapters are designed for outstanding electrical performance with low loss and low VSWR to 18 GHz. Test grade adapters are rugged and versatile for use in lab or field applications.

RF Precision Products,
Division of RF Industries, San Diego, CA
(858) 549-6340,
www.rfp2.com.
Booth 4615

Discrete Matched Power Amplifier

The RF3928 is a 50 V, 280 W discrete matched power amplifier for S-band pulsed radar, air traffic control and surveillance, and general purpose amplifier applications. Using an advanced GaN semiconductor process, this high performance transistor achieves > 50 percent efficiency and 10 dB gain covering broadband 2.8 to 3.4 GHz. RF3928 comes in a hermetic flanged ceramic package with excellent thermal stability via advanced heat sink and power dissipation technologies. Optimized matching networks provide wideband gain and power performance in a single amplifier.
RFMD,
Greensboro, NC (336) 664-1233,
www.rfmd.com.
Booth 1402

Adjustable Delay Line Phase Shifter

RLC Electronics' manually adjustable delay line (phase shifter) offers continuous adjustment of electrical delay over the frequency range from DC to 40 GHz. Adjustment is through a multi-turn, locking shaft. Low insertion loss and VSWR are maintained throughout the adjustment range. The unit comes with a choice of male or female 2.92 mm connectors. Specifications include: insertion loss of 2.5 dB maximum; VSWR of 2.0:1 maximum; delay adjustment range of 56 picoseconds minimum; and phase shift range of 20 degrees/GHz minimum.
RLC Electronics Inc.,
Mount Kisco, NY (914) 241-1334,
www.rlcelectronics.com.
Booth 739

RT/duroid 6035HTC

VENDORVIEW

RT/duroid® 6035HTC laminates exhibit outstanding thermal conductivity of 1.44 W/mK and a low loss tangent of 0.0013 at 10 GHz, for excellent high frequency performance. The high thermal conductivity and low loss of RT/duroid 6035HTC result in exceptional heat transfer away from high power devices for improved circuit and device reliability. These laminates are fabricated with thermally stable, reverse-treated and electrodeposited copper foils. These low-profile copper foils help minimize conductor losses in high frequency circuits, with the thermal stability needed for high reliability in high temperature

Official Guide 2011 IEEE MTT-S International Microwave Symposium MicroApps Program

The MicroApps Program features practical application papers describing state-of-the-art products and processes of interest to the microwave community. MicroApps will receive a free CD/DVD presentation, sponsored by Agilent Technologies

IMS2011 MicroApps Keynote Address
What Makes Successful Mergers?
Wednesday, 8 June 2011
17:00-18:00
Baltimore Convention Center, MicroApps Theater, Booth #413

Keynote Speaker: John Ocampo, M/A-COM Technology Solutions

Abstract: Is it good for your customers? Is it good for your shareholders? If the response is not a resounding yes to both, then it's not going to be a good one.
Even after it passes the first screen, a number of challenges remain. Are the cultures similar or radically different? Can key employees be retained? Will business partners embrace the combined entity, or will it cause friction? The list goes on and on, and if you are lucky, it will still take many years to reach a verdict.
M/A-COM Technology Solutions (MTS) and Mimix Broadband merged in May 2010. Although it is still early to declare victory, signs point to a successful merger. Mimix bookings and revenue have more than doubled since the merger. Mimix brought an important technology that MTS needed. Conversely, MTS had the brand, sales channels, and infrastructure to support new products that Mimix lacked.
Until Apple comes up with a crystal ball (iBall, you heard it here first), we're sticking with a few hard and fast rules to screen M&A opportunities that we are happy to share.

Biography: John Ocampo is Chairman of the Board at M/A-COM Technology Solutions, Inc. He is also a co-founder and President of Gaas Labs. Prior to creating Gaas Labs, John co-founded Sirenza Microdevices, Inc.

(Nasdaq: SMDI), a supplier of radio frequency semiconductors and related components for the commercial communications, consumer and aerospace, defense and homeland security equipment markets. While leading Sirenza through a successful IPO and eventual sale to RF Micro Devices, Inc. (Nasdaq: RFMD), John served at various times in a number of key roles, including President and CEO, CTO and Chairman. Prior to co-founding Sirenza, John served as General Manager at Magnum Microwave, an RF component manufacturer, and as Engineering Manager at Avantek, a telecommunications engineering company later acquired by Hewlett-Packard. John holds a B.S.E.E. from Santa Clara University.

	TUESDAY	WEDNESDAY	THURSDAY
0910			System-Level Simulation in the Design of Advanced Radar Systems Joel Kirshman, *AWR*
0930	Prediction of RF Breakdown in Combline Filters with FEST3D F. J. Pérez, J. Gil, C. Vicente, V. E. Boria, *Aurorasat*	Fast and Accurate CAD Solutions for Passive Waveguide Components and Horn Antenna Feed Systems with the µWave Wizard Ralf Beyer, *Mician*	The Art of Benchmarking RF Test Time David Hall, *National Instruments*
0950	Practical Methods for Estimating the Q of Spiral Inductors Using EM Planar Simulators John Dunn, Charlotte Blair, *AWR*	Customized, Deembedded Ports in 3D Planar EM Tools: Extending Deembedding to Arbitrary Geometries John Dunn, *AWR*	The Alphabet Soup of Vector Network Analyzer Calibration Craig Kirkpatrick, *Cascade Microtech*
1010	Tools for Creating FET and MMIC Thermal Profiles Ted Miracco[1], John Fiala[2], [1]*AWR*, [2]*CapeSym*	SEMCAD X Microwave: Enhanced Simulation of Waveguide Structures Erdem Ofli[1], Pedro Crespo-Valero[1], Jorge Ruiz-Cruz[2], [1]*SPEAG*, [2]*UAM*	Advances in Signal Analyzer Noise Floor and Dynamic Range John Hansen, *Agilent*
1030	Applications and Techniques for Low Phase Noise Signal Generation John Hansen, *Agilent*	Using X-Parameters to Optimize Notch Filter Placement in PA George Crumrine, *Agilent*	Easy, Fast and Versatile Time Domain Waveform Measurement of Microwave Power Transistors Fabien De Groote, Jan Verspecht, Jean-Pierre Teyssier, Jad Faraj, *Verspecht-Teyssier-DeGroote*
1050	Understanding Contributors to Test Time for VSA Measurements David Hall, *National Instruments*	IQ Mixer Measurements: Techniques for Complete Characterization of IQ Mixers Using a Multi-Port Vector Network Analyzer Dara Sariaslani, *Agilent*	EMPIRE XCcel – Efficient Solving of Large Scale EM Problems A. Lauer, W. Simon, A. Wien, *EMPIRE XCcel*
1110	Techniques for Validating a Vector Network Analyzer Calibration When Using Microwave Probes Craig Kirkpatrick, *Cascade Microtech*	pHEMT Amplifier MMICs with Enhanced Robustness Against Process Variations Charles Trantanella, David Folding, *Custom MMIC Design Services*	Transient FEM Solver and Hybrid FE-IE Method; New Technologies in HFSS 13.0 Matthew H. Commens, *ANSYS*
1130	Ultra Low Phase Noise Measurement Technique Using Innovative Optical Delay Lines Guillaume De Giovanni, *NoiseXT*	Design Benefits of Integrating Simulation and Measurement Environments: An LNA Example Gary Wray, *AWR*	QuickWave Electromagnetic Software with CAD Input and GPU Processing Malgorzata Celuch, Maciej Sypniewski, *QWED*
1150	A Multi-Level Conductor Surface Roughness Model Yunhui Chu, *Agilent*		Application Principles for Circulators and Isolators Anthony Edridge, Gene Garcia, *M2 Global*
1210	Understanding the Proper Dielectric Constant of High Frequency Laminates to Be Used for Circuit Modeling and Design John Coonrod, Allen F. Horn, *Rogers*	1200 - 1330 Nonlinear Characterization Expert Forum SPEAKERS: • Loren Betts, Research Scientist/Senior Engineer, *Agilent Technologies* • Steve Reyes, Product Marketing Manager Network Analyzers, *Anritsu* • Marc Vanden Bossche, Founder and CEO, *NMDG Engineering* • Johannes Benedikt, CTO, *Mesuro*	The Design and Test of Broadband Launches Up to 50 GHz on Thin and Thick Substrates Bill Rossas, *Southwest Microwave*
1230	Volume Manufacturing Trends for Automotive Radar Devices Jake Sanderson, *Agilent*		Low-PIM Filter Solutions for Broadband Emission Monitoring Rafi Hershtig, Tim Dolan, *K&L Microwave*
1250	Improved Soldering Techniques for Cylindrical RF Connectors Using HIG Induction Technology Chip Palombini, *iTherm*		Mixed-Signal Active Load Pull – The Fast Track to 3G/4G Amplifier Design Mauro Marchetti, *Maury Microwave*
1310	Power Amplifier Design Utilizing the NVNA and X-Parameters Loren Betts[1], Dylan T. Bespalko[2], Slim Boumaiza[2], [1]*Agilent*, [2]*University of Waterloo*		A Comparison of Noise Parameter Measurement Techniques Erick Kueckels, *Maury Microwave*
1330	Wideband Direct Digital Radio Modeling and Verification David Leiss, Rulon VanDyke, *Agilent*		Vector-Receiver Load Pull – Measurement Accuracy at Its Best Steve Dudkiewicz, *Maury Microwave*
1350	Improved Microwave Device Characterization and Qualification Using Affordable Microwave Microprobing Techniques for High-Yield Production of Microwave Components Gregory Mau *Custom Microwave Components*, Jerry Schappacher, *J micro Technology*	Simulation and Evaluation of Communications Systems in Conformance with Third- and Fourth-Generation Wireless Standards Joel Kirshman, *AWR*	Active and Hybrid Load Pull – A Paradigm Shift Gary Simpson, *Maury Microwave*
1410	Time Domain Measurements in Waveguide Keith Anderson, *Agilent*	Remcom's XFdtd and Wireless InSite: Advanced Tools for Advanced Communication Systems Analysis Joseph J. Rokita, Kyle Labowski, *Remcom*	Local Fundamental Frequency Enhancements for X-Parameter Models Radek Biernacki, Mihai Marcu, *Agilent*
1430	Pulsed S-Parameter Measurements Using PXI Instruments David Broadbent, *National Instruments*	Digital Radio Testing Using an RF Channel Replicator Joe Mazzochette, *EOX*	Beyond the S-Parameter: The Benefits of Nonlinear Device Models Mike Heimlich, *AWR*
1450	Emergence of the Online Design Center Sherry Hess, Dave Kuhn, *AWR*	Advanced Terahertz Device Characterization Keith Anderson, *Agilent*	
1510	Design for Manufacturing: Yield Analysis During EM Simulation Mark Saffian, *AWR*	High Performance RF Photonic Link Technologies Dalma Novak, *Pharad*	
1530	STAN Tool: A New Method for Linear and Nonlinear Stability Analysis of Microwave Circuits Stéphane Dellier, *AMCAD Engineering*	A Practical Approach to Verifying RFICs with Fast Mismatch Analysis George Estep, Paul Colestock, *Agilent*	
1550	Maximizing VSA Dynamic Range Through Appropriate IF Path Selection Raajit Lall, *National Instruments*	Calibration and Accuracy in Millimeter Systems Keith Anderson, *Agilent*	
1610	Waveguide Characteristics and Measurement Errors Keith Anderson, *Agilent*	Instant RF Design Starts with Simulate-able RF Application Notes How-Siang Yap[1], Mike Virostko[2], [1]*Agilent*, [2]*Hittite*	
1630	Memory Effects in RF Circuits: Definition, Manifestations and Fast, Accurate Simulation George Estep, Arnaud Soury, *Agilent*	New Rotary Joint Product Lines for SATCOM Applications Andreas Lermann, *SPINNER*	
1650			
1710		1700 - Keynote Address: What Makes Successful Mergers? John Ocampo, Chairman of M/A-COM Technology Solutions	
1730			
1800			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Active RF and Microwave Components
RF and Microwave Systems and Applications
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NEW WAVES

applications, even at the power levels found in many military electronic-warfare (EW) and commercial communications systems.
Rogers Corp., Advanced Circuit Materials Division, Chandler, AZ (480) 961-1382, www.rogerscorp.com/acm.
Booth 2515

Real-time Spectrum Analyzer

VENDORVIEW

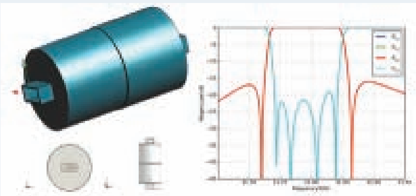
The R&S FSVR family, said to be the world's first signal and real-time spectrum analyzers up to 40 GHz, combines the functions of an all-purpose signal and spectrum analyzer with a real-time spectrum analyzer. In real-time mode, the spectrum analyzer detects everything from sporadic events to ultrashort signals. Measurement without blind times is a major advantage for developers of RF components for commercial transmission systems such as LTE, WiMAX™, WLAN, Bluetooth® and RFID, and for general RF applications such as radar and frequency hopping transmission.
Rohde & Schwarz, Munich, Germany +49 89 4129 12345, www.rohde-schwarz.com.
Booth 2115

Connectors and Cables

Rosenberger will introduce several new products including: new PCB-connector used for test applications to 110 GHz. WSMP connector series ultra-high density, push on interconnects, 45 percent smaller than MiniSMP offering a broad RF range through 100 GHz. Phase stable VNA ruggedized cable to 70 GHz. Rmor™ ruggedized cables for harsh environments. In addition, Rosenberger will show its latest in Passive Intermodulation (PIM) test equipment that incorporates network analyzer functionality and distance to intermodulation source.
Rosenberger of North America LLC, Akron, PA (717) 859-8900, www.rosenbergerna.com.
Booth 1411

Enhanced Simulation of Waveguide Structures

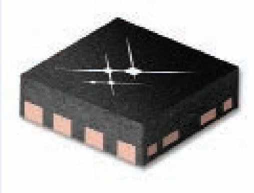
SPEAG developed a new state-of-the-art solver based on the mode-matching technique for the simulation of passive waveguide structures within their simulation suite. The new solver has been integrated into the existing SEMCAD X framework to provide the user with a commonly elaborated simulation environment. Together with the EM and thermal solvers based on the FDTD techniques, SEMCAD X Microwave can be successfully applied to a wide variety of electromagnetic problems ranging from microwave devices, EMC, optics, to bio-medical applications.



Schmid & Partner Engineering AG (SPEAG), Zurich, Switzerland +41 44 245 9700, www.speag.com.
Booth 3204

Low Noise Amplifier

VENDORVIEW



The SKY67014-396LF, the first of three new LNAs for battery powered receiver applications in the 450, 900 and 2400 MHz ISM bands, features noise figure < 1.0 dB, 12 dB gain and 15 dBm OP1dB, and draws 5 mA of current at 3.3 V. This GaAs PHEMT LNA is in a 2 mm square, eight-pin RoHS compliant SMT package. Integrated active bias circuitry reduces external matching requirements and enables a wide supply voltage range of 1.5 to 5 V. An OIP3 of 27 dBm at 2.5 GHz is achievable with 20 mA.
Skyworks Solutions Inc., Woburn, MA (781) 376-3000, www.skyworksinc.com.
Booth 1428

End Launch Connectors

Southwest Microwave's End Launch connector series is being expanded to 1.85 mm, DC to 65 GHz, version in a high and low silhouette mounting block. These high performance connectors are designed to provide the industries lowest VSWR for single-layer or multilayer circuit boards with the microwave layer on top. They are ideally suited for high frequency chip set evaluation, demo boards, test fixtures and board characterization. The connector requires no soldering, and they are reusable and repairable.
Southwest Microwave Inc., Tempe, AZ (480) 783-0201, www.southwestmicrowave.com.
Booth 824

DC Link Power Film Capacitors

Spectrum Advanced Specialty Products now offers DC link power film capacitors with voltage ratings up to 1300 V DC. Due to harsh operating conditions of wind and photovoltaic installations, components used in power inverter applications require superior life expectancy. Spectrum's DC link power capacitors utilize segmented, self-healing metallized polypropylene, internally fused using a T-design pattern, giving them a life expectancy of over 100,000 hours. Spectrum's DC link power film capacitors feature low ESR (1 to 4.3 Ω, typical) and low ESL (50 to 80 nH, typical), ripple currents up to 70A RMS from 10 kHz to 100 kHz, and a capacitance range of 160 to 680 µF standard.
Spectrum Advanced Specialty Products, Fairview, PA (814) 474-0325, www.specemc.com.
Booth 1415

Broadband 50 W Amplifiers

Spectrum Microwave continues adding to its line of S.M.A.R.T. power amplfiers with the addition of a 20 to 800 MHz, 50 W design. With 45 dB of linear gain, this 21 to 30 V DC unit produces 50 W off of only 5.1 amps at 28 V. The QBS-559 amplifier offers a unique feature by automatically adjusting the active biasing to enhance efficiency under various load mismatch conditions. This rugged, high efficiency, push-pull design can even withstand a 10:1 load mismatch. It offers both an internal DC to DC converter as well as an integral heatsink. A variety of fault and monitoring options are also available.
Spectrum Microwave Inc., Philadelphia, PA (215) 464-4000, www.spectrummicrowave.com.
Booth 1415

Precision Airlines

Airlines work as a reference impedance for the DUT and the VNA and are used for precision time domain reflectometry measurements. For a more convenient handling at the VNA side of the airline, the inner conductor is supported by one low-loss dielectric bead. SPINNER precision airlines, which are available for the connector series 7-16, N and 3.5 mm, feature lowest return loss and best possible impedance values.
SPINNER GmbH, München, Germany +49 (0)89 12601-0, www.spinner-group.com.
Booth 431

RF Microwave Kit

SRI's RF microwave is a custom precision RF kit for the microwave industry. Kits can contain any variety or quantity of high frequency connectors and adapters that SRI produces: 1.85, 2.4, 2.9, 3.5 mm, N, SMA, TNC, ZMA, Superites and custom connectors. SRI can also provide a one-stop shopping by sourcing the cables. With its wide range of standard products and custom capabilities, SRI Connector Gage is ready to partner with you to provide high performance, cost-effective coaxial interconnect solutions. SRI offers precision connectors in many other form factors, including 3.5 mm, N, SMA, TNC and ZMA. SRI will execute virtually any coax design related to its product line and deliver it quickly, usually in less than eight weeks.
SRI Connector Gage Inc.,

IEEE MTT-S IMS 2011 MicroApps

Nonlinear Characterization Expert Forum

Baltimore, Maryland, June 8, 12:00 – 1:30 pm

A 90 minute forum and webcast, featuring experts in RF nonlinear device measurement and characterization.

Our panel of experts will discuss solutions and trends in nonlinear device characterization from the perspective of new measurement equipment, techniques and device representation in EDA tools. An open panel discussion session will follow the presentations with audience questions from both live and online participants.

SPEAKERS:

- Loren Betts, Research Scientist/Senior Engineer, Agilent Technologies
- Steve Reyes, Product Marketing Manager Network Analyzers, Anritsu
- Marc Vanden Bossche, Founder and CEO, NMDG Engineering
- Johannes Benedikt, CTO, Mesuro

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Microwave Journal

Frequency Matters.

New Waves

Melbourne, FL (321) 258-9688, www.sriconnectorgage.com.

Booth 531

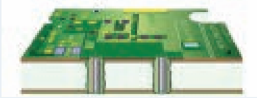
High Reliability Chip Resistors

The Z termination line of miniature, high reliability chip resistors are available in thin and thick film single surface and wrap around designs. The resistors range in size from 0402 (0.040" × 0.020") to 2512 (0.025" × 0.025"), with tolerances from 0.1 perent, power ratings from 50 to 1500 mW temperature coefficients of resistance as low as 25 ppm, and voltage ratings from 30 to 200 V. The operating range for these resistors is from -55° to +125°C. The Z termination resistors are a RoHS compliant product.

State of the Art Inc., State College, PA (814) 458-3401, www.resistor.com.

Booth 1805

Metalized Substrates



Stellar Industries new Copper On Silver conductor offers an economical solution for DC to RF medium substrate power applications. Combining the low cost of thick film silver with Stellar's copper plating technology - Copper On Silver is available for custom designs on alumina, aluminum nitride and beryllium oxide ceramics. Stellar offers the widest selection of copper metallization technologies from Direct Bond Copper (DBC) to thick film copper to Thin Film Copper Plate Up (CPU) for every frequency and power requirement.

Stellar Industries Corp., Millbury, MA (508) 865-1668, www.stellar-ceramics.com.

Booth 319

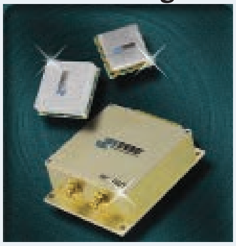
GaN HEMTs

Sumitomo Electric will be featuring its full line of GaN HEMTs for this year's MTT-S IMS Show. Applications include base station, radar and many other general purpose uses. One of the featured products, EGN21C160I2D, supports 2.1G LTE. This is a 160 W Psat device with internal matching circuits and is ideal for 40 W Doherty applications. The high impedance of this GaN HEMT device makes a wide bandwidth of 1.8 to 2.2 GHz possible.

Sumitomo Electric Device Innovation USA, San Jose, CA (408) 232-9500, www.sei-device.com.

Booth 620

Low Noise High Frequency Sources

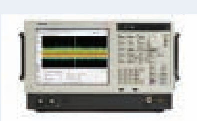


These new ultra-low noise signal sources are designed for single frequency applications such as clock translators for instrumentation and radar markets. These products can also be ideal companions as clock translators for high speed ADC and DDS clocks for improved signal purity. These products convey significant noise floor improvements over multiplied crystal oscillator solutions employed today. The product is available as phase locked sources both in surface-mount FCTS series and SMA coaxial KFCTS series. Products can be made available as phase-locked sources from 300 to 2500 MHz. Model KFCTS1000-10 operates at 1000 MHz, reaches -140 dBc/Hz at 10 kHz offset with ultimate noise floor nearing -170 dBc/Hz at frequency carrier offset of >600 kHz.

Synergy Microwave Corp., Paterson, NJ (973) 881-8800, www.synergymwave.com.

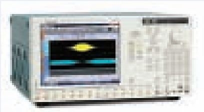
Booth 507, 607

Signal Analyzer



New at MTT-S this year Tektronix will showcase its RSA5000 series signal analyzer. The new instruments

raise the price-performance bar for mid-range signal analyzers by offering more than double currently available acquisition bandwidth and the world's best real time capabilities. By combining reduced time-to-insight and lower cost, the new series is ideal for numerous design and operations applications including spectrum management, radar, electronic warfare, radio communications and EMI/EMC. US MSRP starting as low as $36,400. Also being showcased, Tektronix will highlight its AWG7000C and AWG5000C series of arbitrary waveform generators (AWG) that bring performance and usability enhancements to the industry's most capable family of signal generation solutions.



Tektronix Inc.,
Beaverton, OR (800) 833-9200,
www.tektronix.com.

Booth 1432

CE Marked Thermal Platforms

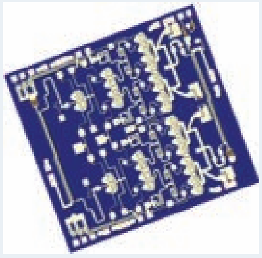
TotalTemp Technologies Inc., a manufacturer of temperature testing equipment, announced the debut of its new line of CE Marked Thermal Platforms (a.k.a. Hot/Cold Plates). These Thermal Platform Systems are specifically designed to conform to the EU electrical safety standard. TotalTemp will have these systems on display at the 2011 IEEE MTT-S International Microwave Symposium.

TotalTemp Technologies Inc.,
San Diego, CA (888) 712-2228,
www.totaltemptech.com.

Booth 1730

Ku-band Power Amplifier

VENDORVIEW



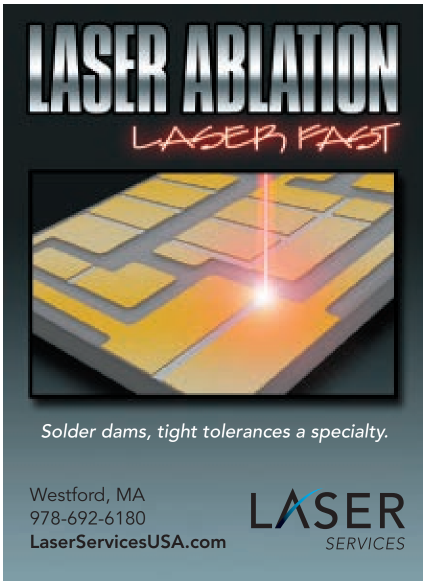
Expanding on the popularity of the packaged version, the TGA2533 provides over 2 W P1dB from 12.7 to 15.4 GHz in a DIE format. With an integrated power detector and 43 dBm TOI, this device is ideal for linear power amplifiers or test equipment in the point-to-point radio and VSAT markets. Running off 6 V at 1300 mA, the TGA2533 offers 28 dB of gain in a 3.2 × 3.0 × 0.1 mm DIE.

TriQuint Stocking Distributor,
RFMW Ltd.,
San Jose, CA (408) 414-1450,
www.rfmw.com.

Booth 2218

4×4 Broadband Beamformer

Serving both airborne and communication system applications, the BFN-4412 is a multi-octave component combining ferrite, coaxial and microstrip technologies achieving high performance in a low profile, small footprint (2.0 × 3.5 × 0.7). Engineered and manufactured in the US, this unit is also used in military radar warning receiver (RWR) designs and early warning and countermeasure control systems. Internally, the BFN-4412 incorporates eight-zero degree dividers, four-zero degree combiners, four-180° combiners and 50 ohm coax delay lines. Operating in the frequency range of



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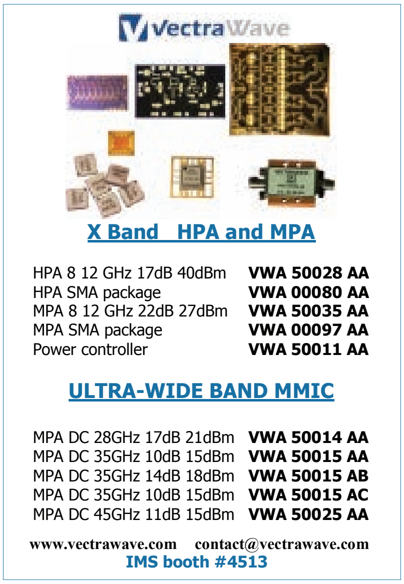
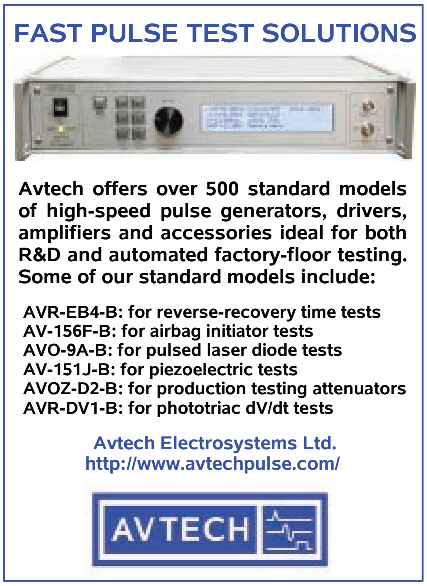




NEW WAVES

500 to 2000 MHz, it delivers typical specifications of: insertion loss of less than 2.5 dB in the low band, greater than 18 dB isolation maximum.
TRM Microwave,
Bedford, NH (603) 627-6000,
www.trmmicrowave.com.

Booth 3902

High Power Circulator

Model CT-1713-S operates at 20 KW peak, 2 KW average power over the frequency range of 380 to 420 MHz. This unit provides isolation of 20

dB minimum, insertion loss of 0.3 dB maximum and 1.20 maximum VSWR. Connectors are 7/8 EIA. Typical applications include radar, medical and scientific equipment.
UTE Microwave Inc.,
Asbury Park, NJ (732) 922-1009,
www.utemicrowave.com.

Booth 1040

Voltage Variable Attenuators

VENDORVIEW

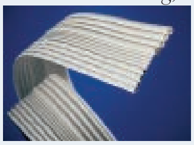
Valpey Fisher's VFVA500 series consists of six models that span the frequency range of 600 MHz to 4 GHz and are offered in a

3.2 × 4.9 mm MCM package. These devices provide a minimum of 25 dB attenuation across a 0 to 5 V control range. Come by Valpey Fisher's booth #1633 for more information.
Valpey Fisher Corp.,
Hopkinton, MA (508) 435-6831,
www.valpeyfisher.com.

Booth 1633

PTFE Cables

W.L. Gore & Associates continues to enhance its engineered PTFE (polytetrafluoroethylene) technology for use in flat and round cables, making them the premier choice for demanding, extreme environments such as semiconductor manufacturing, aerospace and industrial



applications. Gore's customized materials and unique cable designs have resulted in products that minimize particulation and outgassing while maximizing longevity – a combination of qualities not found in any other cable technology. The low coefficient of friction and excellent tear resistance of Gore's expanded PTFE composite jacket material enable its high flex cables to maintain excellent signal integrity.
W.L. Gore & Associates,
Landenberg, PA (410) 506-7787,
www.gore.com.

Booth 320

OCXOs

The Citrine family of OCXOs is available in a frequency range from 5 to 500 MHz and was designed towards the goal of achieving the lowest possible phase noise performance in a dynamic environment. The utilization of "Low-G" Croven Crystal is what enables the oscillator to obtain a g-sensitivity down to <3E10/g. The standard Citrine specs utilize COTS parts, which are ideal for ruggedized environments such as airborne, ship board and ground-based military vehicles. If required, the Citrine line of crystal oscillators can be configured with Hi-Rel components.
Wenzel Associates Inc.,
Austin, TX (512) 450-1400,
www.wenzel.com.

Booth 3409

90° Hybrid Coupler

VENDORVIEW

The Werlatone 90° hybrid coupler, model QH8600, is the first four-port, stripline design, covering the full 30 to 520 MHz bandwidth.

The latest in a series of multi-octave 90° hybrid couplers, the QH8600 is rated at 250 W CW with exceptional loss and port-to-port isolation. With no screws or rivets to hold the circuit's layers together, this chemically bonded, drop-in design provides excellent repeatability in a compact 0.95" × 1.50" × 0.29" form factor. Removes the labor associated

with traditional core windings on 30 to 520 MHz amplifiers.
Werlatone Inc., Patterson, NY (845) 278-2220, www.werlatone.com.

Booth 3402

Assembly and Test Equipment

Design and manufacturer of automatic, semi-automatic, and manual ESD protected microelectronic assembly and test equipment and accessories since 1966. Ultrasonic, thermosonic, and thermocompression wire/ribbon bonders, eutectic and epoxy die bonders, insulated wire bonders and pull testers, LED illuminators, heated and cold workholders, temperature controllers, ultrasonic transducers, ultrasonic power supplies and wire despoolers.
West Bond Inc., Anaheim, CA (714) 978-1551, www.westbond.com.

Booth 3614

Pure-play Wafer Foundry

WIN Semiconductors Corp., established in 1999, has become the world's largest 6" GaAs pure-play wafer foundry. WIN's current capacity from two fabs is 14,000 wafers per month. In addition to 1 µm, 2 µm and high voltage HBT processes, 0.5 µm E-D, 0.15 µm low noise and power, HFET, BiFET(H2W), and Ka/Ku-band 0.25 µm PHEMT processes, WIN is now offering 8 V, 0.25 µm and 0.1 µm power PHEMT processes.
WIN Semiconductors Corp., Tao Yuan Shien, Taiwan 886-3-397-5999, www.winfoundry.com.

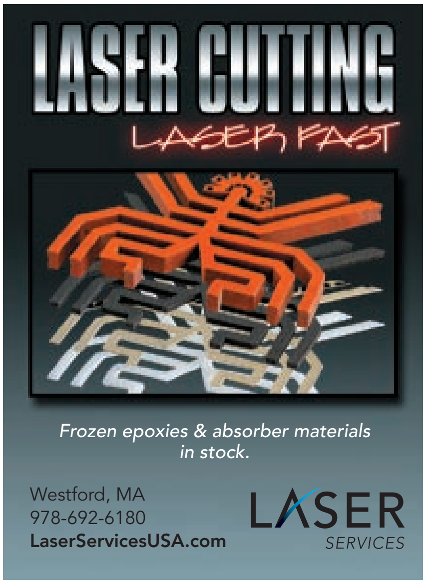
Booth 810

Fixed Frequency Synthesizer

The SFS10000C-LF is a single frequency signal source that is pre-programmed to operate at 10 GHz. This fixed frequency PLL utilizes ceramic resonator topology to achieve typical phase noise performance of -100 dBc/Hz at 10 kHz offset with a reference spur suppression of -70 dBc. Size: 1" × 1" × 0.22".
Z-Communications Inc., San Diego, CA (858) 621-2700, www.zcomm.com.

Booth 313

MICRO-ADS



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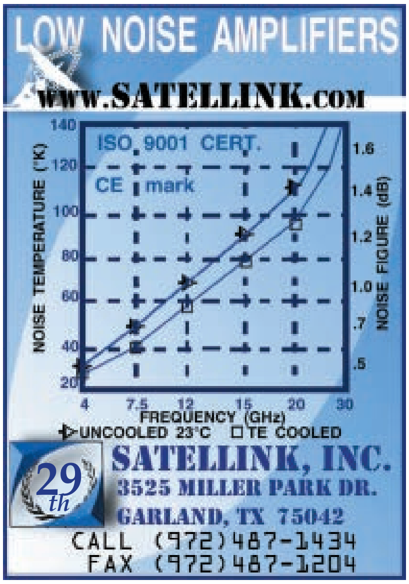

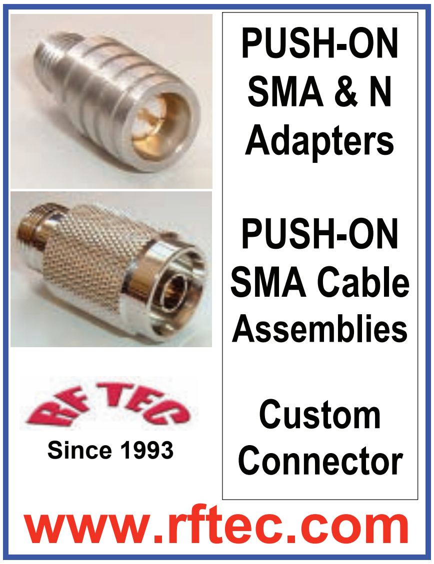

Classic Works in RF Engineering, Volume 2: Microwave and RF Filters

Ralph Levy

With this month's cover feature about the rich history of RF and microwave filter companies in the Mid-Atlantic region of the country, we review a classic book on filters. The purpose of *Classic Works in RF Engineering, Volume 2: Microwave and RF Filters* is to present the reader with a selection of the many papers on RF and microwave filters that is most relevant to the requirements that exist today. Papers that were superseded by later work or were considered too complicated were not included. The object therefore is to present the reader with a comprehensive overview of the subject equivalent to that of a textbook on filter theory and realization. The book starts with the classic paper by Seymour Cohn on direct-coupled-resonator filters and proceeds to cover many types of filters and applications.

This highly practical book is a comprehensive resource on RF and microwave filter theory, design, analysis and applications. It contains 50 classic papers from the 1950s to 2007 on critical topics in the field—from aperture-coupled filters to Zolotarev low pass filters and everything in between. The book includes design procedures, formulas, examples and performance data to help tackle challenging projects without having to research the complete body of literature.

Including insightful introductions to each chapter of papers from Leading Authority and Editor, Ralph Levy, each paper brings definitive project-ready guidance, including theoretical background, applications, selection criteria, design steps, calculations, examples, and input on filter components like capacitors, resistors and inductors. The book includes over 100 diagrams and schematics that help clarify the material at every stage, along with a wealth of problem-solving tips from the top innovators in the field. Whether one needs details on combline, resonator, waveguide, or bandstop filters, this unique volume saves countless hours searching the literature. It is recommended as a great overview and resource on filter technology and applications.

To order this book, contact:

Artech House
685 Canton St., Norwood, MA 02062
800-225-9977;
or
16 Sussex St., London SW1V 4RW, UK
+44 (0) 20 7596-8750
418 pages; $139, £92
ISBN: 978-1-59693-212-8

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May Short Course Webinars

RF/Microwave Training Series
Presented by Besser Associates
Mixers and Frequency Converters
The mixer uses the signal from a local oscillator to convert an incoming RF signal to an intermediate frequency for baseband processing of the transmitted data. This webinar looks at various mixer types, design considerations and key specifications such as conversion loss, isolation, noise figure and spurious outputs.
Live webcast: 5/17/11. 11:00 AM EDT
Sponsored by Mini-Circuits

Innovations in EDA Series
Presented by Agilent Technologies
Direct Filter Synthesis for Customized Response
This webcast looks at direct filter synthesis derived from user-specified input. Direct synthesis eliminates reliance on optimization, which often leads to unnecessarily complex filter topologies with sub-optimal performance.
Available for on demand viewing after 5/5/11
Sponsored by Agilent Technologies

Register to attend at mwjournal.com/webinars

Technical Education Series
Presented by COMSOL
RF and Microwave Heating
This webinar is meant for anyone interested in simulation of RF and microwave heating in antennas, circuit boards, living tissue, or any device that has a combination of lossy dielectric and metallic domains.
Live webcast: 5/19/11. 2:00 PM EDT
Sponsored by COMSOL

Special Event Web Simulcast:
MTT-S IMS MicroApps
Nonlinear Characterization Expert Forum
June 8, 2011. 12:00 - 1:30 pm
This live forum and webcast, featuring experts in RF nonlinear device measurement and characterization explores the trends in nonlinear device characterization from the perspective of new measurement equipment, techniques and device representation in EDA tools. An open panel discussion session will follow the presentations including audience questions from both live and online participants.
To view live webcast online, register at:
www.mwjournal.com/ims_2011_microapps_experts

Past Webinars On Demand

RF/Microwave Training Series
Presented by Besser Associates
- Electrically Small Antennas
- RF Oscillators
- RF Power Amplifiers - Digital Pre-distortion Techniques

Innovations in EDA Series
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- Opto-Electronic Signal Integrity on Optical Fiber Chip-to-Chip Links
- Multi-Technology RF Design Using the New Advances in ADS 2011
- Memory Effects in RF Circuits: Manifestations and Simulation
- X-Parameter Case Study: GaN High Power Amplifier (HPA) Design

Innovations in RF Test Series
Presented by Agilent Technologies
- Use Capture, Playback & Triggering to Completely Analyze a Signal
- See the Future of Arbitrary Waveform Generators
- Three Steps to Successful Modulation Analysis with a Vector Signal Analyzer

Market Research Series
Presented by Strategy Analytics
- Fundamentals and Applications of AESA Radar
- MilSatcom Electronic Market Trends Through 2020

Technical Education Series
- LNA design and characterization using modern RF/microwave software together with T&M instrument

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Middletown, MD 21769
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International Sales
Richard Vaughan
International Sales Manager
16 Sussex Street
London SW1V 4RW, England
Tel: +44 207 596 8742
FAX: +44 207 596 8749
rvaughan@horizonhouse.co.uk

Germany, Austria, and Switzerland (German-speaking)
WMS.Werbe- und Media Service
Brigitte Beranek
Gerhart-Hauptmann-Street 33,
D-72574 Bad Urach
Germany
Tel: +49 7125 407 31 18
FAX: +49 7125 407 31 08
bberanek@horizonhouse.com

Israel
Oreet Ben Yaacov
Oreet International Media
15 Kineret Street
51201 Bene-Berak, Israel
Tel: +972 3 570 6527
FAX: +972 3 570 6526
obenyaacov@horizonhouse.com

Korea
Young-Seoh Chinn
JES Media International
2nd Floor, ANA Bldg.
257-1, Myungil-Dong
Kangdong-Gu
Seoul, 134-070 Korea
Tel: +82 2 481-3411
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yschinn@horizonhouse.com

Japan
Katsuhiro Ishii
Ace Media Service Inc.
12-6, 4-Chome,
Nishiiko, Adachi-Ku
Tokyo 121-0824, Japan
Tel: +81 3 5691 3335
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amskatsu@dream.com

China
Michael Tsui
ACT International
Tel: 86-755-25988571
Tel: 86-21-62511200
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Hong Kong
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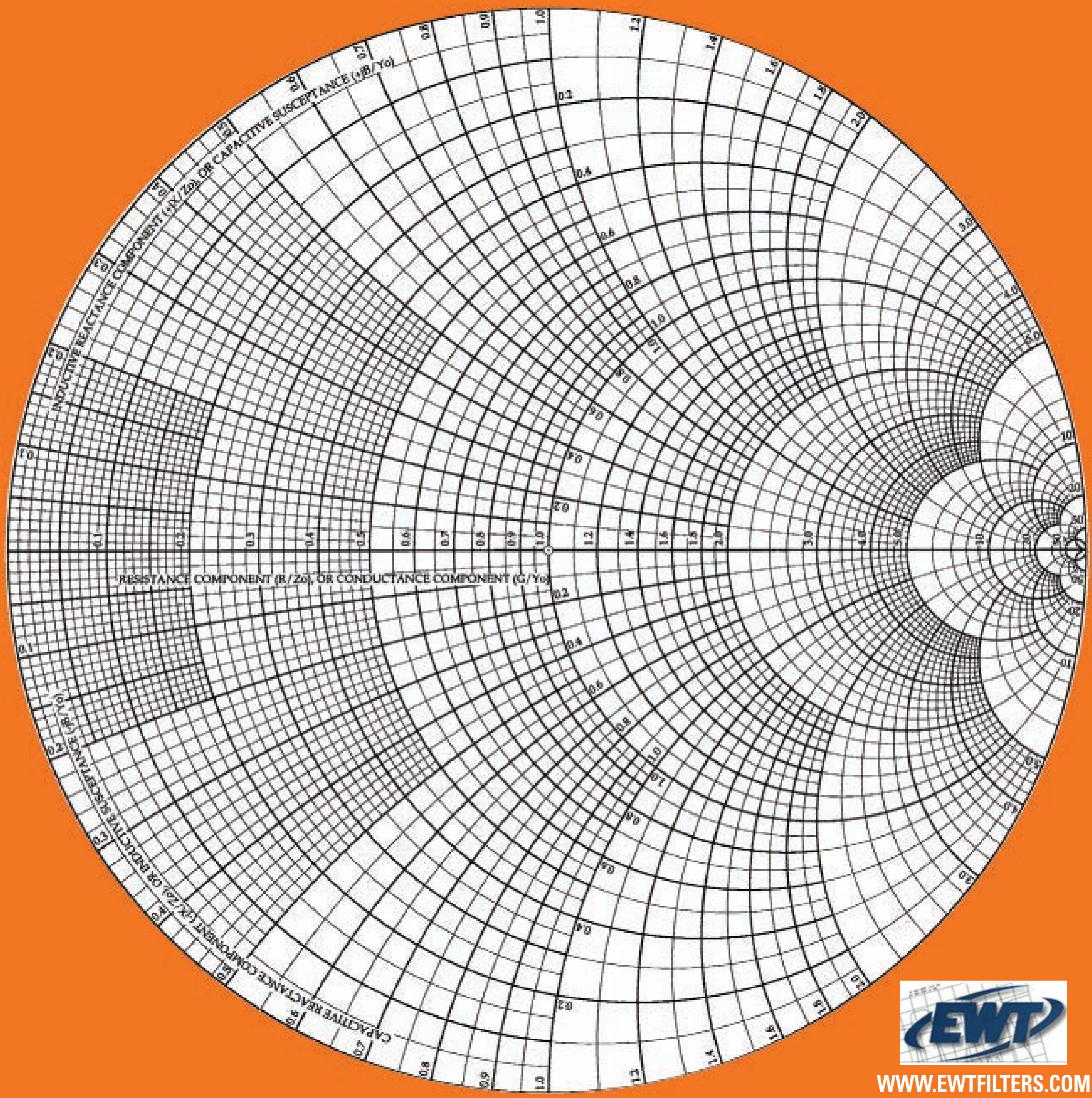

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48. 3.60 -j1.00
49. 2.20 - j0.20
50. 2.00 + j0.20
51. 2.20 + j1.00
52. 1.40 +j1.10
53. 1.20 + j1.30
54. 0.60 + j0.90
55. 1.00 + j0.85
56. 0.65 + j0.75
57. 1.10 + j0.60
58. 1.30 + j0.80
59. 1.80 + j0.80
60. 1.60 + j0.30

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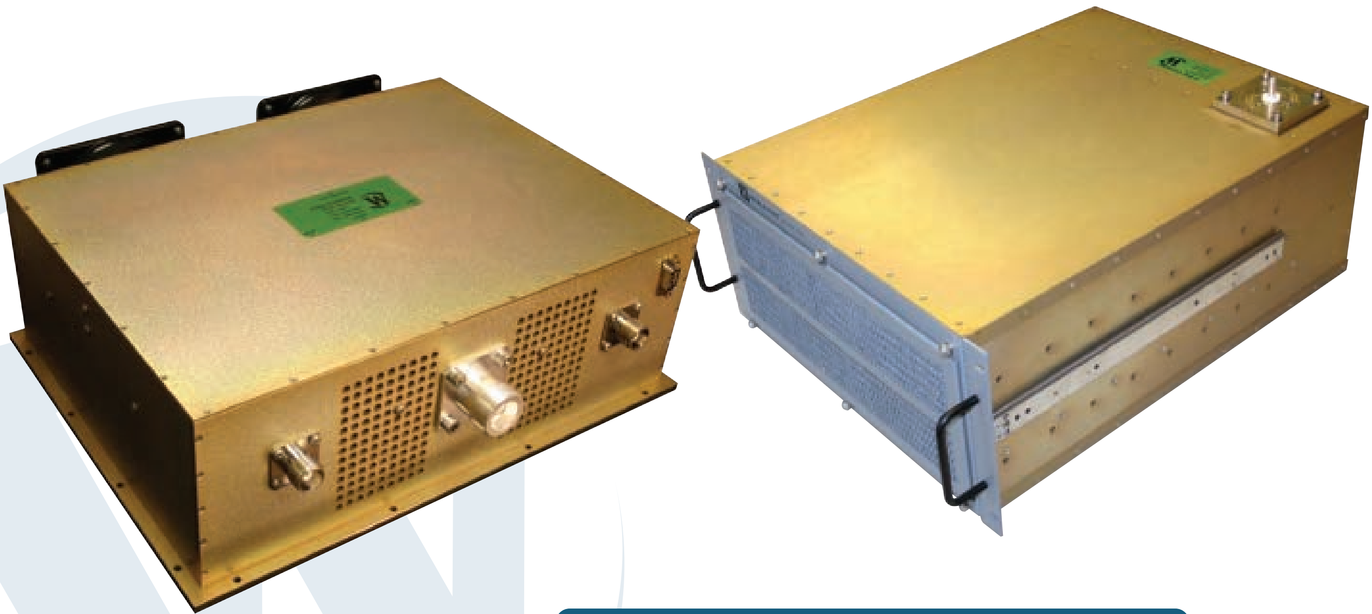

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Model	Type	Frequency (MHz)	Power (W CW)	Insertion Loss (dB)	VSWR	Isolation (dB)	Size (Inches)
D8265	2-Way	1-50	5,000	0.3	1.25	20	15.5 x 15 x 5.25
D2075	2-Way	1.5-30	6,000	0.2	1.25	20	15.5 x 11.75 x 5.25
D8969	2-Way	1.5-30	12,500	0.2	1.25	20	17 x 17 x 8
D6139	4-Way	1.5-32	5,000	0.25	1.25	20	13 x 11 x 5
D6774	4-Way	1.5-32	20,000	0.3	1.20	20	21 x 17.25 x 11
D6846	6-Way	1.5-30	4,000	0.35	1.35	20	3 U, 19" Rack
D8421	8-Way	1.5-30	12,000	0.3	1.30	20	22.5 x 19.5 x 8.75
D7685	4-Way	2-100	2,500	0.5	1.30	20	14.75 x 13 x 7
D2786	4-Way	20-150	4,000	0.5	1.35	20	18 x 17 x 5
D6078	2-Way	100-500	2,000	0.25	1.20	20	13 x 7 x 2.25
H7521	2-Way (180°)	200-400	2,500	0.3	1.30	20	15 x 10 x 2
D7502	2-Way	400-1000	2,500	0.25	1.20	NI*	9.38 x 3.5 x 1.25

*NI+No Isolating Terminations

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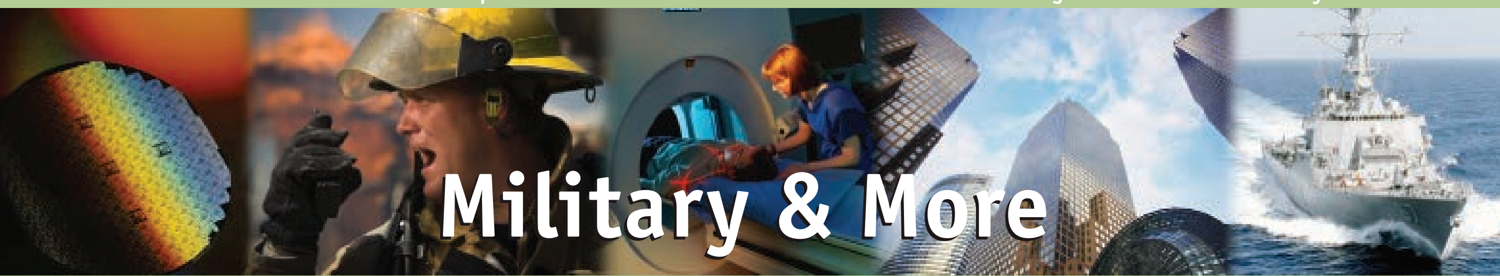

A SUPPLEMENT TO MICROWAVE JOURNAL

2011-12

Product Selection Guide

Choose TriQuint's Innovative RF Solutions

Connecting the Digital World to the Global Network®

TriQuint® SEMICONDUCTOR

Welcome to Our Product Selection Guide

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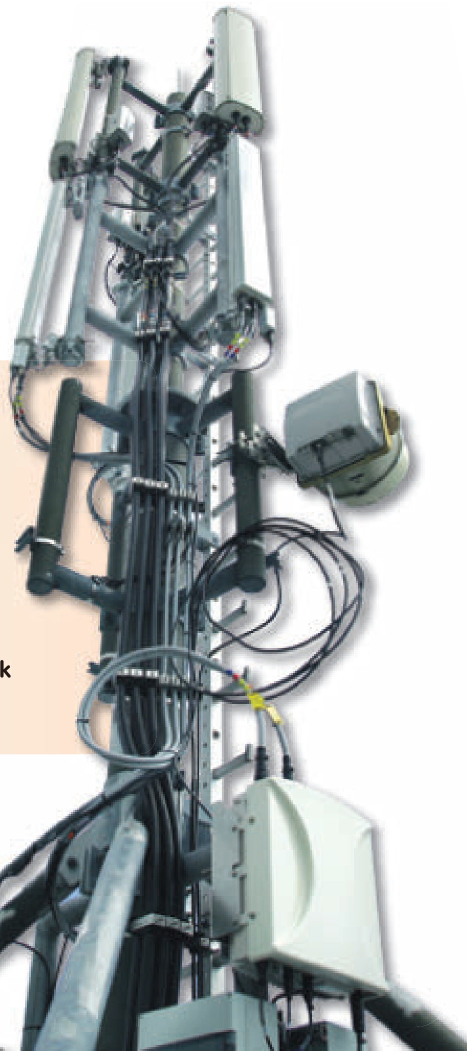
This guide contains a subset of the total selection of products available from TriQuint. If you are unable to locate the product you need, please contact your local sales representative or the factory for more information.

Welcome to TriQuint Semiconductor's 2011-12 Product Selection Guide. Our guide lists over 600 standard products - we also highlight 48 new releases and four new space-qualified products. TriQuint products are organized both by key market applications and product types. We've also included block diagrams with color coding to indicate where TriQuint product solutions exist.

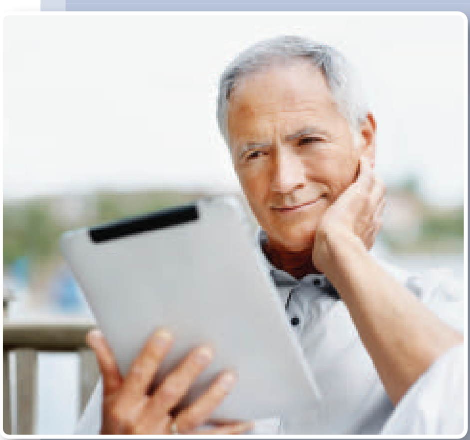
We invite you to visit our website at **www.triquint.com** to obtain full product specifications and to utilize our block diagrams which make it easy to drill down to specific products. TriQuint's Tech Connect page, **www.triquint.com/techconnect**, offers additional ways to simplify RF connectivity through a growing collection of technical resources for key applications. While visiting our website, click on 'subscribe' to receive TriQuint's quarterly e-newsletter and new product announcements.



TriQuint products are available through our worldwide sales, representative and distribution networks. Visit triquint.com/sales to connect with members of TriQuint's extended sales network serving your market.

About TriQuint Semiconductor

TriQuint Semiconductor 'Connects the Digital World to the Global Network®' through our wide selection of innovative RF solutions. We design, develop and manufacture advanced, high-performance RF solutions with Gallium Arsenide (GaAs), Gallium Nitride (GaN), Surface Acoustic Wave (SAW) and Bulk Acoustic Wave (BAW) technologies. Our product portfolio of active and acoustic technologies serves mobile device, 3G / 4G base station, microwave, optical, CATV / FTTH, WLAN and defense / aerospace applications.

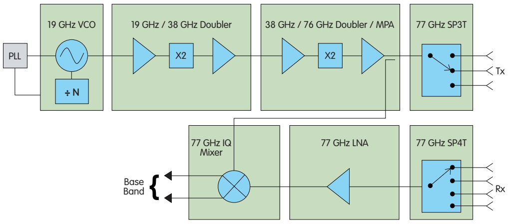


TriQuint solutions, designed and crafted with the industry's largest in-house technology portfolio, enable quicker design turns while lowering overall system costs. We are an award-winning provider of innovative RF products serving start-up firms as well as the world's largest, most well-established companies. We also support the need for custom solutions through the industry's widest selection of foundry processes based on GaAs and GaN technologies.

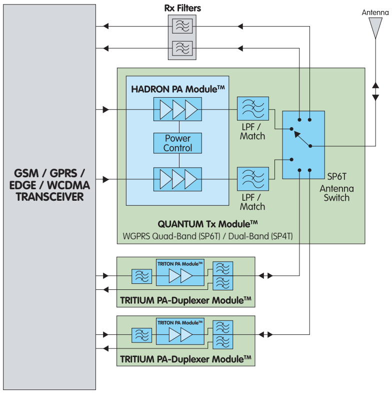
Growth throughout 2010 and 2011 has led to capacity expansion at all three US manufacturing facilities as well as our San Jose Design Center. These expansions will further equip us to meet today's product demands while we position TriQuint to serve the growing needs of wireless manufacturers around the world.

Key advantages of GaAs, GaN, SAW and BAW technologies:

- GaAs can operate efficiently at higher breakdown voltages compared to silicon-based semiconductor technologies while generating less noise in frequencies in excess of 250 MHz. GaAs offers high efficiency, linearity and good wideband performance.
- GaN offers greater power handling and density than GaAs beginning at 20 MHz. Intrinsic GaN technology advantages enables performance at a given power level using fewer or smaller devices. GaN offers strong linearity and efficiency, plus greater wideband capability.
- SAW filter technology offers excellent performance and economy through 2.5 GHz. We are growing our SAW capacity to include an array of temperature-compensated SAW products that will expand this versatile technology's capabilities for new and emerging applications.
- BAW filters offer superior loss levels, stronger ESD performance and greater resistance to temperature effects from 2.5 to 6 GHz. BAW is ideal for challenging applications including co-existence filter requirements.



Example of a 77 GHz Radar Front-End



Cellular & GPS Transceiver for Auto Telematics

Amplifiers & Low Noise Amplifiers

Description	Frequency Range (GHz)	Psat (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
77 GHz LNA	72 - 80	5	20	5	3.5 / 54	Die	TGA4705-FC
77 GHz MPA	76 - 80	14	12	–	3.5 / 75	Die	TGA4706-FC

Switches

Description	Frequency Range (GHz)	Insertion Loss	Isolation (dB)	P1dB (dBm)	Control Voltage (V)	Package Style	Part Number
SP3T	60 - 90	2.3	20	>-13	-5 / 1.35	Die	TGS4305-FC
SP4T	70 - 90	3	20	>-8	-5 / 1.35	Die	TGS4306-FC

Frequency Converters & Mixers

Description	RF Frequency Range (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	Psat (dBm)	Voltage / Current (V / mA)	Package Style	Part Number
19 GHz VCO w/8:1 Prescaler	18.5 - 19.5	–	-105**	7.0	5 / 158	Die	TGV2204-FC
19 / 38 GHz Converter / MPA	36 - 40	9	–	14.5	3.5 / 65	Die	TGC4703-FC
38 / 77 GHz Converter / MPA	76 - 77	6	–	15.0	4 / 230	Die	TGC4704-FC
77 GHz Down Converting I/Q Mixer	75 - 82	-13.5	22	–	1.1 / 7	Die	TGC4702-FC

NOTES: ** = Phase Noise (dBc / Hz @ 1 MHz Offset)

Integrated Products

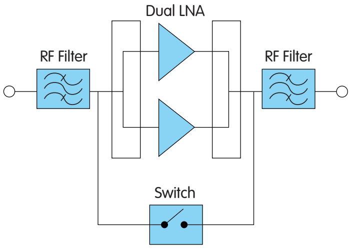
Description	Frequency Bands	Features	Package Size (mm)	Part Number
QB GSM / GPRS Tx Module; PA / LPF / SP6T Switch	GSM850 / 900, DCS / PCS	High System Efficiency & Small Size	6x6x1.1	TQM6M4003
QB GSM / GPRS / EDGE-Polar PA Module	GSM850 / 900, DCS / PCS	-90 dBm Typ Rx Noise, +3 to +8 dBm Pin Nominal	5x5x1	TQM7M5012
WCDMA / HSUPA PA-Duplexer Module; SE Input w/Coupler, Detector	Band 1	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM767021
WCDMA / HSUPA PA-Duplexer Module; SE Input w/Coupler, Detector	Band 2	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM666022
WCDMA / HSUPA PA-Duplexer Module; SE Input w/Coupler, Detector	Bands 5 and 6	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM616025
WCDMA / HSUPA PA-Duplexer Module; SE Input w/Coupler, Detector	Band 8	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM626028L
Quad-Band GSM / GPRS / EDGE-Linear TRP Tx Module: PA / LPF / SP8T WEDGE Switch w/ Quad-Band WCDMA Antenna Pass-Through	GSM850 / 900, DCS / PCS & WCDMA B1, B2, B5 / 6, B8	Integrated QB GSM / GPRS / EDGE PA & Antenna Switch Supporting WCDMA TRP Compliant at 4:1 Mismatch	7x7.5x1.1	TQM6M9014

Filters & Duplexers

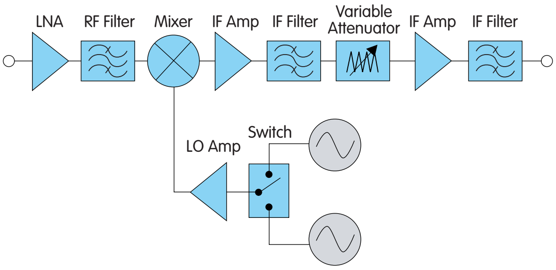
Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
Duplexer, Cell Band	836.5 / 881.5	25 / 25	1.9 / 1.9	SE / SE	–	3.8x3.8	856356
CDMA 2-in-1 Rx Filter	881.5 / 1960	25 / 60	1.6 / 2.2	SE / BAL	–	2x1.5	856565
GPS RF Filter	1575.42	2	1.25	SE / SE	30 @ 1624	2x1.5	856584
GPS RF Filter	1575.42	2	0.75	SE / SE	35 @ 1635	1.4x1.2	856561
GPS RF Filter	1575.42	2	1.1	SE / BAL	20 @ 1635	1.4x1.2	856576
GPS RF Filter, Auto	1575.42	2	1.8	SE / SE	45 @ 1637	3x3	856039
GPS RF Filter, Auto	1575.42	2	1.3	SE / SE	45 @ 1640	3x3	856139
SDARS Filter	2332.5	45	1.7	SE / BAL	35 @ 2100	1.4x1.2	856604
GPS / SDARS Diplexer	1575.42 / 2332.5	3 / 25	0.6 / .08	SE / SE	GPS Port: 40 @ 2332 SDARS Port: 31 @ 1572	3x3	***TQM2M9016****

NOTES: **** = New***

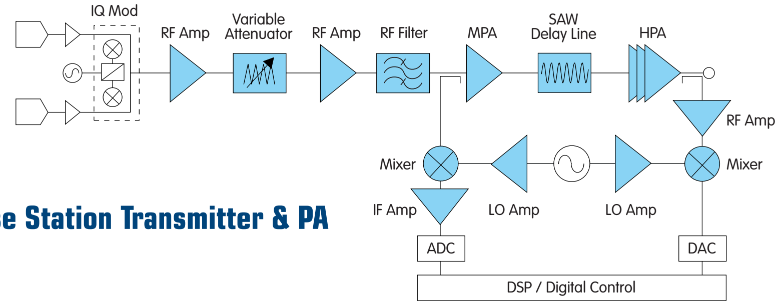
GUIDE BY MARKET | Base Station



Tower Mounted LNA



Base Station Receiver (Single Branch Shown)



Base Station Transmitter & PA

General Purpose Amplifiers

Description	Frequency Range (MHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
General Purpose Gain Block	DC - 3000	18.5 / 33	16.5	3.8	6 / 75	SOT89	AG603
General Purpose Gain Block	DC - 3500	18.5 / 33	13.6	4.4	6 / 75	SOT89	AG602
General Purpose Gain Block	DC - 3500	20.5 / 33.5	17.2	3.5	7 / 96	SOT89	EC1078
General Purpose Gain Block	DC - 4000	19.5 / 31	18.5	2.9	6 / 70	SOT89	EC1019
General Purpose Gain Block	DC - 4000	17.5 / 32	21.5	3.4	6 / 65	SOT89	ECG005
General Purpose Gain Block	DC - 4000	23.5 / 37	14.3	4.6	9 / 120	SOT89	ECG008
General Purpose Gain Block	DC - 4000	18 / 34.5	15.3	5.5	6 / 70	SOT89	ECG040
General Purpose Gain Block	DC - 5500	15 / 30	14.2	3.7	5 / 45	SOT86 / SOT363 / SOT89	ECG006
General Purpose Gain Block	DC - 6000	5.8 / 18.5	11	4.4	5 / 20	SOT86 / SOT363	AG201
General Purpose Gain Block	DC - 6000	7.5 / 19.5	17.7	3.1	5 / 20	SOT86 / SOT363	AG203
General Purpose Gain Block	DC - 6000	12 / 25	14.3	3.2	5 / 35	SOT86 / SOT363	AG302
General Purpose Gain Block	DC - 6000	12.5 / 25	18.4	3	5 / 35	SOT86 / SOT363	AG303
General Purpose Gain Block	DC - 6000	16 / 28.5	14.5	3.7	6 / 60	SOT86 / SOT89	AG402
General Purpose Gain Block	DC - 6000	16 / 28	18.9	3	6 / 60	SOT86 / SOT89	AG403
General Purpose Gain Block	DC - 6000	14.5 / 27.5	19.1	2.9	6 / 45	SOT86 / SOT89	AG503

General Purpose Amplifiers (cont.)

Description	Frequency Range (MHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
General Purpose Gain Block	DC - 6000	19 / 33	18.2	3.5	6 / 75	SOT86 / SOT89	AG604
General Purpose Gain Block	DC - 6000	12.5 / 26	21.4	3.4	5 / 30	SOT363 / SOT89	ECG001
General Purpose Gain Block	DC - 6000	15 / 29	19.5	3.7	5 / 45	SOT86 / SOT363 / SOT89	ECG002
General Purpose Gain Block	DC - 6000	23 / 36	19	3.5	9 / 110	SOT89	ECG003
General Purpose Gain Block	DC - 6000	13 / 27	15.5	3.2	5 / 35	SOT89	ECG004
General Purpose Gain Block	DC - 6000	18 / 32	20.1	3.4	6 / 65	SOT86 / SOT89	ECG055
MESFET IF Gain Block	50 - 870	20 / 41	13	3	5 / 150	SOT89	AH3
MESFET IF Amplifier	50 - 1000	22 / 42	19	2.2	5 / 150	SOT89	AH31
+5V Active Bias IF Gain Block	50 - 1000	20.5 / 44	19.5	5	5 / 95	SOT89	WJA1500
+5V Active Bias IF Gain Block	50 - 1000	19.5 / 36.5	19.3	4.7	5 / 65	SOT89	WJA1505
+5V Active Bias IF Gain Block	50 - 1000	20 / 47	14.4	5.4	5 / 95	SOT89	WJA1510
+5V Active Bias Gain Block	50 - 2300	19 / 36.5	15	5.2	5 / 85	SOT89	WJA1010
+5V Active Bias Gain Block	50 - 3000	20 / 44	19	5.4	5 / 100	SOT89	WJA1001
+5V Active Bias Gain Block	50 - 4000	20 / 40	18.5	5.6	5 / 90	SOT89	WJA1021
+5V Active Bias Gain Block	50 - 4000	19.5 / 37	14.5	5.5	5 / 80	SOT89	WJA1030
E-pHEMT LNA Gain Block	50 - 4000	20 / 37.5	21.5	1.1	5 / 85	SOT89	TQP3M9008
E-pHEMT LNA Gain Block	50 - 4000	21.4 / 37.5	22	1.1	5 / 85	3x3 QFN	***TQP3M9018****
E-pHEMT LNA Gain Block	50 - 4000	22 / 40.5	24.7	0.9	5 / 125	SOT89	TQP3M9009
E-pHEMT LNA Gain Block	50 - 4000	22 / 40.5	24.7	0.9	5 / 125	3x3 QFN	***TQP3M9019****
E-pHEMT LNA Gain Block	50 - 4000	21.5 / 40	15	2	5 / 85	SOT89	***TQP3M9028****
MESFET Gain Block	60 - 3000	15 / 32	14	2.4	4.5 / 50	SOT89	AG101
MESFET Gain Block	60 - 3000	18 / 36	14	2.4	4.5 / 70	SOT89	AG102
MESFET Gain Block	60 - 3000	18 / 39	14	2.4	4.5 / 78	SOT89	AM1
MESFET Dual Amplifier	150 - 3000	24 / 46	12	4.1	5 / 300	SOIC-8	AH11
MESFET Amplifier	250 - 4000	21.5 / 42	14	3.2	5 / 150	SOT89	AH1
E-pHEMT LNA Gain Block	500 - 4000	22 / 35	19	0.8	5 / 55	3x3 QFN	***TQP3M9005****
E-pHEMT LNA Gain Block	500 - 4000	22.5 / 38.5	18.5	1	5 / 90	3x3 QFN	***TQP3M9006****
E-pHEMT LNA Gain Block	500 - 4000	23.5 / 42	18	1.3	5 / 135	SOT89	***TQP3M9007****

NOTES: ***** = New**

High Linearity Driver Amplifiers

Description	Frequency Range (MHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
26.5 dBm MESFET Amplifier	50 - 1500	26.5 / 47	13.5	3.5	9 / 200	SOT89	AH101
30 dBm MESFET Amplifier	50 - 2200	30 / 47	17	2.5	11 / 330	6x6 QFN	AH202
24.5 dBm HBT Amplifier	50 - 4000	24.5 / 41.5	21	4.5	5 / 88	SOT89	***TQP7M9101****
24 dBm HBT Amplifier	60 - 2500	24 / 40	19	5	5 / 150	SOT89	AH114
27 dBm MESFET Amplifier	60 - 2700	27 / 46	29	2.5	4.5; 9 / 275	SOIC-8	AH103A
24.7 dBm HBT Amplifier	60 - 3500	24.7 / 40	19.5	4	5 / 160	SOT89	AH118
25 dBm HBT Amplifier	60 - 3500	25 / 40	19.5	4.6	5 / 115	SOT89	AH128
27 dBm MESFET Amplifier	350 - 3000	27 / 46	14.5	3.1	9 / 200	SOT89	AH102A
31 dBm HBT Amplifier	400 - 2300	31 / 46	18	7	5 / 450	4x4 QFN	ECP100
31 dBm HBT Amplifier	400 - 2300	31 / 46	18	7	5 / 450	SOIC-8	AH215
33 dBm HBT Amplifier	400 - 2300	33 / 49	18	8	5 / 800	4x4 QFN	ECP200
33 dBm HBT Amplifier	400 - 2300	33 / 49	18	8	5 / 800	SOIC-8	AH312
27.5 dBm HBT Amplifier	400 - 4000	27.5 / 44	21	4	5 / 140	SOT89	***TQP7M9102****
28.5 dBm HBT Amplifier	400 - 3600	28.5 / 45	20	4.5	5 / 150	SOT89	AH125
31 dBm HBT Amplifier	400 - 2700	31 / 47	20	5.9	5 / 300	SOIC-8	AH225
33 dBm HBT Amplifier	400 - 2700	33 / 49	19.5	4.6	5 / 500	SOIC-8	AH322
35.5 dBm HBT Amplifier	400 - 2700	35.5 / 50	16	7	5 / 800	4x5 DFN	AH420

NOTES: ***** = New**

High Linearity Driver Amplifiers (cont.)

Description	Frequency Range (MHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
33 dBm HBT Amplifier	700 - 2700	33 / 50	27.5	7	5 / 680	5x5 QFN	AH323
39 dBm HBT Amplifier	700 - 2900	39 / –	16.5	8	12 / 300	5x6 DFN	AP561
28 dBm HBT Amplifier	700 - 3800	28 / 42	28.5	2.9	5 / 225	4x4 QFN	TQP8M9013
28.7 dBm HBT Amplifier	800 - 1000	28.7 / 43	17.5	7	5 / 250	SOIC-8	AH116
28.5 dBm HBT Amplifier	1800 - 2300	28.5 / 44	14.5	6	5 / 250	SOIC-8	AH115
30 dBm HBT Amplifier	1800 - 2700	30 / 46	24.6	5.5	5 / 400	SOIC-8 / 4x5 DFN	AH212
39 dBm HBT Amplifier	3300 - 3800	39 / –	11.5	8	12 / 400	5x6 DFN	AP562
33 dBm HBT Amplifier	3300 - 3800	33 / –	25	7.3	5 / 600	5x5 QFN	AH315

Variable Gain Amplifiers

Description	Frequency Range (MHz)	P1dB / OIP3 (dBm)	Gain (dB)	Gain Range (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
Variable Gain Amplifier	50 - 2200	22 / 42	15.5	20	5 / 150	4x4 QFN	VG025
Variable Gain Amplifier	700 - 1000	22 / 40	16	29	5 / 150	6x6 QFN	VG101
Variable Gain Amplifier	700 - 2800	27.5 / 43	29	30	5 / 240	5x5 QFN	***TQM8M9074****
Variable Gain Amplifier	1800 - 2700	22 / 39.5	13.5	26.5	5 / 150	6x6 QFN	VG111
Digital Variable Gain Amplifier	1800 - 2700	24.5 / 41.5	31	31.5	5 / 200	6x6 QFN	***TQM879006****

NOTES: ***** = New**

Low Noise Amplifiers

Description	Frequency Range (GHz)	P1dB / IIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
LNA, Balanced FET Low Band	700 - 915	– / 13.5	20.5	0.55	4 / 70	4x4 QFN	TQP3M6004
LNA, Discrete Low Band High Linearity	700 - 915	26 / 23.5	16	0.8	5 / 150	SOT89	TGF2021-04-SD
LNA, Balanced FET	800 - 3000	21 / 11	22	0.4	4 / 100	2x2 QFN	TGA2602-SM
LNA, Balanced FET Mid Band	1700 - 2000	– / 14.4	18	0.55	3.5 / 50	4x4 QFN	***TQP3M6005****

NOTES: ***** = New**

28V Transistors

Description	Frequency Range (MHz)	P1dB / IMD3 (dBm) / (dBc)	Gain (dB)	Efficiency (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
InGaP HBT PA, 1.8W, Ultra High Linearity	800 - 2350	32.5 / -60	15.8	55	28 / 40	5x6 DFN	AP601
InGaP HBT PA, 3.7W, Ultra High Linearity	800 - 2350	35.7 / -62	15.5	55	28 / 80	5x6 DFN	AP602
InGaP HBT PA, 7W Ultra High Linearity	800 - 2350	38.5 / -51	17	53	28 / 160	5x6 DFN	AP603

TriPower™ High Power Transistors

Description	Frequency Range (GHz)	P1dB (Psat)	Gain (dB)	PAE (%)	Voltage / Current (V / mA)	Package Style	Part Number
120W TriPower™ HVHBT Amplifier	2.11 - 2.17	51.1	16.6	64.5	28 / 550	Flanged Screw Down	***TG2H214120-FL****
120W TriPower™ HVHBT Amplifier	2.11 - 2.17	51.1	16.6	64.5	28 / 550	Flanged Solder Down	***TG2H214120-FS****
220W TriPower™ HVHBT Amplifier	2.11 - 2.17	53.9	16.4	65.4	28 / 600	Flanged Screw Down	***TG2H214220-FL****

NOTES: ***** = New**

Control Products

Description	Frequency Range (MHz)	Insertion Loss (dB)	Isolation / Atten Range (dB)	P1dB (dBm)	Control Voltage (V)	Package Style (mm)	Part Number
SP3T Switch	DC - 2000	0.45	28 / –	>36.5	2.6 / 0	3x3 QFN	TQP4M3018
SP3T Switch	DC - 2000	0.6	22 / –	>34.5	2.6 / 0	2x2 QFN	TQP4M3019
Through Line	DC - 6000	0.1	–	–	–	3x3 QFN	***TQM4M9073****
6-Bit, Digital Attenuator, Parallel Ctrl	DC - 4000	1.3	– / 31.5	30	5 / 0	4x4 QFN	TQP4M9071

NOTES: ***** = New**

Control Products (cont.)

Description	Frequency Range (MHz)	Insertion Loss (dB)	Isolation / Atten Range (dB)	P1dB (dBm)	Control Voltage (V)	Package Style (mm)	Part Number
6-Bit, Digital Attenuator, Serial Ctrl	DC - 4000	1.3	– / 31.5	30	5 / 0	4x4 QFN	TQP4M9072
SPDT Switch	1000 - 6000	0.6	28 / –	31.5	3 / 0	1.3x2 DFN	TQS5200
DPDT Switch	1000 - 6000	0.8	33 / –	33	3 / 0	3x3 QFN	TQS5202

Frequency Converters & Mixers

Description	RF Frequency Range (MHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage Current (V / mA)	Package Style (mm)	Part Number
WB Mixer, LO	500 - 2500	-5.7	8	24	3 - 6 / 6	MW6	CMY210
WB Mixer, LO, IF	500 - 2500	10	8	9	3 - 6 / 12	SCT598	CMY212
WB Mixer, LO, IF, Low Current	500 - 2500	9.5	10	10	3 - 6 / 8	SCT598	CMY213
Mixer, LO	700 - 1500	-9	17	36	5 / 50	MSOP-8	ML483
Single Branch Converter, RF, LO, IF	800 - 915	22	60	15	5 / 360	6x6 QFN	CV110-1A
Single Branch Converter, RF, LO, IF	800 - 960	22	60	15	5 / 360	6x6 QFN	CV110-3A
Dual Branch Converter, LO, IF	800 - 960	10.5	14	18.5	5 / 390	6x6 QFN	CV210-3A
Mixer, LO	1500 - 3200	-8.5	2	35	5 / 45	MSOP-8	ML485
Single Branch Converter, RF, LO, IF	1700 - 2000	21	45	17	5 / 360	6x6 QFN	CV111-1A
Single Branch Converter, RF, LO, IF	1900 - 2200	21	40	17	5 / 360	6x6 QFN	CV111-3A
Mixer, LO	1900 - 2700	-8.1	9	30	5 / 110	SOIC-8	ML501

NOTES: RF = RF Amplifier, LO = LO Amplifier, IF = IF Amplifier

Discrete Transistors

Description	Frequency Range (MHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage Current (V / mA)	Package Style (mm)	Part Number
MESFET	DC - 2500	26.5 / –	11	1.72 / 55	2 - 6 / 350	SOT223	CLY5
MESFET	DC - 3000	23.5 / –	15.5	1.48 / 55	2 - 6 / 180	MW6	CLY2
0.5W HFET	DC - 6000	28 / 40	18	3.2 / –	8 / 100	SOT89	TGF2960-SD
1W HFET	DC - 6000	31 / 43	16	4 / –	8 / 200	SOT89	TGF2961-SD
MESFET	50 - 4000	21 / 42	19	2 / –	5 / 140	SOT89	FH1
MESFET	50 - 4000	18 / 36	19	2 / –	5 / 140	SOT89	FH101
0.5W HFET	50 - 4000	27 / 40	19	2.7 / –	8 / 125	SOT89	FP1189
1W HFET	50 - 4000	30 / 44	18	4.5 / –	8 / 250	SOT89	FP2189
2.5W HFET	50 - 4000	34 / 46	18	3.5 / –	9 / 450	6x6 QFN	FP31QF

RF Filters

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
FRS RF or GPS IF Filter	465	6	1.4	SE / SE	40 @ 445	3x3	856288
RF Filter – Band 12 Uplink	707	18	1.5	SE / SE	9 @ 728	3x3	856884
RF Filter – Band 12 Downlink	737	18	1.8	SE / SE	37 @ 708	3x3	856883
RF Filter – Band 13 Downlink	751.5	11	1.5	SE / SE	40 @ 776	3x3	***856794****
RF Filter – Band 13 Uplink	781.5	11	1.5	SE / SE	38 @ 757	3x3	856764
RF Filter – Band 13 Uplink	782	10	1.52	SE / SE	15 @ 765	3x3	856844
RF Filter – Band 5 Uplink	836.5	25	2.7	SE / SE	28 @ 869	3x3	855729
RF Filter – Band 5 Uplink	836.5	25	2.7	SE / SE	28 @ 869	3x3	***856503****
RF Filter – Band 5 Uplink	836.5	25	1.9	SE / SE	35 @ 869	3x3	855821
RF Filter – Band 5 Uplink	836.5	25	2	SE / SE	10 @ 869	3x3	856704
RF Filter – Band 20 Uplink	847	30	1.3	SE / SE	10 @ 882	3x3	***856932****
RF Filter – Band 5 Downlink	881.5	25	2.7	SE / SE	40 @ 849	3x3	***856504****
RF Filter – Band 5 Downlink	881.5	25	2.7	SE / SE	40 @ 849	3x3	855728

NOTES: **** = New***

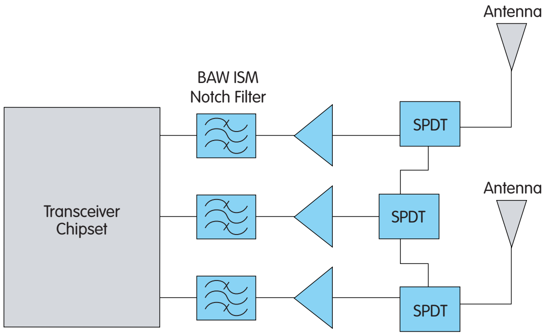
RF Filters (cont.)

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
RF Filter – Band 5 Downlink	881.5	25	1.8	SE / SE	35 @ 849	3x3	855782
Cell Band Delay Filter, 450 ns	881.5	25	25	SE / BAL	–	7.x5.5	856716
RF Filter – Band 8 Uplink	897.5	35	1.9	SE / SE	14 @ 930	3x3	856671
RF Filter – Band 8 Uplink	897.5	35	1.5	SE / SE	15 @ 930	3x3	856657
RF Filter – Band 8 Uplink	897.5	35	1.4	SE / SE	10 @ 984	3x3	856824
RF Filter – Band 8 Downlink	942.5	35	2	SE / SE	5 @ 915	3x3	855820
RF Filter – Band 8 Downlink	942.5	35	3.2	SE / SE	12 @ 915	3x3	855810
RF Filter – Band 8 Downlink	942.5	35	2.5	SE / SE	25 @ 915	3x3	856528
GSM Band Delay Filter, 450 ns	942.5	35	25.5	SE / SE	–	7x5.5	856766
RF Filter – Band 11 Uplink	1445.4	35	1.25	SE / SE	20 @ 1495.9	3x3	***856928****
RF Filter – Band 3 Uplink	1747.5	75	2	SE / SE	22 @ 1676	3x3	856654
RF Filter – Band 3 Downlink	1842.5	75	1.9	SE / SE	10 @ 1785	3x3	855860
RF Filter – Band 2 Uplink	1880	60	2.4	SE / SE	7 @ 1930	3x3	855849
RF Filter – Band 2 Uplink	1880	60	2.8	SE / SE	30 @ 1930	3x3	856530
RF Filter – Band 2 Uplink	1880	60	2.2	SE / SE	15 @ 1806	3x3	856705
RF Filter – Band 2 Uplink	1880	60	2.3	SE / SE	10 @ 1790	3x3	856880
RF Filter – Band 1 Uplink	1950	60	2.2	SE / SE	40 @ 2110	3x3	856532
RF Filter – Band 1 Uplink	1950	60	1.8	SE / SE	20 @ 2100	3x3	856678
RF Filter – Band 2 Downlink	1960	60	2.1	SE / SE	10.3 @ 1910	3x3	855817
RF Filter – Band 2 Downlink	1960	60	2.25	SE / SE	14 @ 1910	3x3	856531
Delay Filter, PCS 450 ns	1960	60	25	SE / BAL	–	7x5.5	856717
Delay Filter, UMTS 450 ns	2140	60	25	SE / BAL	–	7x5.5	856649
RF Filter – Band 1 Downlink	2140	60	2.3	SE / SE	25 @ 1980	3x3	856738

NOTES: ***** = New***

TriQuint Semiconductor offers a wide variety of **base station IF filters**. To view a selection of the most common filters, please go to the SAW filter section on pages 31 - 36.

GUIDE BY MARKET | BWA / WiMAX / LTE



Broadband Transceiver

Amplifiers

Description	Frequency Range (GHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
39 dBm HBT Amplifier	0.7 - 2.9	39 / –	16.5	8	12 / 300	5x5 QFN	AP561
33 dBm HBT Amplifier	3.3 - 3.8	33 / –	25	–	5 / 600	5x5 QFN	AH315
39 dBm HBT Amplifier	3.3 - 3.8	39 / –	11.5	–	12 / 400	5x6 DFN	AP562
WiMAX Driver Amp / PA, SB	3.4 - 3.8	30 / 42	24	–	6 / 770	5x5 QFN	TGA2703-SM

NOTES: SB = Self Biased

GUIDE BY MARKET | BWA / WiMAX

Discrete Transistors

Description	Frequency Range (GHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
MESFET	DC - 3000	23.5 / –	15.5	1.48 / 55	2 - 6 / 180	MW6	CLY2
0.5W HFET	DC - 6000	28 / 40	18	3.2 / –	8 / 100	SOT89	TGF2960-SD
1W HFET	DC - 6000	31 / 43	16	4 / –	8 / 200	SOT89	TGF2961-SD
MESFET	50 - 4000	21 / 42	19	2 / –	5 / 140	SOT89	FH1
MESFET	50 - 4000	18 / 36	19	2 / –	5 / 140	SOT89	FH101
0.5W HFET	50 - 4000	27 / 40	19	2.7 / –	8 / 125	SOT89	FP1189
1W HFET	50 - 4000	30 / 44	18	4.5 / –	8 / 250	SOT89	FP2189
2.5W HFET	50 - 4000	34 / 46	18	3.5 / –	9 / 450	6x6 QFN	FP31QF

Switches

Description	Frequency Range (GHz)	Insertion Loss (dB)	Isolation (dB)	P1dB (dBm)	Control Voltage (V)	Package Style (mm)	Part Number
SP2T 802.11 a, b, g	DC - 6	0.6	28	31.5	3 / 0	1.3x2 DFN	TQS5200

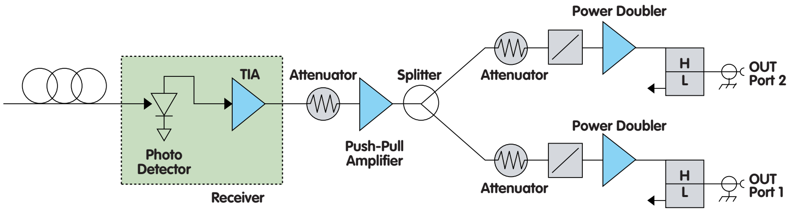
Filters For Coexistence

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
ISM Passband Filter for Coexistence	2436	72	2	SE / SE	20 @ 2495	1.7x1.3	885007
ISM Notch RF Filter for Coexistence	2440	72	1.5 (Out of Band IL)	SE / SE	25 @ 2440 (Notch Rej)	1.7x1.3	885008
ISM Notch RF Filter for Coexistence	2440	85	2 (Out of Band IL)	SE / SE	18 @ 2440 (Notch Rej)	1.7x1.3	885010

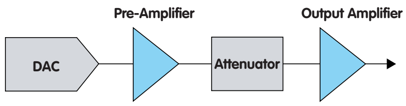
IF Filters

TriQuint Semiconductor offers a wide variety of BWA / WiMAX IF filters. To view a selection of the most common filters, please go to the SAW filter section on pages 31-36.

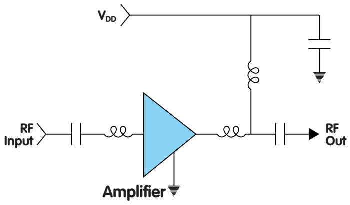
GUIDE BY MARKET | Cable



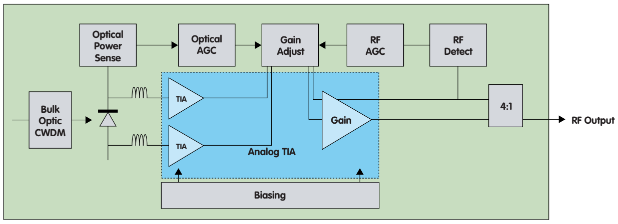
CATV Infrastructure



Edge QAM DOCSIS® 3.0



Subscriber Home Amplifiers



FTTH / RFoG

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Amplifiers

Description	Application	Frequency Range (MHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
CATV Gain Block, Flex Gain	Home Amplifier	DC-2000	21 / 38	16-21	2	5 - 8 / 100	SOT89	***TAT7457****
Dual HBT Amplifier	General Purpose	DC - 2700	19 / 33	18	3.5	>6 / 75	SOT86 / SOT89	AG604
On-Chip Linearized Amplifier	DOCSIS® 3.0 OUTPUT	40 - 1000	– / 43	17	4.7	5 / 380	SOIC-8	TAT7467H
CATV Gain Block	DOCSIS® 3.0 OUTPUT	40 - 1000	27 / 46	20	1.5	8 / 350	4x4 QFN	TGA2803-SM
CATV Gain Block	DOCSIS® 3.0 OUTPUT	40 - 1000	27 / 46	20	1.5	8 / 350	5x5 QFN	TGA2806-SM
CATV Gain Block	DOCSIS® 3.0 OUTPUT	40 - 1000	28 / –	18.5	2.5	6 / 318	5x5 QFN	TGA2807-SM
Dual pHEMT Amplifier, High Gain	Infrastructure GP	50 - 1000	– / 38	17.5	3.2	5 / 235	SOIC-8	TAT7469
Dual pHEMT Amplifier	Infrastructure GP	50 - 1000	– / 41	13	4	6 / 190	SOIC-8	TAT7466
Dual MESFET Amplifier	Infrastructure GP	50 - 1000	25.5 / 43	11.1	4.5	5 / 320	SOIC-8	AH22S
Fiber to the Home TIA + Output Amp	Fiber to the Home, RFoG, Low Input	50 - 1000	-60 dBc CTB / CSO	38	2.9 pA / rtHz EIN	10 - 12 / 120	4x4 QFN	***TAT6254B****
CATV Gain Block, High Gain	Home Amplifier, MOCA Multi	50 - 1000	– / 41	22.5	2	8 / 190	SOT89	TAT7430B
CATV Gain Block, High Gain	Home Amplifier, MOCA	50 - 1000	– / 39	18	2	6 / 145	SOT89	TAT7427
CATV Gain Block	Home Amplifier	50 - 1000	– / 39	16	2.7	6 / 130	SOT89	TAT7461
MESFET Amplifier	General Purpose	50 - 1000	20 / 40	14.8	3.5	5 / 150	SOT89	AH2
Single Ended Darlington	Return Path Amplifier	50 - 1000	20 / 37	13.5	4.5	>7 / 165	SOIC-8	AG606
Fiber to the Home TIA + Output Amp	Fiber to the Home, RFoG	50 - 1000	-62 dBc CTB / CSO	32	3.9 pA / rtHz EIN	5, 12 / 200, 130	4x4 QFN	TAT6254D
Fiber to the Home TIA + Output Amp	Fiber to the Home, High Output	50 - 1000	-63 dBc CTB / CSO	33	3.9 pA / rtHz EIN	5, 12 / 200, 130	4x4 QFN	TAT6254C
MESFET Amplifier	General Purpose	50 - 1500	30 / 50	10.4	5.3	9 / 400	SOT89	AH101
Dual pHEMT Amplifier, Wideband	CATV+SAT Wideband Amp / VONU	50 - 2600	-77 dBc CTB / -83 dBc CSO	13	4.4	5 / 160	SOIC-8	TAT7464
CATV Gain Block, Wideband	CATV+SAT Wideband Amp / VONU	50 - 2600	– / 36	16.5	2.5	5 / 100	SOT89	TAT7460
HFET Gain Block	General Purpose	50 - 4000	27 / 39	12.4	2.7	8 / 200	SOT89	FP1189
MMIC Gain Block	General Purpose	60 - 3000	15 / 32	14	2.4	4 - 5 / 50	SOT89	AG101
MESFET Gain Block	General Purpose	60 - 3000	21 / 39	10	2.4	4.5 / 150	SOT89	AM1

NOTES: **** = New***

Filters

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
Cable IF Filter	36.15	8	19.7	SE / SE	38 @ 10.23	DIP	855748
Cable IF Filter	44	6	20.4	SE / SE	38 @ 7.6	DIP	855079
Cable IF Filter	202.75	1.2	6.6	SE / SE	40 @ 10	13.3x6.5	855068
Cable IF Filter	499.25	1	7	SE / SE	35 @ 6	9x7	855104
Tuner IF Filter	1086	10	4	BAL / BAL	40 @ 1046	3x3	855964
Tuner IF Filter	1086	10	4	BAL / BAL	40 @ 1046	3x3	856330
Tuner IF Filter	1090	10	5	BAL / BAL	50 @ 1050	3.8x3.8	856096
Tuner IF Filter	1216	8	3.75	BAL / BAL	12 @ 24	3x3	856365
Tuner IF Filter	1220	10	4.5	BAL / BAL	30 @ 60	3x3	856298
Tuner IF Filter	1220	50	3.9	BAL / BAL	33 @ 96	3.8x3.8	856598
Tuner IF Filter	1250	96	6	BAL / BAL	44 @ 1152	3x3	856653
Tuner IF Filter	1892	8	4.2	BAL / BAL	23 @ 1932	2.5x2	856236

Protectors

Description	Application	Leakage Current (nanoAmps)	Trigger Voltage (V)	Series Capacitance (pF)	Package Area (mm^2)	Package Style	Part Number
CATV Protector	ESD & Secondary Protection	20 @ 1V, 500 @ 15V	18, 25, 41	0.29, 0.29, 0.22	1.8	T / SLP-3	TQP200002

GUIDE BY MARKET | Defense & Aerospace

TriQuint Semiconductor has been supporting the defense and aerospace market for more than 25 years with the industry's most advanced technology and world class customer support. We continue to build on that legacy with our pioneering innovation and leadership in Gallium Nitride (GaN) as well as new packaged product releases and multichip module capabilities. With a full-service wafer fab including the option of our DoD-accredited 'Trusted Foundry' program, plus our internal package and test capability, TriQuint is uniquely positioned to offer a complete solution to our customer's most demanding requirements. The flexibility that TriQuint provides in offering a variety of process technologies, products and packaging styles is ideal in supporting a growing number of applications such as:

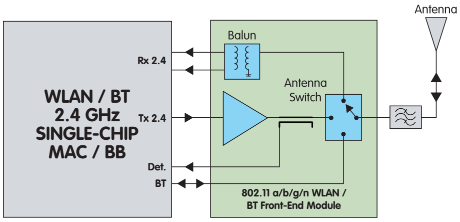
- ***Phased Array Radar***
- ***Communications***
- ***GPS Navigation Systems***
- ***Electronic Warfare***
- ***Missile Systems***


Image Courtesy of Jamie Hunter/Aviacom

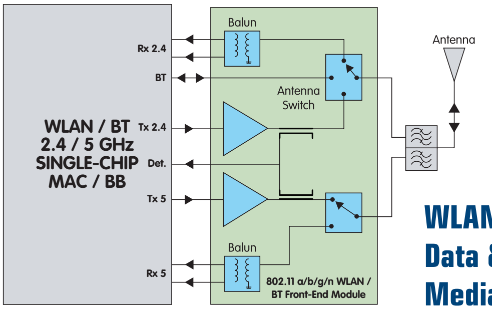
Many TriQuint products listed in this brochure support both commercial and defense-related applications. Those listed under a specific commercial market are also available for defense and aerospace use. If needed, products can be specially screened to meet the unique requirements of our customers. Offering 100% electrical screening along with visual inspection to either MIL-STD-883 Class B or Class S, our customers can be assured they are receiving a high-quality, highly reliable product.

The TriQuint portfolio includes a large array of amplifiers along with key control products such as phase shifters, switches, attenuators and limiters that are ideal for defense and aerospace applications. Along with these active components, TriQuint also offers filter and oscillator products utilizing our in-house SAW and BAW technologies. Filter solutions with center frequencies between 30 MHz and 20 GHz are available in package sizes potentially as small as 1.5x0.8mm. Oscillators, with phase noise as low as -180 dBc/Hz and exceptional g-sensitivity, provide best-in-class performance. Come see what TriQuint can do for you.

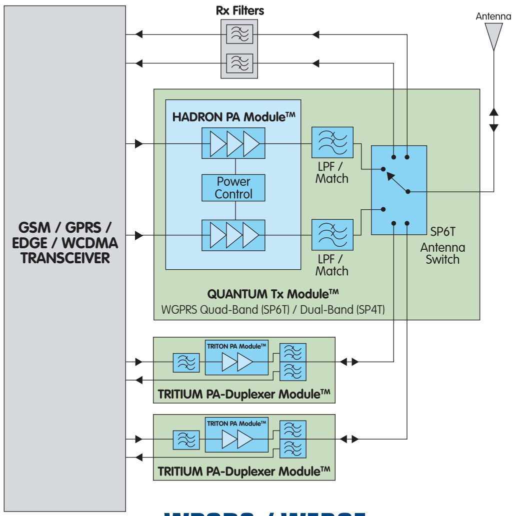
GUIDE BY MARKET | Mobile Devices



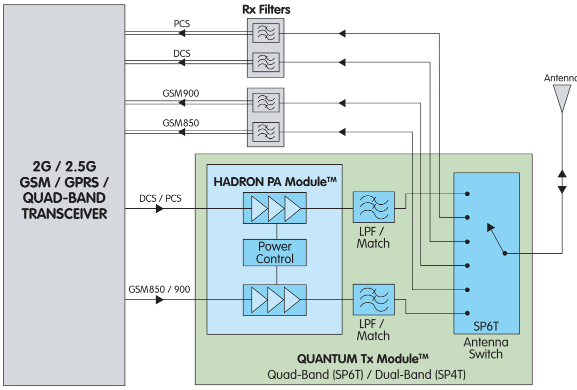
WLAN for Handsets



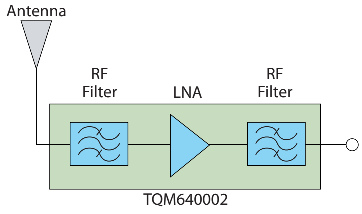
WLAN for Wireless Data & Personal Media Devices



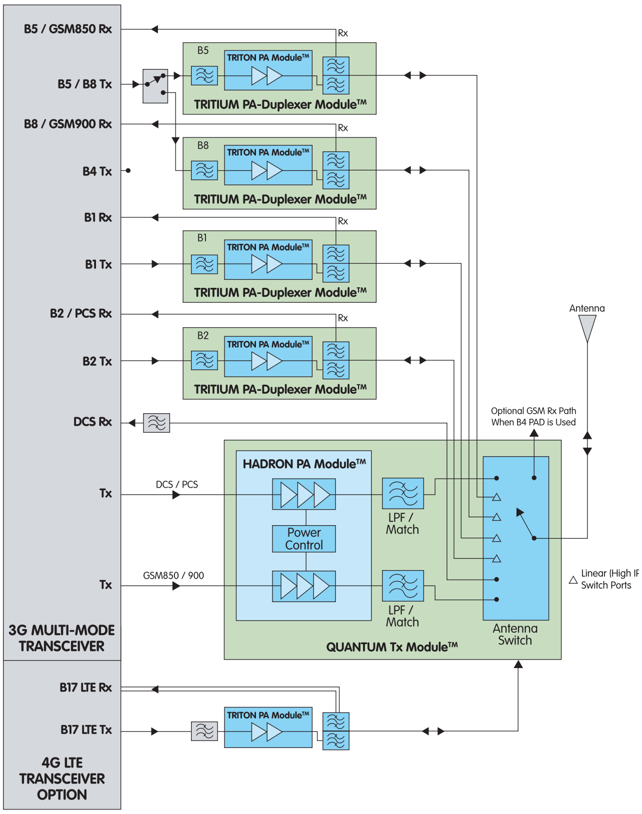
WPGRS / WEDGE



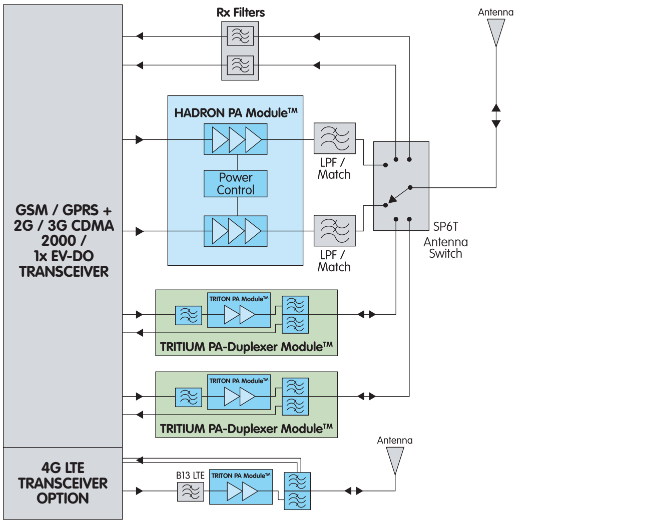
GSM / GPS / EDGE



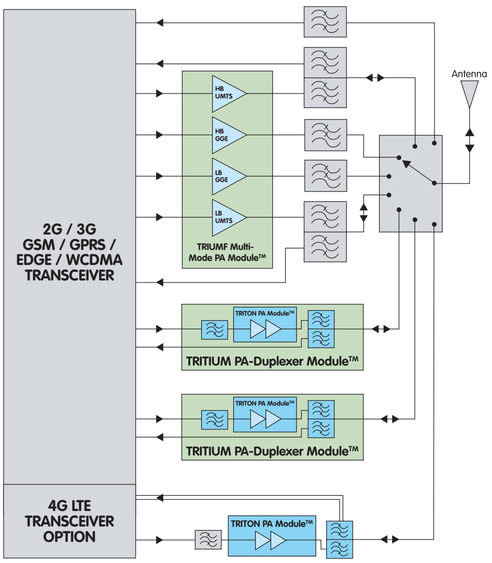
GPS Integrated Module



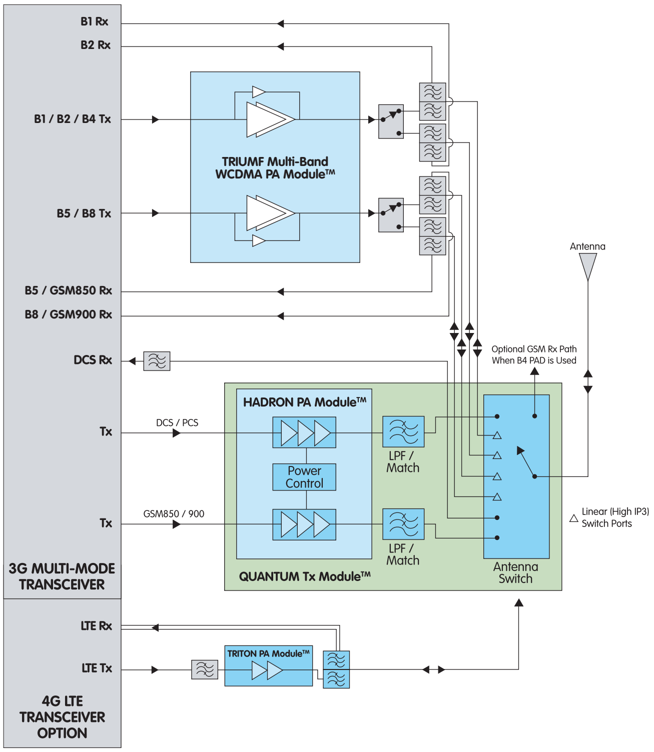
3G - WCDMA / WGPRS / WEDGE, 4G - LTE



3G - CDMA / EV-DO, 4G - LTE



3G - WGPRS / WEDGE, 4G - LTE



3G - WCDMA / WGPRS / WEDGE, 4G - LTE

GSM / GPRS PA Module

Description	Bands	Features	Package Size (mm)	Part Number
Quad-Band GSM / GPRS PA Module	GSM900 & GSM850 / PCS	Low Band Ibatt<1.5A @ Pcal w / PAE 55%	5x5x1	TQM7M4007

QUANTUM Tx Module™ Family (GSM / GPRS / EDGE)

Description	Bands	Features	Package Size (mm)	Part Number
Dual-Band GSM / GPRS Tx Module; PA / LPF / SP4T Switch; Quad-Band Tx & Dual-Band Rx	GSM900 / DCS or GSM850 / PCS	High Efficiency Broadband Tx, 2 Rx Ports	6x6x1	TQM6M4048
Quad-Band GSM / GPRS Tx Module; PA / LPF / SP6T Switch; Quad-Band Tx & Quad-Band Rx	GSM900 / DCS & GSM850 / PCS	High Efficiency Broadband Tx, 4 Rx Ports	6x6x1	TQM6M4049
Dual-Band GSM / GPRS Tx Module; PA / LPF / SP4T Switch; Quad-Band Tx & Dual-Band Rx	GSM900 / DCS or GSM850 / PCS	High Efficiency Broadband Tx, 2 Rx Ports	6x6x1	***TQM6M4050****
Dual-Band GSM / GPRS Tx Module; PA / LPF / SP4T Switch; Quad-Band Tx & Dual-Band Rx	GSM900 / DCS or GSM850 / PCS	High Efficiency Broadband Tx, 2 Rx Ports	5x6x1	***TQM6M4068****

NOTES: **** = New***

HADRON II PA Module™ Family (EDGE, 5x5mm Footprint)

Description	Bands	Features	Package Size (mm)	Part Number
Quad-Band GSM / GPRS / EDGE-Linear PA Module	GSM900 / DCS & GSM850 / PCS	Low Band Ibatt < 1.5A @ Pcal w/PAE 55%	5x5x1	TQM7M5005H
Quad-Band GSM / GPRS / EDGE-Polar PA Module	GSM900 / DCS & GSM850 / PCS	+3 to +8 dBm Pin Nominal	5x5x1	TQM7M5012H
Quad-Band GSM / GPRS / EDGE-Linear PA Module	GSM900 / DCS & GSM850 / PCS	Input Power Controlled for GMSK & 8PSK	5x5x1	TQM7M5013
Quad-Band GSM / GPRS / EDGE-Polar PA Module	GSM900 / DCS & GSM850 / PCS	+3 to +8 dBm Pin Nominal	5x5x1	TQM7M5022

CDMA Switches

Description	Bands	Features	Package Size (mm)	Part Number
CDMA SP3T Switch	Cellular / PCS / AWS	Antenna Routing	2x2x0.6	TQP4M3019

TRITON PA Module™ Family (CDMA, WCDMA / HSUPA, LTE)

Description	Bands	Features	Package Size (mm)	Part Number
WCDMA / HSUPA PA Module, w/Coupler	Band 1	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM776011
CDMA & WCDMA / HSUPA PA Module, w/Coupler	PCS / Band 2	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM766012
CDMA & WCDMA / HSUPA PA Module, w/Coupler	AWS / Band 4	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM756014
CDMA & WCDMA / HSUPA PA Module, w/Coupler	Cellular / Band 5	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM716015
WCDMA / HSUPA PA Module, w/Coupler	Band 8	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM726018
LTE PA Module, w/Coupler	Band 13	LTE 1-Bit (Hi / Lo Power Modes)	3x3x0.9	***TQM700013****

NOTES: **** = New***

TRITIUM II PA-Duplexer Module™ Family (CDMA, 7x4mm Footprint)

Description	Bands	Features	Package Size (mm)	Part Number
CDMA PA-Duplexer Module; SE Input w/Coupler	Cellular	2-Bit (Hi / Med / Lo Power Modes)	7x4x1.1	TQM613029
CDMA PA-Duplexer Module; SE Input w/Coupler	PCS	2-Bit (Hi / Med / Lo Power Modes)	7x4x1.1	TQM663029A
CDMA PA-Duplexer Module; SE Input w/Coupler	AWS	2-Bit (Hi / Med / Lo Power Modes)	7x4x1.1	TQM653029

TRITIUM III PA-Duplexer Module™ Family (WCDMA / HSUPA, 7x4mm Footprint)

Description	Bands	Features	Package Size (mm)	Part Number
WCDMA / HSUPA PA-Duplexer Module; SE Input w/Coupler, Detector	Band 1	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM676021
WCDMA / HSUPA PA-Duplexer Module; SE Input w/Coupler, Detector	Band 2	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM666022
WCDMA / HSUPA PA-Duplexer Module; SE Input w/Coupler, Detector	Band 4	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM656024
WCDMA / HSUPA PA-Duplexer Module; SE Input w/Coupler, Detector	Bands 5 & 6	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM616025
WCDMA / HSUPA PA-Duplexer Module; SE Input w/Coupler, Detector	Band 8	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM626028L

QUANTUM II Tx Module™ Family (WGPRS & WEDGE)

Description	Bands	Features	Package Size (mm)	Part Number
Quad-Band GSM / GPRS / EDGE-Linear TRP Tx Module: PA / LPF / SP8T WEDGE Switch w/ Quad-Band WCDMA Antenna Pass-Through	GSM850 / 900, DCS / PCS & WCDMA B1, B2, B5 / 6, B8	Integrated QB GSM / GPRS / EDGE PA & Antenna Switch Supporting WCDMA TRP Compliant at 4:1 Mismatch	7x7.5x1.1	TQM6M9014
Dual-Band GSM Tx Module: PA / LPF / SP6T WGPRS Switch w/ Dual-Band WCDMA Antenna Pass-Through	GSM900 / DCS of GSM850 / PCS & 2 WCDMA Bands	Integrated DB GSM / GPRS & 2 WCDMA Antenna Switch Ports	5x6x1	***TQM6M9069****

NOTES: ***** = New***

TRIUMF Module™ Family- GSM / GPRS / EDGE / WCDMA / HSUPA / LTE

Description	Bands	Features	Package Size (mm)	Part Number
Multi-Mode Quad-Band GMSK / EDGE / WCDMA PA Module	GSM850 / 900, DCS / PCS & WCDMA B1 & B8	2-Bit (Hi / Med / Lo Power Modes)	5x7.5x1	***TQM7M9023****
Multi-Mode Quad-Band GMSK / EDGE / WCDMA PA Module	GSM850 / 900, DCS / PCS & WCDMA B1 & B5	2-Bit (Hi / Med / Lo Power Modes)	5x7.5x1	***TQM7M9032****
Multi-Band WCDMA / HSUPA / HSPA+ / PA Module	High Bands 1,2,3,4,9,10 & Low Bands 5,6,8	1-Bit (Hi / Lo Power Modes); 1-Bit Band Specific Pout Adjust	5x4x0.9	***TQM7M9070****

NOTES: ***** = New***

3G / 4G Duplexers

Description	Bands	Features	Package Size (mm)	Part Number
LTE SE / BAL SAW Duplexer	Band 13	1.5 dB (Tx) / 1.6 dB (Rx) Insertion Loss	2.5x2x0.6	856879
LTE SE / BAL SAW Duplexer	Band 17	1.8 dB (Tx) / 2 dB (Rx) Insertion Loss	2.5x2x0.6	856931
LTE SE / BAL SAW Duplexer	Band 20	High Performance Temp. Compensated SAW	2.5x2x0.6	***856979****
BC10 SE / BAL SAW Duplexer	BC10 (PCS)	Excellent Triple Beat performance	2.5x2x0.6	***856999****
BC14 SE / SE BAW Duplexer	BC14 (Cellular)	Excellent Triple Beat performance	2.5x2x0.9	***TQM963014****

NOTES: ***** = New***

WLAN PA

Description	Bands	Features	Package Size (mm)	Part Number
802.11a 5 GHz WLAN PA MMIC	802.11 a	ETSLP-16 Package, Detector, Hi / Lo Linearity Mode	3x3x0.45	TQP787011

WLAN Switch

Description	Bands	Features	Package Size (mm)	Part Number
2.4 GHz & 5 GHz SPDT Switch MIMC	802.11 a, b, g	Slim-7 Package	1.3x2x0.45	TQS5200

WLAN LNA / Antenna Switch

Description	Bands	Features	Package Size (mm)	Part Number
2.4 GHz WLAN LNA + SP3T Switch MMIC WLAN Tx & Bluetooth® Paths	802.11 b, g	LNA Bypass, ETSLP-12 Package	1.5x1.5x0.55	TQP879001A

WLAN PA / Antenna Switch

Description	Bands	Features	Package Size (mm)	Part Number
2.4 GHz WLAN PA + Switch MMIC w/WLAN Rx Balun & Bluetooth® Path	802.11 a	ETSLP-16 Package, Coupler / Detector	3x3x0.45	TQM679002A
2.4 GHz & 5 GHz WLAN PA + Switch MMIC w/WLAN Rx Baluns & Bluetooth® Path	802.11 a, b, g, n	ETSLP-24 Package, Coupler / Detector	4x4x0.45	TQP6M9002

WLAN Filters

Description	Bands	Features	Package Size (mm)	Part Number
ISM Passband Filter	2436 MHz	72 MHz Bandwidth, 2 dB Insertion Loss	1.7x1.3x0.46	885007

Bluetooth® PA

Description	Bands	Features	Package Size (mm)	Part Number
Bluetooth® EDR v2.0 Class 1 PA MMIC	2.4 to 2.5 GHz ISM Band	STSLP-12 Package	2x2x0.57	TQP770001

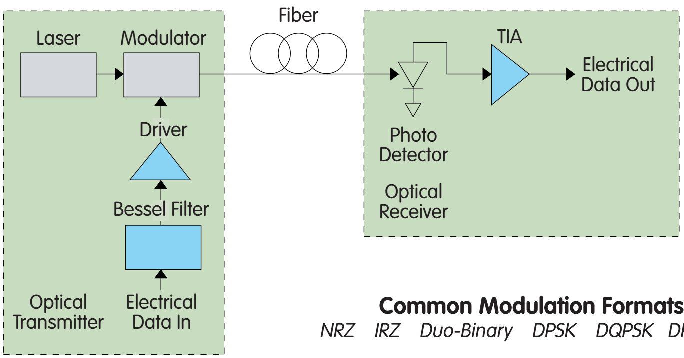
GPS LNA / Filter Module

Description	Bands	Features	Package Size (mm)	Part Number
GPS Filter-LNA-Filter Module	1575 MHz, GPS L1	Low Noise (1.56 dB) and High Gain (16 dB)	3x3x1.0	TQM640002

GPS Filters

Description	Bands	Features	Package Size (mm)	Part Number
GPS SAW Filter, SE / SE	1575 MHz, GPS L1	Ultra-low Insertion Loss of 0.5 dB (Hermetic CSP)	1.4x1.2x0.46	856756
GPS SAW Filter, SE / SE	1575 MHz, GPS L1	0.75 dB Insertion Loss (Hermetic CSP)	1.4x1.2x0.46	856561
GPS SAW Filter, SE / BAL	1575 MHz, GPS L1	1.1 dB Insertion Loss (Hermetic CSP)	1.4x1.2x0.46	856576
GPS SAW Filter, SE / SE	1575 MHz, GPS L1	0.6 dB Insertion Loss (Hermetic CSP)	1.4x1.2x0.46	856793

GUIDE BY MARKET | Optical



Optical Systems (10, 40 & 100 Gb/s)

Common Modulation Formats

NRZ IRZ Duo-Binary DPSK DQPSK DP-QPSK

Drivers

Description	Frequency Range (GHz)	Power	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
9.9 - 12.5 Gb/s 3V - 7V Driver	DC - 13	3 - 7Vpp	32	–	3.3 - 5 / 115	8x8 QFN	TGA4956-SM
9.9 - 12.5 Gb/s Mod. Driver	DC - 16	3 - 10Vpp	35	2.5	5.5 - 8 / 210	11.4x8.9 SL	TGA4953-SL
9.9 - 12.5 Gb/s Mod. Driver	DC - 16	3 - 9Vpp	35	2.5	5.5 - 8 / 210	11.4x8.9 SL	TGA4954-SL
12.5 Gb/s NRZ Driver	DC - 18	3 - 11Vpp	16	–	8 / 285	Die	TGA4807
12.5 Gb/s NRZ Driver	DC - 18	6 - 8Vpp	16	3.5	5 - 8 / 70 - 175	Die	TGA1328-SCC
12.5 Gb/s NRZ Driver	DC - 18	4 - 8Vpp	16	3.5	8 / 175	8.9x8.9 SL	TGA8652-SL
15 Gb/s 10V Linear Mod. Driver	DC - 20	3 - 10Vpp	22	–	7 / 280	6x6 QFN	TGA4826-SM
40 & 100 Gb/s 8 Vpp SE Driver	DC - 30	3 - 9Vpp	32	–	6 - 7 / 270	14.4x7 SL	TGA4943-SL
45 Gb/s 8V pp SE Driver	DC - 35	5 - 9Vpp	30	–	6 - 7 / 300	16x8 SL	**TGA4942-SL****
45 Gb/s 9Vpp Diff In / Out Driver	DC - 50	6 - 10Vpp Diff	27 Diff	–	5 - 6 / 500	Die	**TGA4958****
32 Gb/s 9Vpp Diff In / Out Driver	DC - 35	6 - 9Vpp Diff	25 Diff	–	5 - 6 / 500	10x7 SL	**TGA4959-SL****
Wideband Driver (40 Gb/s)	DC - 35	4Vpp	12	–	5 / 135	Die	TGA4832
43 Gb/s Driver	DC - 78	3.5Vpp	8	5	6 / 82	Die	TGA4803
10.7 - 12.5 Gb/s Linear Mod. Driver	0.03 - 8	12.5Vpp	20	–	8 / 310	8x8 QFN	TGA4823-2-SM

NOTES: **** = Coming Soon**, SB = Self Biased, SE = Single-Ended

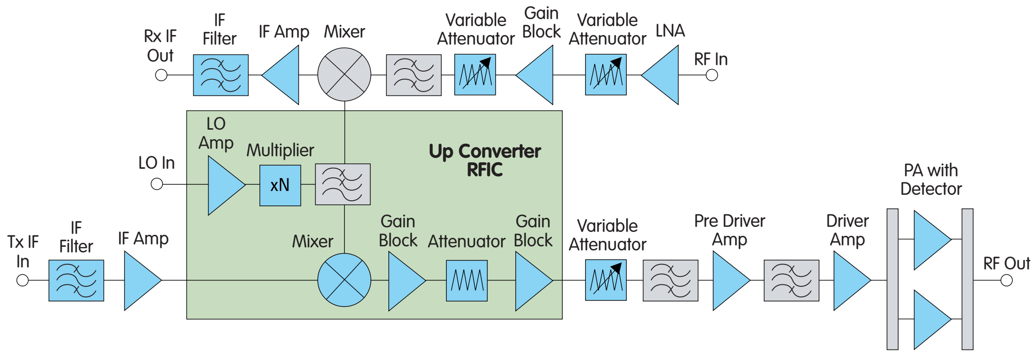
Amplifiers

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
LNA / Gain Block (40 Gb/s)	DC - 40	11.5	13	3.2	5 / 50	Die	TGA4830
CATV TFA / Gain Block	0.04 - 1	27 / 46	20	1.5	8 / 350	4x4 QFN	TGA2803-SM

Control Products

Description	Frequency Range (GHz)	Insertion Loss (dB)	Control Range (dB)	P1dB (dBm)	Supply Voltage (V)	Package Style (mm)	Part Number
Analog Attenuator	DC - 30	2	17	–	0 to -2	3x3 QFN	TGL4203-SM
Analog Attenuator	DC - >50	2	17	–	0 to -2	Die	TGL4203
Discrete Thru (0 dB Attenuator)	DC - 65	0	0	–	–	Die	TGL4201-00
Discrete Attenuators	DC - 65	–	2, 3, 6, 10	–	–	Die	TGL4201-02, 03, 06, 10
Bessel Filter	–	6, 7, 8, 9, 10 & 11 Cut-Off Freq	–	–	–	Die	TGB2010-00, -09 etc.
Bessel Filter	–	5, 6, 6.5, 7.5, 8 & 9 Cut-Off Freq	–	–	–	2x2 QFN	TGB2010-00, -09-SM etc.

GUIDE BY MARKET | PtP Radio



Point-to-Point Radio

Amplifiers

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
2W HPA	5.5 - 8.5	32 (34) / 41	30	7 / –	6 / 1260	5x5 QFN	TGA2706-SM
2.5W HPA	5.9 - 8.5	34 / 42	18	7.5 / 37	6 / 1000	6x6 QFN	TGA2701-SM
HPA	6 - 18	(34.5) / –	24	– / 20	8 / 1200	Die	TGA9092-SCC
Gain Block	6 - 18	12.5 / –	13	5 / –	5 / 80	Die	TGA8035-SCC
2.8W HPA	6 - 18	(34.5) / –	24	– / 20	7 - 9 / 800 - 1200	Die	TGA2501
HPA	7 - 8.5	(38) / –	21	– / 42	7 / 2000	Die	TGA2701
Driver Amp	7 - 13	(30) / 37	25	– / 30	9 / 450	Die	TGA2700
Wideband Driver Amp	8 - 18	13 / –	17	5 / –	4.5 / 50	Die	TGA8399C
HPA	9 - 10.5	(38) / –	20	– / >38	4 - 9 / 2000	Die	TGA2704
HPA	10.5 - 12	(38) / –	19	– / >39	4 - 9 / 2000	Die	TGA2710
Driver Amp, SB	11 - 17	17 / –	23	6 / –	6 / 75	4x4 QFN	TGA2507-SM
Driver Amp	12 - 16	26 (26.5) / 37	23	7 / –	5 / 300	3x3 QFN	***TGA2524-SM****
Driver Amp, SB	12 - 18	14 / –	17	–	6 / 40	Die	TGA2506
Driver Amp, SB	12 - 18	20 / –	28	6 / –	6 / 80	Die	TGA2507
1W HPA	12 - 19	30 / –	30	–	5 - 7 / 435	Die	TGA2508
HPA	12 - 19	29 / –	25	–	5 - 7 / 435	4x4 QFN	TGA2508-SM
2W HPA	12.3 - 15.7	(31) / –	33	7.0 / –	6 / 850	Die	TGA2520
2W HPA	12.5 - 16	(32) / 37	32	–	6 - 7 / 680	4x4 QFN	TGA2503-SM
2W HPA	12.5 - 17	(34) / –	26	– / 25	7.5 / 650	Die	TGA2510
2W HPA	12.5 - 17	(33.5) / –	25	– / 25	7.5 / 650	6.4x9.4 SG	TGA2510-SG
2W HPA	12.7 - 15.4	34 (35) / 43	28	6 / –	6 / 1300	Die	***TGA2533****
2W HPA	12.7 - 15.4	33 (34.5) / 43	27	6 / –	6 / 1300	5x5 QFN	***TGA2533-SM****
2W HPA	13 - 17	(34) / 40	32	–	6 - 7 / 680	Die	TGA2503
2W HPA	13 - 17	(34) / –	25	–	6 - 7 / 640	Die	TGA2505
2W HPA	13 - 17	(34) / –	33	–	5 - 8 / 680	17.8x8.4 FL	TGA2904-FL
2W HPA, PD	13 - 17	(34) / 38.5	26	– / 30	7.5 / 650	6.4x9.4 SG	TGA2902-1-SCC-SG
2W HPA	13 - 17	(34) / 40	33	–	5 - 8 / 680	6.4x9.4 SG	TGA8658-SG
4W HPA, Balanced	13 - 17	(36) / 44	25	– / 30	6 - 7 / 1300	Die	TGA2502
2W HPA, PD	13.75 - 14.5	(34) / 38.5	26	– / 30	7.5 / 650	6.4x9.4 SG	TGA2902-2-SCC-SG
1W HPA, PD	17 - 20	30 (32) / 42	20	–	5 - 7 / 825	Die	TGA4530
HPA	17 - 20	31 / 41	22	6.5 / –	6 / 820	4x4 QFN	TGA4532-SM
HPA	17 - 20	30.5 / 41	23	–	6 / 900	Die	TGA4532
Driver Amp	17 - 24	22 / –	19	4 / –	5 / 270	4x4 QFN	TGA2521-SM
HPA	17 - 24	31 (32) / 40	23	6 / –	7 / 720	Die	TGA4531
HPA, AGC, PD	17 - 24	(29) / 38	22	–	5 / 712	4x4 QFN	TGA2522-SM
HPA	17 - 27	29 (31) / 37	22	–	7 / 760	Die	TGA4502-SCC
Gain Block & 2x / 3x Multiplier	17 - 37	18 (22) / 26	20	7 / –	5 / 140	3x3 QFN	TGA4030-SM
Gain Block & 2x / 3x Multiplier	17 - 40	18 (22) / 24	22	7 / –	5 / 140	3x3 QFN	TGA4031-SM
Gain Block, Multiplier	17 - 43	22 / –	25	–	5 / 225	Die	TGA4040
2W HPA	18 - 23	32 (33) / 39	26	–	7 / 840	Die	TGA4022
HPA	18 - 27	29 / 37	14	–	6 / 480	Die	TGA1135-SCC
MPA	19 - 27	25 / 32	22	–	5 - 7 / 220	Die	TGA1073G-SCC
Gain Block	19 - 38	(22) / 30	20	–	5 / 160	Die	TGA4036
HPA	21 - 24	31 (32) / 41	22	6 / –	6 / 880	4x4 QFN	***TGA4533-SM****
MPA	25 - 35	25 / –	18	–	6 / 220	4x4 QFN	TGA4902-SM
MPA	26 - 35	25 (32) / –	19	–	5 - 7 / 220	Die	TGA1073A-SCC
1W HPA	27 - 31	30 / –	22	– / 25	4 - 6 / 420	Die	TGA4509
2W HPA	27 - 31	32.5 (33) / 36.5	20	–	6 / 840	Die	TGA4513
HPA	27 - 32	28.5 / –	25	–	6 - 8 / 420	Die	TGA1073B-SCC
1W HPA	28 - 31	30 / –	19	– / 25	6 / 420	4x4 QFN	TGA4509-SM
Driver Amp	29 - 37	16 / –	16	–	6 / 60	Die	TGA4510

NOTES: **** = New***, SB = Self Biased, AGC = Automatic Gain Control, PD = Power Detector

Amplifiers (cont.)

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
2W HPA	30 - 40	31.5 (33) / –	20	–	6 / 1050	Die	TGA4516
MPA	32 - 45	24 (25) / 33	16	–	6 / 175	Die	TGA4521
MPA	33 - 47	27 (27.5) / 36	18	–	6 / 400	Die	TGA4522
HPA	37 - 40	28 / 38	24	–	5 / 600	Die	TGA4538
HPA	36 - 40	26 / –	15	–	5 - 7 / 240	Die	TGA1073C-SCC
HPA	36 - 40	30 / –	14	–	6 - 7 / 500	Die	TGA1171-SCC

Low Noise Amplifiers

Description	Frequency Range (GHz)	P1dB / IIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
LNA, AGC	2 - 18	18 / 29	17	2	5 / 75	Die	TGA2525
LNA, AGC	2 - 20	19 / –	17.5	2.5	5 / 100	Die	TGA2526
LNA, AGC	2 - 20	17.5 / –	9	3.5	5 - 8 / 60	Die	TGA1342-SCC
LNA, AGC	2 - 20	16 / –	17	2.5	5 / 75	4x4 QFN	TGA2513-SM
LNA, AGC	2 - 23	17 / 26	17	2	5 / 75	Die	TGA2513
LNA, SB, AGC	4 - 14	6 / 16	22	2.3	5 / 90	4x4 QFN	TGA2512-1-SM
LNA, AGC, GB	4 - 14	13 / 24	25	2.3	5 / 160	4x4 QFN	TGA2512-2-SM
LNA, SB, AGC	5 - 15	6 / 13	27	1.4	5 / 90	Die	TGA2512
LNA, SB	6 - 13	11 / –	26	1.5	5 / 65	Die	TGA8399B-SCC
LNA, SB, AGC	6 - 14	6 / 12	20	1.3	5 / 90	Die	TGA2511
LNA	20 - 27	12 / –	21	2.2	3.5 / 60	Die	TGA4506
LNA	28 - 36	12 / 21	22	2.3	3 / 60	Die	TGA4507
LNA	30 - 42	14 / –	21	2.8	3 / 40	Die	TGA4508
LNA	57 - 69	–	13	4	3 / 41	Die	TGA4600

NOTES: SB = Self Biased, AGC = Automatic Gain Control, GB = Gate Bias

Discrete Transistors

Description	Frequency Range (GHz)	P1dB (Psat) (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
24mm HFET	DC - 4	40	13	– / 51	8 / 2170	Die	TGF4124
18mm HFET	DC - 6	38.5	13.5	– / 53	8 / 1690	Die	TGF4118
12mm HFET	DC - 8	37	14	– / 55	8 / 750	Die	TGF4112
4.8mm HFET	DC - 10.5	34	8.5	– / 53	8 / 200	Die	TGF4250-SCC
9.6mm HFET	DC - 10.5	37	9.5	– / 52	8.5 / 520	Die	TGF4260-SCC
1.2mm HFET	DC - 12	28.5	10	– / 55	8 / 50	Die	TGF4230-SCC
2.4mm HFET	DC - 12	31.5	10	– / 56	8 / 100	Die	TGF4240-SCC
1mm Pwr pHEMT	DC - 12	(31.5)	11	– / 55	12 / 900	Die	TGF2021-01
2mm Pwr pHEMT	DC - 12	(34.5)	11	– / 55	12 / 150	Die	TGF2021-02
4mm Pwr pHEMT	DC - 12	(37.5)	11	– / 55	12 / 300	Die	TGF2021-04
8mm Pwr pHEMT	DC - 12	(40.2)	11	– / 55	12 / 600	Die	TGF2021-08
12mm Pwr pHEMT	DC - 12	(42)	11	– / 52	12 / 900	Die	TGF2021-12
0.3mm MESFET	DC - 18	13	11	1.5 / –	3 / 15	Die	TGF1350-SCC
0.6mm Pwr pHEMT	DC - 20	(29)	13	– / 56	12 / 45	Die	TGF2022-06
1.2mm Pwr pHEMT	DC - 20	(32)	13	– / 56	12 / 90	Die	TGF2022-12
2.4mm Pwr pHEMT	DC - 20	(35)	13	– / 58	12 / 180	Die	TGF2022-24
4.8mm Pwr pHEMT	DC - 20	(38)	13	– / 58	12 / 360	Die	TGF2022-48
6mm Pwr pHEMT	DC - 20	(39)	12.5	– / 53	12 / 448	Die	TGF2022-60
0.3mm pHEMT	DC - 22	16	13	0.8 / –	3 / 15	Die	TGF4350

Switches

Description	Frequency Range (GHz)	Insertion Loss (dB)	Isolation (dB)	P1dB (dBm)	Control Voltage (V)	Package Style (mm)	Part Number
SP2T 802.11 a, b, g	DC - 6	0.6	28	31.5	3 / 0	1.3x2 DFN	TQS5200
SPDT FET	DC - 18	1.5	36	27	-5	Die	TGS2306
SPDT FET	DC - 18	2	39	21	-7 / 0	Die	TGS8250-SCC
SP3T VPIN	1 - 20	0.5	35	23	10 mA	Die	TGS2303
SP4T VPIN	1 - 20	0.6	38	23	10 mA	Die	TGS2304-SCC
SP3T VPIN	4 - 18	1	35	20	+/- 2.7	Die	TGS2313
SPDT VPIN	4 - 20	0.9	35	>20	+/- 2.7	Die	TGS2302
SPDT VPIN	24 - 43	<2	36	27	+/- 5	Die	TGS4301
SPDT VPIN	27 - 46	0.9	30	>34	+/ -5 / 15	Die	TGS4302
SPDT VPIN Absorptive	32 - 40	1	36	>33	+/- 5 / 18	Die	TGS4304

Frequency Converters & Mixers

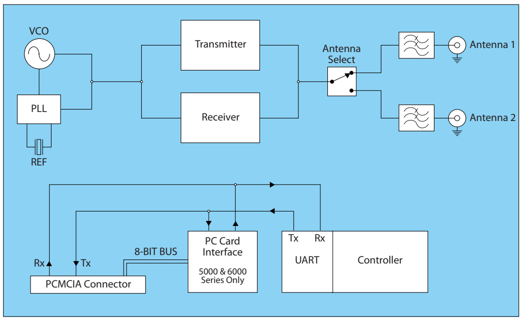
Description	RF Frequency Range (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
Doubler w/Amplifier	16 - 30	18	30	–	5 / 150	Die	TGC4403
Doubler w/Amplifier	16 - 30	18	30	–	5 / 150	4x4 QFN	TGC4403-SM
Upconverting Mixer	17 - 26	-9	40	–	-0.9 / 0	4x4 QFN	TGC4402-SM
Upconverting Mixer	17 - 27	-9	35	18	-0.9 / 0	Die	TGC4402
Upconverter	17 - 27	13	30	–	5 / 425	Die	TGC4405
Upconverter	17 - 27	13	30	–	5 / 425	4x4 QFN	TGC4405-SM
Gain Block & 2x / 3x Multiplier	17 - 37	9	–	6	5 / 140	3x3 QFN	TGA4030-SM
Gain Block & 2x / 3x Multiplier	17 - 40	9	–	2	5 / 140	3x3 QFN	TGA4031-SM
Doubler (Input 10 - 20 GHz)	20 - 40	-12	25	18	–	Die	TGC1430F
Tripler (Input 8.5 - 13.5 GHz)	20 - 40	-15	15	18	–	Die	TGC1430G

Control Products

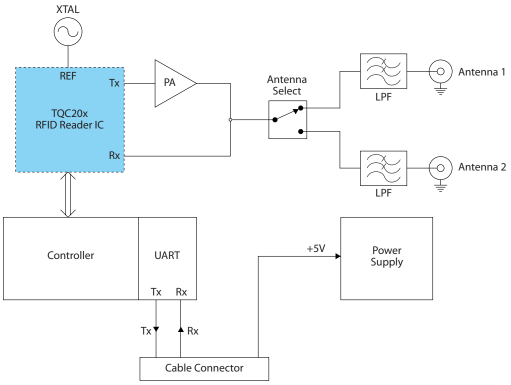
Description	Frequency Range (GHz)	Insertion Loss (dB)	Control Range (dB)	P1dB (dBm)	Supply Voltage (V)	Package Style (mm)	Part Number
Discrete Thru (0 dB Attenuator)	DC - 65	0	0	–	–	Die	TGL4201-00
Analog Attenuator	DC - >50	2	17	–	0 to -2	Die	TGL4203
Analog Attenuator	DC - 30	2	17	–	0 to -2	3x3 QFN	TGL4203-SM
Discrete Attenuators	DC - 65	–	2, 3, 6, 10	–	–	Die	TGL4201-02, 03, 06, 10
Analog Attenuator	2 - 20	2	15	23	2.5	Die	TGL8784-SCC
Passive Wideband Limiter	3 - 25	<0.5	–	18	–	Die	TGL2201
Lange Coupler	12 - 21	<0.25	–	–	–	Die	TGB2001
Lange Coupler	18 - 32	<0.25	–	–	–	Die	TGB4001
Lange Coupler	27 - 45	<0.25	–	–	–	Die	TGB4002

Filters

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
High Selectivity IF Filter	140	1.5	12.1	SE and BAL	48 @ 143	9.1x4.8	856691
High Selectivity IF Filter	140	3	13.6	SE and BAL	46 @ 144	9.1x4.8	856692
High Selectivity IF Filter	140	6	11	BAL / BAL	39 @ 147	9.1x4.8	856693
High Selectivity IF Filter	140	7	13.6	SE and BAL	43 @ 147	9.1x4.8	856694
High Selectivity IF Filter	140	10	10	BAL / BAL	41 @ 152.5	9.1x4.8	856695
High Selectivity IF Filter	140	14	8.5	SE and BAL	43 @ 155	9.1x4.8	856696
High Selectivity IF Filter	140	20	9.8	BAL / BAL	40 @ 158.5	9.1x4.8	856697
High Selectivity IF Filter	140	28	18	SE and BAL	42 @ 168	9.1x4.8	856698



WJR Series Functional Block Diagram



WJM Series Application Block Diagram

UHF RFID Modules

Description	Frequency Range (MHz)	Channels / Spacing (kHz)	Max Output Power (W)	Protocol Support	Region of Operation	Interface	Part Number
Reader PCMCIA Form Factor Module (ETSI 302.208)	865.7 - 867.5	4 / 600	1	ISO18000-6B & -6C	Europe	Serial TTL	WJR7081
Reader PCMCIA Form Factor Module (FCC Pt 15)	902.75 - 927.25	50 / 500	1	ISO18000-6C	N. America	Serial TTL	WJR7000
Embedded Reader Module (FCC Pt 15)	902.75 - 927.25	50 / 500	1	ISO18000-6B & -6C	N. America	Serial TTL	WJM3000
Embedded Reader Module (FCC Pt 15)	902.75 - 927.25	50 / 500	0.25	ISO18000-6B & -6C	N. America	Serial TTL	WJM1000
PCMCIA Form Factor Module	910.6 - 913.4	15 / 200	1	ISO18000-6B & -6C	Korea	Serial TTL	WJR7090
PCMCIA Reader Module (FCC Pt 15)	902.75 - 927.25	50 / 500	0.5	ISO18000-6B & -6C	N. America	PCMCIA	WJR6000

GUIDE BY MARKET | Space

Qualified Amplifiers

TriQuint has a proud space / aerospace history, supplying highly-reliable active / acoustic devices for satellite and planetary missions. Space qualification includes high-level visual inspection, 100% element electrical results and wafer lot qualification testing. See tables for standard products already space qualified; most foundry and standard products throughout this brochure may be space qualified.

Qualified Amplifiers

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
12.5 Gb/s NRZ Driver	DC - 18	24 / –	16	3.5 / –	5 - 8 / 70 - 175	Die	TGA1328-SCC
Wideband Driver (40 Gb/s)	DC - 35	18 / –	12	–	5 / 135	Die	TGA4832
Gain Block, SB	2 - 10	17 / –	17	6 / –	5 / 90	Die	TGA8810-SCC
Gain Block	2 - 18	20 / –	7.5	5.5 / –	6 / 100	Die	TGA8300-SCC
Wideband Gain Block, AGC	2 - 20	20 / –	7.5	7 / –	6 / 150	Die	TGA8622-SCC
Wideband PA, AGC	2 - 20	26 / –	8	–	8 / 440	Die	TGA8334-SCC
0.5W PA	6 - 18	27 / –	11	8 / –	8 / 400	Die	TGA8014-SCC
HPA	6.5 - 11.5	37 (39) / –	19	– / 35	7 - 9 / 1200	Die	TGA9083-SCC
Wideband Driver Amp	8 - 18	13 / –	17	5 / –	4.5 / 50	Die	TGA8399C
HPA	9 - 10.5	(38) / –	20	– / >38	4 - 9 / 2000	Die	TGA2704
Driver Amp, SB	11 - 17	17 / –	23	6 / –	6 / 75	4x4 QFN	TGA2507-SM

NOTES: SB = Self Biased, AGC = Automatic Gain Control

Qualified Amplifiers (cont.)

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
Driver Amp, SB	12 - 18	20 / –	28	6 / –	6 / 80	Die	TGA2507
2W HPA	12.5 - 17	(34) / –	26	– / 25	7.5 / 650	Die	***TGA2510****
4W HPA, Balanced	13 - 17	(36) / 44	25	– / 30	6 - 7 / 1300	Die	TGA2502
2W HPA	18 - 23	32 (33) / 39	26	–	7 / 840	Die	***TGA4022****
Gain Block	19 - 38	(22) / 30	20	–	5 / 160	Die	TGA4036
HPA	24 - 31	35.5 (36) / –	23	–	6 / 2100	Die	TGA4505
3.5W HPA	31 - 37	(35.5) / –	20	–	6 / 2000	Die	TGA4517
MPA	32 - 45	24 (25) / 33	16	–	6 / 175	Die	TGA4521
HPA	36 - 40	30 / –	14	–	6 - 7 / 500	Die	***TGA1171-SCC****

NOTES: **** = Newly Qualified***, SB = Self Biased

Qualified Low Noise Amplifiers

Description	Frequency Range (GHz)	P1dB (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
LNA, AGC	DC - 14	16	11	3.1	8 / 80	Die	TGA8349-SCC
LNA, AGC	2 - 18	16	19	4	5 / 120	Die	TGA8344-SCC
LNA, AGC	2 - 20	17.5	9	3.5	5 - 8 / 60	Die	TGA1342-SCC
LNA, AGC	2 - 20	17.5	9	3.5	5 - 8 / 60	Die	TGA8310-SCC
LNA, SB	6 - 13	11	26	1.5	5 / 65	Die	TGA8399B-SCC
LNA	20 - 27	12	21	2.2	3.5 / 60	Die	TGA4506
LNA	28 - 36	12 / 21	22	2.3	3 / 60	Die	***TGA4507****
LNA	30 - 42	14	21	2.8	3 / 40	Die	TGA4508

NOTES: **** = Newly Qualified***, SB = Self Biased, AGC = Automatic Gain Control

Qualified Frequency Converters & Mixers

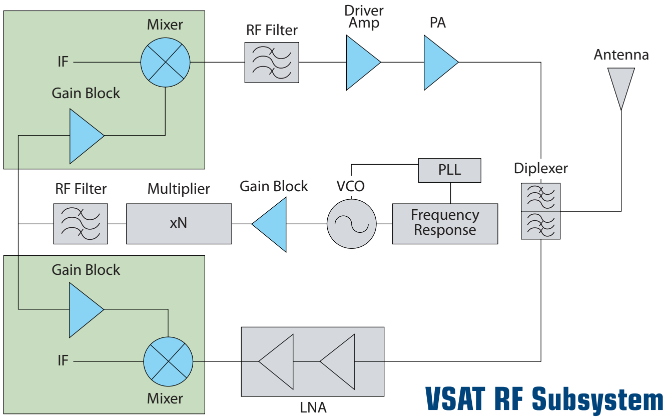
Description	RF Frequency Range (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage / Current (V / mA)	Package Style	Part Number
Tripler (Input 8.5 - 13.5 GHz)	20 - 40	-15	15	18	–	Die	TGC1430G

Qualified Optical Drivers

Description	Frequency Range(GHz)	Power	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
12.5 Gb/s NRZ Driver	DC - 18	6 - 8Vpp	16	3.5	5 - 8 / 70 - 175	Die	TGA1328-SCC
Wideband Driver (40 Gb/s)	DC - 35	4Vpp	12	–	5 / 135	Die	TGA4832

Qualified Control Products

Description	Frequency Range (GHz)	Insertion Loss (dB)	Control Range (dB)	P1dB (dBm)	Supply Voltage (V)	Package Style	Part Number
Analog Attenuator	DC - >50	2	17	–	0 to -2	Die	TGL4203
Analog Attenuator	2 / 20	2 - 20	15	23	2.5	Die	TGL8784-SCC



VSAT RF Subsystem

Amplifiers

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
Driver Amp, SB	11 - 17	17 / –	23	6 / –	6 / 75	4x4 QFN	TGA2507-SM
Driver Amp, SB	12 - 18	14 / –	17	–	6 / 40	Die	TGA2506
Driver Amp, SB	12 - 18	20 / –	28	6 / –	6 / 80	Die	TGA2507
1W HPA	12 - 19	30 / –	30	–	5 - 7 / 435	Die	TGA2508
HPA	12 - 19	29 / –	25	–	5 - 7 / 435	4x4 QFN	TGA2508-SM
2W HPA	12.3 - 15.7	(31) / –	33	7 / –	6 / 850	Die	TGA2520
2W HPA	12.5 - 16	(32) / 37	32	–	6 - 7 / 680	4x4 QFN	TGA2503-SM
2W HPA	12.5 - 17	(34) / –	26	– / 25	7.5 / 650	Die	TGA2510
2W HPA	12.5 - 17	(33.5) / –	25	– / 25	7.5 / 650	9.4x6.4 SG	TGA2510-SG
4W HPA	13 - 15	(36) / 41	25	–	7 / 1300	8.4x17.8 FL	TGA8659-FL
6.5W HPA	13 - 16	(38) / –	24	–	8 / 2600	11.4x17.3 FL	TGA2514-FL
2W HPA	13 - 17	(34) / 40	32	–	6 - 7 / 680	Die	TGA2503
2W HPA	13 - 17	(34) / –	25	–	6 - 7 / 640	Die	TGA2505
2W HPA	13 - 17	(34) / –	33	–	5 - 8 / 680	8.4x17.8 FL	TGA2904-FL
2W HPA	13 - 17	(34) / 40	33	–	5 - 8 / 680	9.4x6.4 SG	TGA8658-SG
2W HPA, PD	13 - 17	(34) / 38.5	26	– / 30	7.5 / 650	9.4x6.4 SG	TGA2902-1-SG
4W HPA, Balanced	13 - 17	(36) / 44	25	– / 30	6 - 7 / 1300	Die	TGA2502
6.5W HPA	13 - 18	(38) / 44	24	–	8 / 3600	Die	TGA2514
2W HPA, PD	13.75 - 14.5	(34) / 38.5	26	– / 30	7.5 / 650	9.4x6.4 SG	TGA2902-2-SG
4W HPA	24 - 31	35.5 (36) / –	23	–	6 / 2100	Die	TGA4505
4W HPA	25 - 31	35.5 (36) / –	22	–	6 / 2100	13.34x9.65 CP	TGA4905-CP
MPA	25 - 35	25 / –	18	–	6 / 220	4x4 QFN	TGA4902-SM
7W HPA	26 - 31	(38.5) / –	22	–	6 / 4200	13.4x16.5 CP	TGA4915-CP
1W HPA	27 - 31	30 / –	22	– / 25	4 - 6 / 420	Die	TGA4509
2W HPA	27 - 31	32.5 (33) / 36.5	20	– / 25	6 / 840	Die	TGA4513
MPA	27 - 32	24 / –	15	–	5 / 170	4x4 QFN	TGA4903-SM
1W HPA	28 - 31	30 / –	19	– / 25	6 / 420	4x4 QFN	TGA4509-SM
4W HPA	28 - 31	36 (36.5) / –	22	– / 22	6 / 1600	Die	TGA4906
4W HPA	28 - 31	36 (36.5) / –	22	– / 22	6 / 1600	5x5 QFN	TGA4906-SM
7W HPA	28 - 31	(38.5) / –	22	– / 20	6 / 3200	Die	TGA4916
Driver Amp	28 - 32	17 / 24	14.5	–	6 / 60	3x3 QFN	TGA4512-SM
Driver Amp	29 - 37	16 / –	16	–	6 / 60	Die	TGA4510

NOTES: SB = Self Biased, PD = Power Detector

Frequency Converters & Mixers

Description	RF Frequency Range (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
Doubler w/Amplifier	16 - 30	18	30	–	5 / 150	Die	TGC4403
Doubler w/Amplifier	16 - 30	15	25	–	5 / 150	4x4 QFN	TGC4406-SM

Up to 1W

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage Current (V / mA)	Package Style (mm)	Part Number
CATV Gain Block, Flex Gain	DC - 2	21 / 38	16 - 21	2 / –	5 - 8 / 100	SOT89	***TAT7457****
12.5 Gb/s NRZ Driver	DC - 18	24 / –	16	3.5 / –	5 - 8 / 70 - 175	Die	TGA1328-SCC
12.5 Gb/s NRZ Driver	DC - 18	25 / –	16	3.5 / –	8 / 175	8.9x8.9 SL	TGA8652-SL
Wideband Driver (40 Gb/s)	DC - 35	18 / –	12	–	5 / 135	Die	TGA4832
CATV TIA / Gain Block, SB	0.04 - 1	27 / 46	20	1.5 / –	8 / 350	5x5 QFN	TGA2806-SM
CATV Gain Block	0.04 - 1	28 / –	18.5	2.5 / –	6 / 318	5x5 QFN	TGA2807-SM
On-Chip Linearized Amplifier DOCSIS® 3.0 Out	0.04 - 1	– / 43	17	4.7 / –	5 / 380	SOIC-8	TAT7467H
MESFET Amplifier	0.05 - 1	20 / 40	14.8	3.5 / –	5 / 150	SOT89	AH2
Dual HBT Amplifier	0.05 - 1	20 / 37	13.5	4.5 / –	>7 / 165	SOIC-8	AG606
Dual MESFET Amplifier	0.05 - 1	25.5 / 43	11.1	4.5 / –	5 / 320	SOIC-8	AH22S
MESFET IF Amplifier	0.05 - 1	22 / 42	19	2.2 / –	5 / 150	SOT89	AH31
Fiber to the Home TIA + Output Amp	0.05 - 1	-60 dBc CTB / CSO	38	2.9 pA / rtHz EIN	10 - 12 / 120	4x4 QFN	***TAT6254B****
Fiber to the Home TIA + Output Amp (RFoG)	0.05 - 1	-62 dBc CTB / CSO	32	3.9 pA / rtHz EIN	5, 12 / 200, 130	4x4 QFN	TAT6254D
Fiber to the Home TIA + Output Amp (Hi Out)	0.05 - 1	-63 dBc CTB / CSO	33	3.9 pA / rtHz EIN	5, 12 / 200, 130	4x4 QFN	TAT6254C
Dual pHEMT Amplifier, High Gain	0.05 - 1	– / 38	17.5	3.2 / –	5 / 235	SOIC-8	TAT7469
CATV Gain Block, High Gain, MOCA Multi	0.05 - 1	– / 41	22.5	2 / –	8 / 190	SOT89	TAT7430B
CATV Gain Block, High Gain, MOCA	0.05 - 1	– / 39	18	2 / –	6 / 145	SOT89	TAT7427
CATV Gain Block	0.05 - 1	– / 39	16	2.7 / –	6 / 130	SOT89	TAT7461
MESFET Amplifier	0.05 - 1.5	26.5 / 47	13.5	3.5 / –	9 / 200	SOT89	AH101
Dual pHEMT Amplifier	0.05 - 2	– / 41	13	4 / –	6 / 190	SOIC-8	TAT7466
30 dBm MESFET Amplifier	0.05 - 2.2	30 / 47	17	2.5 / –	11 / 330	6x6 QFN	AH202
Dual pHEMT Amplifier, Wideband	0.05 - 2.6	-77 dBc CTB / -83 dBc CSO	13	4.4 / –	5 / 160	SOIC-8	TAT7464
CATV Gain Block, Wideband	0.05 - 2.6	– / 36	16.5	2.5 / –	5 / 100	SOT89	TAT7460
24 dBm HBT Amplifier	0.06 - 2.5	24 / 40	19	5 / –	5 / 150	SOT89	AH114
MESFET Amplifier, 2-Stage	0.06 - 2.7	27 / 46	29	2.5 / –	4.5; 9 / 275	SOIC-8	AH103A
MESFET Gain Block	0.06 - 3	15 / 32	14	2.4 / –	4.5 / 50	SOT89	AG101
MESFET Gain Block	0.06 - 3	18 / 36	14	2.4 / –	4.5 / 70	SOT89	AG102
MESFET Gain Block	0.06 - 3	18 / 39	14	2.4 / –	4.5 / 78	SOT89	AM1
24.7 dBm HBT Amplifier	0.06 - 3.5	24.7 / 40	19.5	4 / –	5 / 160	SOT89	AH118
24.5 dBm HBT Amplifier	0.05 - 4	24.5 / 41.4	21	4.5 / -	5 / 88	SOT89	***TQP7M9101****
25 dBm HBT Amplifier	0.06 - 3.5	25 / 40	19.5	4.6 / –	5 / 115	SOT89	AH128
MESFET Dual Amplifier	0.15 - 3	24 / 46	12	4.1 / –	5 / 300	SOIC-8	AH11
MESFET Amplifier	0.25 - 4	21.5 / 42	14	3.2 / –	5 / 150	SOT89	AH1
MESFET Amplifier	0.35 - 3	27 / 46	14.5	3.1 / –	9 / 200	SOT89	AH102A
27.5 dBm HBT Amplifier	0.4 - 4	27.5 / 44	21	4 / –	5 / 140	SOT89	***TQP7M9102****
28.5 dBm HBT Amplifier	0.4 - 3.6	28.5 / 45	20	4.5 / –	5 / 150	SOT89	AH125
28 dBm HBT Amplifier	0.7 - 3.8	28 / 42	28.5	2.9 / –	5 / 225	4x4 QFN	TQP8M9013
28.7 dBm HBT Amplifier	0.8 - 1	28.7 / 43	17.5	7 / –	5 / 250	SOIC-8	AH116
28.5 dBm HBT Amplifier	1.8 - 2.3	28.5 / 44	14.5	6 / –	5 / 250	SOIC-8	AH115
Wideband PA, AGC	2 - 20	26 / –	8	–	8 / 440	Die	TGA8334-SCC
Wideband PA, AGC	2 - 22	28.5 (30) / 36	17	–	12 / 1100	Die	TGA2509
Bluetooth® Class 1 PA	2.4 - 2.5	21.5 / –	27	– / 50	0 - 3.3 / 160	2x2 QFN	TQP770001
WiMAX Driver Amp / PA, SB	3.4 - 3.8	30 / 42	24	–	6 / 770	5x5 QFN	TGA2703-SM
0.5W PA	6 - 18	27 / –	11	8 / –	8 / 400	Die	TGA8014-SCC
Driver Amp	7 - 13	(30) / 37	25	– / 30	9 / 450	Die	TGA2700
Wideband Driver Amp	8 - 18	13 / –	17	5 / –	4.5 / 50	Die	TGA8399C
Driver Amp	12 - 16	26 (26.5) / 37	23	7 / –	5 / 300	3x3 QFN	***TGA2524-SM****
1W HPA	12 - 19	30 / –	30	–	5 - 7 / 435	Die	TGA2508
HPA	12 - 19	29 / –	25	–	5 - 7 / 435	4x4 QFN	TGA2508-SM

NOTES: **** = New***, SB = Self Biased, AGC = Automatic Gain Control

Up to 1W (cont.)

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
1W HPA, PD	17 - 20	30 (32) / 42	20	–	5 - 7 / 825	Die	TGA4530
Driver Amp	17 - 24	22 / –	19	4 / –	5 / 270	4x4 QFN	TGA2521-SM
HPA, AGC, PD	17 - 24	(29) / 38	22	–	5 / 712	4x4 QFN	TGA2522-SM
HPA	17 - 27	29 (31) / 37	22	–	7 / 760	Die	TGA4502-SCC
HPA	18 - 27	29 / 37	14	–	6 / 480	Die	TGA1135-SCC
MPA	19 - 27	25 / 32	22	–	5 - 7 / 220	Die	TGA1073G-SCC
MPA	25 - 35	25 / –	18	–	6 / 220	4x4 QFN	TGA4902-SM
MPA	26 - 35	25 (32) / –	19	–	5 - 7 / 220	Die	TGA1073A-SCC
1W HPA	27 - 31	30 / –	22	– / 25	4 - 6 / 420	Die	TGA4509
MPA	27 - 32	24 / –	15	–	5 / 170	4x4 QFN	TGA4903-SM
HPA	27 - 32	28.5 / –	25	–	6 - 8 / 420	Die	TGA1073B-SCC
1W HPA	28 - 31	30 / –	19	– / 25	6 / 420	4x4 QFN	TGA4509-SM
Driver Amp	28 - 32	17 / 24	14.5	–	6 / 60	3x3 QFN	TGA4512-SM
Driver Amp	29 - 37	16 / –	16	–	6 / 60	Die	TGA4510
MPA	32 - 45	24 (25) / 33	16	–	6 / 175	Die	TGA4521
HPA	36 - 40	26 / –	15	–	5 - 7 / 240	Die	TGA1073C-SCC
HPA	36 - 40	30 / –	14	–	6 - 7 / 500	Die	TGA1171-SCC
MPA	33 - 47	27 (27.5) / 36	18	–	6 / 400	Die	TGA4522
HPA	37 - 40	28 / 38	24	6 / –	5 / 600	Die	TGA4538
0.5W HPA	40 - 45	28 / –	9	–	7 / 500	Die	TGA4043
Driver Amp	41 - 45	18 / –	14	–	6 / 168	Die	TGA4042

NOTES: AGC = Automatic Gain Control, PD = Power Detector

1W to 4W

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
31 dBm HBT Amplifier	0.4 - 2.3	31 / 46	18	7 / –	5 / 450	4x4 QFN	ECP100
33 dBm HBT Amplifier	0.4 - 2.3	33 / 49	18	8 / –	5 / 800	4x4 QFN	ECP200
31 dBm HBT Amplifier	0.4 - 2.3	31 / 46	18	7 / –	5 / 450	SOIC-8	AH215
33 dBm HBT Amplifier	0.4 - 2.3	33 / 49	18	8 / –	5 / 800	SOIC-8	AH312
31.5 dBm HBT Amplifier	0.4 - 2.7	31 / 47	20	5.9 / –	5 / 300	SOIC-8	AH225
33.5 dBm HBT Amplifier	0.4 - 2.7	33.5 / 50	19	4.6 / –	5 / 500	SOIC-8	AH322
35.5 dBm HBT Amplifier	0.4 - 2.7	35.5 / 50	16	7 / –	5 / 800	4x5 DFN	AH420
33 dBm HBT Amplifier	0.7 - 2.7	33 / 50	27.5	7 / –	5 / 680	5x5 QFN	AH323
InGaP HBT PA, 1.8W, Ultra High Linearity	0.8 - 2.35	32.5 / 49	15.8	– / 55	28 / 40	5x6 DFN	AP601
InGaP HBT PA, 3.7W, Ultra High Linearity	0.8 - 2.35	35.7 / 52	15.5	– / 55	28 / 80	5x6 DFN	AP602
30 dBm HBT Amplifier	1.8 - 2.7	30.5 / 46.5	27	5.5 / –	5 / 400	SOIC-8 / 4x5 DFN	AH212
33 dBm HBT Amplifier	3.3 - 3.8	33 / –	25	–	5 / 600	5x5 QFN	AH315
2W HPA	5.5 - 8.5	32 (34) / 41	30	7 / –	6 / 1260	5x5 QFN	TGA2706-SM
2.5W HPA	5.9 - 8.5	34 (35) / 42	18	7.5 / 37	6 / 1000	6x6 QFN	TGA2701-SM
2.8W HPA	6 - 18	(34.5) / –	24	– / 20	7 - 9 / 800 - 1200	Die	TGA2501
HPA	6 - 18	(34.5) / –	24	– / 20	8 / 1200	Die	TGA9092-SCC
2W HPA	12.3 - 15.7	(31) / –	33	7 / –	6 / 850	Die	TGA2520
2W HPA	12.5 - 16	(32) / 37	32	–	6 - 7 / 680	4x4 QFN	TGA2503-SM
2W HPA	12.5 - 17	(34) / –	26	– / 25	7.5 / 650	Die	TGA2510
2W HPA	12.5 - 17	(33.5) / –	25	– / 25	7.5 / 650	6.4x9.4 SG	TGA2510-SG
2W HPA	12.7 - 15.4	34 (35) / 43	28	6 / –	6 / 1300	Die	***TGA2533****
2W HPA	12.7 - 15.4	33 (34.5) / 43	27	6 / –	6 / 1300	5x5 QFN	***TGA2533-SM****
4W HPA	13 - 15	(36) / 41	25	–	7 / 1300	17.8x8.4 FL	TGA8659-FL
2W HPA	13 - 17	(34) / 40	32	–	6 - 7 / 680	Die	TGA2503
2W HPA	13 - 17	(34) / –	25	–	6 - 7 / 640	Die	TGA2505
2W HPA, PD	13 - 17	(34) / 38.5	26	– / 30	7.5 / 650	6.4x9.4 SG	TGA2902-1-SG

NOTES: ***= New**, PD = Power Detector

1W to 4W (cont.)

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
2W HPA	13 - 17	(34) / –	33	–	5 - 8 / 680	17.8x8.4 FL	TGA2904-FL
2W HPA	13 - 17	(34) / 40	33	–	5 - 8 / 680	6.4x9.4 SG	TGA8658-SG
2W HPA, PD	13.75 - 14.5	(34) / 38.5	26	– / 30	7.5 / 650	6.4x9.4 SG	TGA2902-2-SG
HPA	17 - 20	30.5 / 41	23	– / –	6 / 900	Die	TGA4532
HPA	17 - 20	31 (32) / 41	22	6.5 / –	6 / 820	4x4 QFN	TGA4532-SM
HPA	17 - 24	31 (32) / 40	23	6 / –	7 / 720	Die	TGA4531
2W HPA	18 - 23	32 (33) / 39	26	–	7 / 840	Die	TGA4022
HPA	21 - 24	31 (32) / 41	22	6 / –	6 / 880	4x4 QFN	***TGA4533-SM****
4W HPA	24 - 31	35.5 (36) / –	23	–	6 / 2100	Die	TGA4505
4W HPA	25 - 31	35.5 (36) / –	22	–	6 / 2100	13.34x9.65 CP	TGA4905-CP
2W HPA	27 - 31	32.5 (33) / 36.5	20	– / 25	6 / 840	Die	TGA4513
3.5W HPA	30-38	(35) / –	18	– / 20	6 / 2100	Die	***TGA2575****
2W HPA	30 - 40	31.5 (33) / –	20	–	6 / 1050	Die	TGA4516
2W HPA	31 - 35	31.5 (33.5) / –	19	–	6 - 7 / 1150	Die	TGA4514
3.5W HPA	31 - 37	(35.5) / –	20	–	6 / 2000	Die	TGA4517
2W HPA	41 - 47	(33) / –	16	–	6 / 2000	Die	TGA4046
77 GHz MPA	76 - 80	14 / –	12	–	3.5 / 75	Die	TGA4706-FC

NOTES: ***** = New***, PD = Power Detector

More Than 4W

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	PAE (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
10W HPA	0.03 - 3	39.5 / 43	19.5	40	35 / 360	Flange	TGA2540-FL
39 dBm HBT Amplifier	0.7 - 2.9	39 / –	16.5	8	12 / 300	5x6 DFN	AP561
InGaP HBT PA, 7W Ultra High Linearity	0.8 - 2.35	38.5 / 55.5	17	53	28 / 160	5x6 DFN	AP603
14W HPA	2 - 18	41.5 / –	10	23	35 / 1200	Die	TGA2573
120W TriPower™ HVHBT Amplifier	2.11 - 2.17	51.1 / –	16.6	64.5	28 / 550	Flanged Screw Down	***TG2H214120-FL****
120W TriPower™ HVHBT Amplifier	2.11 - 2.17	51.1 / –	16.6	64.5	28 / 550	Flanged Solder Down	***TG2H214120-FS****
220W TriPower™ HVHBT Amplifier	2.11 - 2.17	53.9 / –	16.4	65.4	28 / 600	Flanged Screw Down	***TG2H214220-FL****
30W HPA	2.5 - 6	(45) / –	27	38	30 / 1400	Die	***TGA2576****
39 dBm HBT Amplifier	3.3 - 3.8	39 / –	11.5	–	12 / 400	5x6 DFN	AP562
HPA	6.5 - 11.5	37 (39) / –	19	35	7 - 9 / 1200	Die	TGA9083-SCC
16W HPA	6.5 - 12.5	42 / –	27	35	12 / 3000	Die	TGA2517
HPA	7 - 8.5	(38) / –	21	42	7 / 2000	Die	TGA2701
HPA	9 - 10.5	(38) / –	20	>38	4 - 9 / 2000	Die	TGA2704
HPA	10.5 - 12	(38) / –	19	>39	4 - 9 / 2000	Die	TGA2710
6.5W HPA	13 - 16	(38) / –	24	–	8 / 2600	11.4x17.3 FL	TGA2514-FL
4W HPA, Balanced	13 - 17	(36) / 44	25	30	6 - 7 / 1300	Die	TGA2502
6.5W HPA	13 - 18	(38) / 44	24	–	8 / 3600	Die	TGA2514
20W HPA	14 - 16	(43) / –	19	>30	35 / 2000	Die	***TGA2572****
7W HPA	26 - 31	(38.5) / –	22	–	6 / 4200	13.4x16.5 CP	TGA4915-CP
4W HPA	28 - 31	36 (36.5) / –	22	22	6 / 1600	Die	TGA4906
4W HPA	28 - 31	36 (36.5) / –	22	22	6 / 1600	5x5 QFN	TGA4906-SM
7W HPA	28 - 31	(38.5) / –	22	20	6 / 3200	Die	TGA4916

NOTES: ***** = New***

Variable Gain Amplifiers

Description	Frequency Range (GHz)	P1dB / OIP3 (dB)	Gain (dB)	Gain Range (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
Variable Gain Amplifier	0.05 - 2.2	22 / 42	15.5	20	5 / 150	4x4 QFN	VG025
Variable Gain Amplifier	0.7 - 1	22 / 40	16	29	5 / 150	6x6 QFN	VG101
Variable Gain Amplifier	0.7 - 2.8	27.5 / 43	29	30	5 / 240	5x5 QFN	***TQM8M9074****
Variable Gain Amplifier	1.8 - 2.7	22 / 39.5	13.5	26.5	5 / 150	6x6 QFN	VG111
Digital Variable Gain Amplifier	1.8 - 2.7	24.5 / 41.5	31	31.5	5 / 200	6x6 QFN	***TQM879006****

NOTES: **** = New***

Gain Block

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
General Purpose Gain Block	DC - 3	18.5 / 33	16.5	3.8	6 / 75	SOT89	AG603
General Purpose Gain Block	DC - 3.5	18.5 / 33	13.6	4.4	6 / 75	SOT89	AG602
General Purpose Gain Block	DC - 3.5	20.5 / 33.5	17.2	3.5	7 / 96	SOT89	EC1078
General Purpose Gain Block	DC - 4	19.5 / 31	18.5	2.9	6 / 70	SOT89	EC1019
General Purpose Gain Block	DC - 4	17.5 / 32	21.5	3.4	6 / 65	SOT89	ECG005
General Purpose Gain Block	DC - 4	23.5 / 37	14.3	4.6	9 / 120	SOT89	ECG008
General Purpose Gain Block	DC - 4	18 / 34.5	15.3	5.5	6 / 70	SOT89	ECG040
General Purpose Gain Block	DC - 5.5	15 / 30	14.2	3.7	5 / 45	SOT86 / SOT363 /	ECG006
General Purpose Gain Block	DC - 6	5.8 / 18.5	11	4.4	5 / 20	SOT86 / SOT363	AG201
General Purpose Gain Block	DC - 6	7.5 / 19.5	17.7	3.1	5 / 20	SOT86 / SOT363	AG203
General Purpose Gain Block	DC - 6	12 / 25	14.3	3.2	5 / 35	SOT86 / SOT363	AG302
General Purpose Gain Block	DC - 6	12.5 / 25	18.4	3	5 / 35	SOT86 / SOT363	AG303
General Purpose Gain Block	DC - 6	16 / 28.5	14.5	3.7	6 / 60	SOT86 / SOT89	AG402
General Purpose Gain Block	DC - 6	16 / 28	18.9	3	6 / 60	SOT86 / SOT89	AG403
General Purpose Gain Block	DC - 6	14.5 / 27.5	19.1	2.9	6 / 45	SOT86 / SOT89	AG503
General Purpose Gain Block	DC - 6	19 / 33	18.2	3.5	6 / 75	SOT86 / SOT89	AG604
General Purpose Gain Block	DC - 6	12.5 / 26	21.4	3.4	5 / 30	SOT363 / SOT89	ECG001
General Purpose Gain Block	DC - 6	15 / 29	19.5	3.7	5 / 45	SOT86 / SOT363 /	ECG002
General Purpose Gain Block	DC - 6	23 / 36	19	3.5	9 / 110	SOT89	ECG003
General Purpose Gain Block	DC - 6	13 / 27	15.5	3.2	5 / 35	SOT89	ECG004
General Purpose Gain Block	DC - 6	18.2 / 32	20.1	3.4	6 / 65	SOT86 / SOT89	ECG055
MESFET IF Gain Block	0.05 - 0.87	20 / 41	13	3	5 / 150	SOT89	AH3
LNA / Gain Block (40 Gb/s)	DC - 40	11.5 / 20	13	3.2	5 / 50	Die	TGA4830
CATV TIA / Gain Block, SB	0.04 - 1	27 / 46	20	1.5	8 / 350	4x4 QFN	TGA2803-SM
+5V Active Bias IF Gain Block	0.05 - 1	20.5 / 33	17.5	5	5 / 95	SOT89	WJA1500
+5V Active Bias IF Gain Block	0.05 - 1	19 / 33.5	17.5	4.7	5 / 65	SOT89	WJA1505
+5V Active Bias IF Gain Block	0.05 - 1	20 / 36	14	5.4	5 / 95	SOT89	WJA1510
+5V Active Bias Gain Block	0.05 - 2.3	19 / 28.5	14	5.2	5 / 85	SOT89	WJA1010
+5V Active Bias Gain Block	0.05 - 3	20 / 34	16.7	5.4	5 / 100	SOT89	WJA1001
E-pHEMT LNA Gain Block	0.05 - 4	21 / 36	20	1.3	5 / 85	SOT89	TQP3M9008
E-pHEMT LNA Gain Block	0.05 - 4	21.4 / 37.5	22	1.1	5 / 85	3x3 QFN	***TQP3M9018****
E-pHEMT LNA Gain Block	0.05 - 4	22 / 40	21.5	1.3	5 / 125	SOT89	TQP3M9009
E-pHEMT LNA Gain Block	0.05 - 4	22 / 40.5	24.7	0.9	5 / 125	3x3 QFN	***TQP3M9019****
E-pHEMT LNA Gain Block	0.05 - 4	21.5 / 40	15	2.0	5 / 85	SOT89	***TQP3M9028****
+5V Active Bias Gain Block	0.05 - 4	20 / 37.5	16.7	5.6	5 / 90	SOT89	WJA1021
+5V Active Bias Gain Block	0.05 - 4	19.3 / 36.5	14.5	5.5	5 / 80	SOT89	WJA1030
E-pHEMT LNA Gain Block	0.5 - 4	22 / 35	19	0.8	5 / 55	3x3 QFN	***TQP3M9005****
E-pHEMT LNA Gain Block	0.5 - 4	22.5 / 38.5	18.5	1	5 / 90	3x3 QFN	***TQP3M9006****
E-pHEMT LNA Gain Block	0.5 - 4	23.5 / 42	18	1.3	5 / 135	SOT89	***TQP3M9007****
Gain Block, SB	2 - 10	17 / –	17	6	5 / 90	Die	TGA8810-SCC
Gain Block	2 - 18	20 / –	7.5	5.5	6 / 100	Die	TGA8300-SCC

NOTES: **** = New***, SB = Self Biased

Gain Block

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
Wideband Gain Block, AGC	2 - 20	20 / –	7.5	7	6 / 150	Die	TGA8622-SCC
Gain Block	6 - 18	12.5 / –	13	5	5 / 80	Die	TGA8035-SCC
Driver Amp, SB	11 - 17	17 / –	23	6	6 / 75	4x4 QFN	TGA2507-SM
Driver Amp, SB	12 - 18	14 / –	17	–	6 / 40	Die	TGA2506
Driver Amp, SB	12 - 18	20 / –	28	6	6 / 80	Die	TGA2507
Gain Block & 2x / 3x Multiplier	17 - 37	18 (22) / 26	20	7	5 / 140	3x3 QFN	TGA4030-SM
Gain Block & 2x / 3x Multiplier	17 - 40	18 (22) / 24	22	7	5 / 140	3x3 QFN	TGA4031-SM
Gain Block, Multiplier	17 - 43	22 / –	25	–	5 / 225	Die	TGA4040
Gain Block	19 - 38	(22) / 30	20	–	5 / 160	Die	TGA4036

NOTES: SB = Self Biased, AGC = Automatic Gain Control

Low Noise

Description	Frequency Range (GHz)	P1dB / IIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
LNA, AGC	DC - 14	16 / –	11	3.1	8 / 80	Die	TGA8349-SCC
LNA / Gain Block (40 Gb/s)	DC - 40	11.5 / 20	13	3.2	5 / 50	Die	TGA4830
E-pHEMT LNA Gain Block	0.05 - 4	21 / 36	20	1.3	5 / 85	SOT89	TQP3M9008
E-pHEMT LNA Gain Block	0.05 - 4	21.4 / 37.5	22	1.1	5 / 85	3x3 QFN	***TQP3M9018****
E-pHEMT LNA Gain Block	0.05 - 4	22 / 40	21.5	1.3	5 / 125	SOT89	TQP3M9009
E-pHEMT LNA Gain Block	0.05 - 4	22 / 40.5	24.7	0.9	5 / 125	3x3 QFN	***TQP3M9019****
E-pHEMT LNA Gain Block	0.05 - 4	21.5 / 40	15	2	5 / 85	SOT89	***TQP3M9028****
E-pHEMT LNA Gain Block	0.5 - 4	22 / 35	19	0.8	5 / 55	3x3 QFN	***TQP3M9005****
E-pHEMT LNA Gain Block	0.5 - 4	22.5 / 38.5	18.5	1	5 / 90	3x3 QFN	***TQP3M9006****
E-pHEMT LNA Gain Block	0.5 - 4	23.5 / 42	18	1.3	5 / 135	SOT89	***TQP3M9007****
LNA, Balanced FET Low Band	0.7 - 0.92	– / 13.5	20.5	0.55	4 / 70	4x4 QFN	TQP3M6004
LNA, Discrete Low Band	0.7 - 0.92	26 / 23.5	16	0.8	5 / 150	SOT89	TGF2021-04-SD
LNA, Balanced FET	0.8 - 3	21 / 11	22	0.7	4 / 100	2x2 QFN	TGA2602-SM
LNA, Balanced FET Mid Band	1.7 - 2	– / 14.4	18	0.55	3.5 / 50	4x4 QFN	***TQP3M6005****
LNA, AGC	2 - 18	18 / 29	17	2	5 / 75	Die	TGA2525
LNA, AGC	2 - 18	16 / –	19	4	5 / 120	Die	TGA8344-SCC
LNA, AGC	2 - 20	17.5 / –	9	3.5	5 - 8 / 60	Die	TGA1342-SCC
LNA, AGC	2 - 20	19 / –	17.5	2.5	5 / 100	Die	TGA2526
LNA, AGC	2 - 20	17.5 / –	9	3.5	5 - 8 / 60	Die	TGA8310-SCC
LNA, AGC	2 - 20	16 / –	17	2.5	5 / 75	4x4 QFN	TGA2513-SM
LNA, AGC	2 - 23	17 / 26	17	2	5 / 75	Die	TGA2513
LNA, SB, AGC	4 - 14	6 / 16	22	2.3	5 / 90	4x4 QFN	TGA2512-1-SM
LNA, AGC, GB	4 - 14	13 / 24	25	2.3	5 / 160	4x4 QFN	TGA2512-2-SM
LNA, SB, AGC	5 - 15	6 / 13	27	1.4	5 / 90	Die	TGA2512
LNA, SB	6 - 13	11 / –	26	1.5	5 / 65	Die	TGA8399B-SCC
LNA, SB, AGC	6 - 14	6 / 12	20	1.3	5 / 90	Die	TGA2511
LNA	20 - 27	12 / –	21	2.2	3.5 / 60	Die	TGA4506
LNA	28 - 36	12 / 21	22	2.3	3 / 60	Die	TGA4507
LNA	30 - 42	14 / –	21	2.8	3 / 40	Die	TGA4508
LNA	57 - 69	–	13	4	3 / 41	Die	TGA4600
77 GHz LNA	72 - 80	–	20	5	3.5 / 54	Die	TGA4705-FC

NOTES: **** = New***, SB = Self Biased, AGC = Automatic Gain Control, GB = Gate Bias

Discrete Transistors

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
MESFET	DC - 2.5	26.5 / –	11	1.72 / 55	2 - 6 / 350	SOT223	CLY5
MESFET	DC - 3	23.5 / –	15.5	1.48 / 55	2 - 6 / 180	MW6	CLY2

Discrete Transistors (cont.)

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
24mm HFET	DC - 4	40 / –	13	– / 51	8 / 2170	Die	TGF4124
18mm HFET	DC - 6	38.5 / –	13.5	– / 53	8 / 1690	Die	TGF4118
0.5W HFET	DC - 6	28 / 40	18	3.2 / –	8 / 100	SOT89	TGF2960-SD
1W HFET	DC - 6	31 / 43	16	4 / –	8 / 200	SOT89	TGF2961-SD
12mm HFET	DC - 8	37 / –	14	– / 55	8 / 750	Die	TGF4112
4.8mm HFET	DC - 10.5	34 / –	8.5	– / 53	8 / 200	Die	TGF4250-SCC
9.6mm HFET	DC - 10.5	37 / –	9.5	– / 52	8.5 / 520	Die	TGF4260-SCC
1.2mm HFET	DC - 12	28.5 / –	10	– / 55	8 / 50	Die	TGF4230-SCC
2.4mm HFET	DC - 12	31.5 / –	10	– / 56	8 / 100	Die	TGF4240-SCC
1mm Pwr pHEMT	DC - 12	(31.5) / –	11	– / 55	12 / 900	Die	TGF2021-01
2mm Pwr pHEMT	DC - 12	(34.5) / –	11	– / 55	12 / 150	Die	TGF2021-02
4mm Pwr pHEMT	DC - 12	(37.5) / –	11	– / 55	12 / 300	Die	TGF2021-04
8mm Pwr pHEMT	DC - 12	(40.2) / –	11	– / 55	12 / 600	Die	TGF2021-08
12mm Pwr pHEMT	DC - 12	(42) / –	11	– / 52	12 / 900	Die	TGF2021-12
0.3mm MESFET	DC - 18	13 / –	11	1.5 / –	3 / 15	Die	TGF1350-SCC
1.25mm GaN HEMT	DC - 18	(38) / –	15	– / 55	28 / 125	Die	TGF2023-01
2.5mm GaN HEMT	DC - 18	(41) / –	15	– / 55	28 / 250	Die	TGF2023-02
5.0 GaN HEMT	DC - 18	(44) / –	15	– / 55	28 / 500	Die	TGF2023-05
10mm GaN HEMT	DC - 18	(47) / –	15	– / 55	28 / 1000	Die	TGF2023-10
20mm GaN HEMT	DC - 18	(50) / –	15	– / 55	28 / 2000	Die	TGF2023-20
0.6mm Pwr pHEMT	DC - 20	(29) / –	13	– / 56	12 / 45	Die	TGF2022-06
1.2mm Pwr pHEMT	DC - 20	(32) / –	13	– / 56	12 / 90	Die	TGF2022-12
2.4mm Pwr pHEMT	DC - 20	(35) / –	13	– / 58	12 / 180	Die	TGF2022-24
4.8mm Pwr pHEMT	DC - 20	(38) / –	13	– / 58	12 / 360	Die	TGF2022-48
6mm Pwr pHEMT	DC - 20	(39) / –	12.5	– / 53	12 / 448	Die	TGF2022-60
0.3mm pHEMT	DC - 22	16 / –	13	0.8 / –	3 / 15	Die	TGF4350
7W GaN HEMT	DC - 6	(40.4) / –	9.5	– / 50	28 / 50	Ceramic Flat Lead	T1G6000528-Q3
18W GaN HEMT	DC - 6	(43.4) / –	15	– / 50	28 / 50	Ceramic Flat Lead	***T1G6001528-Q3****
55W GaN HEMT	DC - 3.5	47.2 / –	15	– / 50	28 / 200	Ceramic Flat Lead	***T1G4005528-FS****
MESFET	0.05 - 4	21 / 42	19	2 / –	5 / 140	SOT89	FH1
MESFET	0.05 - 4	18 / 36	19	2 / –	5 / 140	SOT89	FH101
0.5W HFET	0.05 - 4	27 / 40	19	2.7 / –	8 / 125	SOT89	FP1189
1W HFET	0.05 - 4	30 / 44	18	4.5 / –	8 / 250	SOT89	FP2189
2.5W HFET	0.05 - 4	34 / 46	18	3.5 / –	9 / 450	6x6 QFN	FP31QF
30W LDMOS	0.5 - 2	45 / –	10	– / 45	28 / 200	PowerBand™	T1L2003028-SP
10W pHEMT	0.5 - 3	40 / –	10	– / 45	12 / 200	PowerBand™	T1P2701012-SP

NOTES: **** = New***

GUIDE BY PRODUCT TYPE I Control Products

Frequency Converters & Mixers

Description	RF Frequency Range (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
WB Mixer, LO	0.5 - 2.5	-5.7	8	24	3 - 6 / 6	MW6	CMY210
WB Mixer, LO, IF	0.5 - 2.5	10	8	9	3 - 6 / 12	SCT598	CMY212
WB Mixer, LO, IF, Low Current	0.5 - 2.5	9.5	10	10	3 - 6 / 8	SCT598	CMY213
Mixer, LO	0.7 - 1	-9	17	36	5 / 50	MSOP-8	ML483
Single Branch Converter, RF, LO, IF	0.8 - 0.92	22	60	15	5 / 360	6x6 QFN	CV110-1A
Single Branch Converter, RF, LO, IF	0.8 - 0.96	22	60	15	5 / 360	6x6 QFN	CV110-3A
Dual Branch Converter, LO, IF	0.8 - 0.96	10.5	14	18.5	5 / 390	6x6 QFN	CV210-3A
Mixer, LO	1.5 - 3.2	-8.5	2	35	5 / 40	MSOP-8	ML485
Single Branch Converter, RF, LO, IF	1.7 - 2.0	21	45	17	5 / 360	6x6 QFN	CV111-1A

Frequency Converters & Mixers (cont.)

Description	RF Frequency Range (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
Single Branch Converter, RF, LO, IF	1.9 - 2.2	21	40	17	5 / 360	6x6 QFN	CV111-3A
Mixer, LO	1.9 - 2.7	-8.1	9	30	5 / 110	SOIC-8	ML501
Doubler w/Amplifier	16 - 30	18	30	22	5 / 150	Die	TGC4403
Doubler w/Amplifier	16 - 30	18	30	19	5 / 150	4x4 QFN	TGC4403-SM
Upconverting Mixer	17 - 26	-9	40	–	-0.9 / 0	4x4 QFN	TGC4402-SM
Upconverting Mixer	17 - 27	-9	35	18	-0.9 / 0	Die	TGC4402
Upconverter	17 - 27	13	30	–	5 / 425	Die	TGC4405
Upconverter	17 - 27	13	30	–	5 / 425	4x4 QFN	TGC4405-SM
Gain Block & 2x / 3x Multiplier	17 - 37	9	–	6	5 / 140	3x3 QFN	TGA4030-SM
Gain Block & 2x / 3x Multiplier	17 - 40	9	–	2	5 / 140	3x3 QFN	TGA4031-SM
19 GHz VCO w/8:1 Prescaler	18.5 - 19.5	–	-105**	7	5 / 158	Die	TGV2204-FC
Doubler (Input 10 - 20 GHz)	20 - 40	-12	25	18	–	Die	TGC1430F
Tripler (Input 8.5 - 13.5 GHz)	20 - 40	-15	15	18	–	Die	TGC1430G
19 / 38 GHz Converter / MPA	36 - 40	9	–	14.5	3.5 / 65	Die	TGC4703-FC
Down Converting I/Q Mixer	75 - 82	-13.5	22	–	1.1 / 7	Die	TGC4702-FC
38 / 77 GHz Converter / MPA	76 - 77	6	–	15	4 / 230	Die	TGC4704-FC

NOTES: ** = Phase Noise (dBc / Hz @ 1 MHz Offset), LO = LO Amplifier, IF = IF Amplifier

Signal Conditioning

Description	Frequency Range (GHz)	Insertion Loss (dB)	Control Range dB or (Deg.)	P1dB (dBm)	Supply Voltage (V)	Package Style (mm)	Part Number
Through Line	DC - 6	0.1	–	–	–	3x3 QFN	***TQM4M9073****
6-Bit, Digital Attenuator, Parallel Ctrl	DC - 4	1.3	31.5	30	5 / 0	4x4 QFN	TQP4M9071
6-Bit, Digital Attenuator, Serial Ctrl	DC - 4	1.3	31.5	30	5 / 0	4x4 QFN	TQP4M9072
Analog Attenuator	DC - 30	2	17	–	0 to -2	3x3 QFN	TGL4203-SM
Analog Attenuator	DC - >50	2	17	–	0 to -2	Die	TGL4203
Discrete Thru (0 dB Attenuator)	DC - 65	0	0	–	–	Die	TGL4201-00
Discrete Attenuators	DC - 65	–	2, 3, 6, 10	–	–	Die	TGL4201-02, 03, 06, 10
Passive Wideband Limiter	2 - 12	<1	–	18	–	3x3 QFN	***TGL2201-SM****
Analog Attenuator	2 - 20	2	15	23	2.5	Die	TGL8784-SCC
Passive Wideband Limiter	3 - 25	<0.5	–	18	–	Die	TGL2201
5-Bit Phase Shifter	6 - 18	9	(348)	–	6	Die	TGP6336
Bessel Filter	–	6, 7, 8, 9, 10 & 11 Cut-Off Freq	–	–	–	Die	TGB2010-00, -09 etc.
Bessel Filter	–	5, 6, 6.5, 7.5, 8 & 9 Cut-Off Freq	–	–	–	2x2 QFN	TGB2010-00, -09-SM etc.
6-Bit Phase Shifter	8.5 - 11	5	(354)	–	0 / -5	Die	TGP2103
Lange Coupler	12 - 21	<0.25	–	–	–	Die	TGB2001
5-Bit Phase Shifter	18 - 20	5	(180)	–	-2.5	Die	TGP1439
Lange Coupler	18 - 32	<0.25	–	–	–	Die	TGB4001
Lange Coupler	27 - 45	<0.25	–	–	–	Die	TGB4002
5-Bit Phase Shifter	28 - 32	6	(348)	–	5	Die	TGP2100
5-Bit Phase Shifter	33 - 37	6	(348)	–	-5	Die	TGP2102
1-Bit Phase Shifter	34 - 36	4	180	–	0 / 5	Die	TGP2104

NOTES: ***** = New***

Switches

Description	Frequency Range (GHz)	Insertion Loss (dB)	Isolation (dB)	P1dB (dBm)	Control Voltage (V)	Package Style (mm)	Part Number
SP3T High Power CDMA	DC - 2	0.6	22	34.5	2.6 / 0	2x2 QFN	TQP4M3019
SP2T 802.11 a, b, g	DC - 6	0.6	28	31.5	3 / 0	1.3x2 DFN	TQS5200
Diversity Switch 802.11 a, b, g	DC - 6	0.8	33	33	3 / 0	3x3 QFN	TQS5202
SPDT - GaN	DC - 6	<1	40	45	-40 / 0	Die	***TGS2351****
SPDT - GaN	DC - 6	<1	40	45	-40 / 0	4x4 QFN	***TGS2351-SM****
SPDT - GaN	DC - 12	<1	35	43	-40 / 0	Die	***TGS2352****
SPDT - GaN	DC - 18	<1	30	40	-40 / 0	Die	***TGS2353****
SPDT FET	DC - 18	1.5	36	27	-5	Die	TGS2306
SPDT FET	DC - 18	2	39	21	-7 / 0	Die	TGS8250-SCC
SP3T VPIN	1 - 20	0.5	35	23	10 mA	Die	TGS2303
SP4T VPIN	1 - 20	0.6	38	23	10 mA	Die	TGS2304-SCC
SP3T VPIN	4 - 18	1	35	20	+/- 2.7	Die	TGS2313
SPDT VPIN	4 - 20	0.9	35	>20	+/- 2.7	Die	TGS2302
SPDT VPIN	24 - 43	<2	36	27	+/- 5	Die	TGS4301
SPDT VPIN	27 - 46	0.9	30	>34	+/ -5 / 15	Die	TGS4302
SPDT VPIN Absorptive	32 - 40	1	36	>33	+/- 5 / 18	Die	TGS4304
SP3T	60 - 90	2.3	20	>-13	-5 / 1.35	Die	TGS4305-FC
SP4T	70 - 90	3	20	>-8	-5 / 1.35	Die	TGS4306-FC

NOTES: ***** = New**

Protectors

Description	Application	Leakage Current (nanoAmps)	Trigger Voltage (V)	Series Capacitance (pF)	Package Area (mm²)	Package Style	Part Number
CATV Protector	ESD & Secondary Protection	20 @ 1V, 500 @ 15V	18, 25, 41	0.29, 0.29, 0.22	1.8	T / SLP-3	TQP200002

GUIDE BY PRODUCT TYPE | Filters

SAW

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
Cable IF Filter	36.15	8	19.7	SE / SE	38 @ 10.23	DIP	855748
Cable IF Filter	44	6	20.4	SE / SE	38 @ 7.6	DIP	855079
CDMA IF Filter	69.99	1.26	17.1	SE / SE	25 @ 1.68	24.6x9	856199
BWA / WiMAX IF Filter	70	8	12.95	SE / SE	35 @ 3.2	13.3x6.5	855677
Low Loss IF Filter	70	0.5	7.6	SE / SE	35 @ 1.28	19x6.5	854651
Low Loss IF Filter	70	1	7.3	SE / SE	40 @ 2.8	19x6.5	854652
Low Loss IF Filter	70	1.5	7.5	SE / SE	40 @ 3.2	19x6.5	854653
Low Loss IF Filter	70	2	7.85	SE / SE	40 @ 4.25	19x6.5	854654
Low Loss IF Filter	70	2.5	8.75	SE / SE	40 @ 4.6	19x6.5	854655
Low Loss IF Filter	70	3	6.95	SE / SE	35 @ 6.9	13.3x6.5	854656
Low Loss IF Filter	70	3.5	7.25	SE / SE	35 @ 7.2	13.3x6.5	854657
Low Loss IF Filter	70	4	6.8	SE / SE	40 @ 8.25	13.3x6.5	854658
Low Loss IF Filter	70	4.5	6.8	SE / SE	35 @ 8.5	13.3x6.5	854659
Low Loss IF Filter	70	5	7.25	SE / SE	40 @ 9.35	13.3x6.5	854660
Low Loss IF Filter	70	6	7.5	SE / SE	40 @ 10.2	13.3x6.5	854661
Low Loss IF Filter	70	7	8.5	SE / SE	40 @ 11.55	13.3x6.5	854662
Low Loss IF Filter	70	8	9	SE / SE	40 @ 13.25	13.3x6.5	854663
Low Loss IF Filter	70	9	9.75	SE / SE	40 @ 13.9	13.3x6.5	854664
Low Loss IF Filter	70	10	10	SE / SE	40 @ 15	13.3x6.5	854665
Low Loss IF Filter	70	12	11.5	SE / SE	40 @ 17.35	13.3x6.5	854666

SAW (cont.)

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
Low Loss IF Filter	70	14	12.5	SE / SE	40 @ 19.5	13.3x6.5	854667
Low Loss IF Filter	70	16	12.5	SE / SE	40 @ 21.4	13.3x6.5	854668
Low Loss IF Filter	70	18	13.5	SE / SE	40 @ 23.4	13.3x6.5	854669
Low Loss IF Filter	70	20	14.5	SE / SE	40 @ 25.4	13.3x6.5	854670
Low Loss IF Filter	70	22	15	SE / SE	40 @ 27.25	13.3x6.5	854671
Low Loss IF Filter	70	24	16.25	SE / SE	40 @ 29.65	13.3x6.5	854672
Low Loss IF Filter	70	26	17	SE / SE	40 @ 32	13.3x6.5	854673
Low Loss IF Filter	70	28	17.6	SE / SE	40 @ 33.75	13.3x6.5	854674
Low Loss IF Filter	70	30	17.5	SE / SE	40 @ 37	13.3x6.5	854675
Low Loss IF Filter	70	36	20.2	SE / SE	40 @ 43.3	13.3x6.5	854678
Low Loss IF Filter	70	40	21.5	SE / SE	40 @ 47.25	13.3x6.5	854680
High Selectivity IF Filter	70	0.3	16.36	SE / SE	40 @ 0.9	24.6x9	855735
High Selectivity IF Filter	70	0.5	21.3	SE / SE	40 @ 1.63	24.6x9	855736
High Selectivity IF Filter	70	1	22.2	SE / SE	40 @ 2.11	24.6x9	855737
High Selectivity IF Filter	70	1.5	21.6	SE / SE	40 @ 2.52	24.6x9	855738
High Selectivity IF Filter	70	2	23	SE / SE	40 @ 3.4	24.6x9	855739
High Selectivity IF Filter	70	2.5	20.25	SE / SE	40 @ 4.3	24.6x9	855740
High Selectivity IF Filter	70	3	23	SE / SE	40 @ 4.46	24.6x9	855741
High Selectivity IF Filter	70	3.5	19	SE / SE	40 @ 6	15.3x6.5	855742
High Selectivity IF Filter	70	4	23	SE / SE	40 @ 6	19x6.5	855743
High Selectivity IF Filter	70	4.5	23.7	SE / SE	40 @ 6.64	19x6.5	855744
High Selectivity IF Filter	70	5.5	22.2	SE / SE	40 @ 7.84	19x6.5	855745
CDMA IF Filter	73.59	1.2	11.9	SE / SE	45 @ 79.58	19x6.5	856111
Medical IF Filter	73	0.3	6	SE / SE	45 @ 69.9	24.6x9	***856152****
BWA / WiMAX IF Filter	80	8	11.7	SE / SE	35 @ 14.25	13.3x6.5	855679
GSM IF Filter	86.6	0.4	5.3	SE / BAL	28 @ 1.58	19x6.5	854823
GSM IF Filter	87	0.4	4.4	BAL / BAL	28 @ 1.59	19x6.5	855500
CDMA IF Filter	118.58	3.69	17.4	SE / SE	43 @ 123.48	13.3x6.5	855958
GSM IF Filter	125	0.4	5.9	SE / SE	20 @ 2.4	9.1x4.8	856444
Low Loss Filter	140	1.7	11	SE / SE	40 @ 3.5	19x6.5	***855579****
Low Loss IF Filter	140	4	10.85	SE / SE	40 @ 9.1	13.3x6.5	854909
Low Loss IF Filter	140	7	5.5	SE / SE	40 @ 11.1	13.3x6.5	854913
Low Loss IF Filter	140	10	8.3	SE / SE	35 @ 15	13.3x6.5	854916
Low Loss IF Filter	140	10	11	SE / SE	35 @ 15	13.3x6.5	856656
Low Loss IF Filter	140	12	8.87	SE / SE	35 @ 21.3	13.3x6.5	854917
Low Loss IF Filter	140	15	11	SE / SE	35 @ 22	13.3x6.5	856684
Low Loss IF Filter	140	16	8.4	SE / SE	35 @ 22	13.3x6.5	854919
Low Loss IF Filter	140	18	9.1	SE / SE	40 @ 48	13.3x6.5	854920
Low Loss IF Filter	140	18.4	9.1	SE / SE	36 @ 26.4	7x5.5	***856929****
Low Loss IF Filter	140	20	11	SE / SE	35 @ 24	13.3x6.5	856592
Low Loss IF Filter	140	24	11.3	SE / SE	35 @ 33.5	13.3x6.5	854923
Low Loss IF Filter	140	32	11.5	SE / SE	35 @ 44	13.3x6.5	854927
High Selectivity IF Filter	140	0.8	20.8	SE / SE	40 @ 1.93	19x6.5	856062
High Selectivity IF Filter	140	1.5	21.9	SE / SE	40 @ 3.5	19x6.5	856063
High Selectivity IF Filter	140	2	21.5	SE / SE	40 @ 3.45	19x6.5	856064
High Selectivity IF Filter	140	3	22.4	SE / SE	40 @ 4.86	19x6.5	856065
High Selectivity IF Filter	140	6	23	SE / SE	40 @ 8.34	13.3x6.5	856066
High Selectivity IF Filter	140	7	24.5	SE / SE	40 @ 9.15	13.3x6.5	856067
High Selectivity IF Filter	140	8	23.4	SE / SE	40 @ 11.28	13.3x6.5	856068
High Selectivity IF Filter	140	10	20.87	SE / SE	40 @ 13.17	13.3x6.5	856069
High Selectivity IF Filter	140	14	23.3	SE / SE	40 @ 18.26	13.3x6.5	856070
High Selectivity IF Filter	140	16	21.7	SE / SE	40 @ 20.69	13.3x6.5	856071

NOTES: ***** = New***

SAW (cont.)

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
High Selectivity IF Filter	140	28	20	SE / SE	40 @ 37	9x7	856019
High Selectivity IF Filter	140	28.56	27.7	SE / SE	40 @ 44	13.3x6.5	856817
High Selectivity IF Filter	140	32	21.7	SE / SE	40 @ 40.7	9x7	856072
High Selectivity IF Filter	140	44	21.75	SE / SE	40 @ 54.1	9x7	856073
High Selectivity IF Filter	140	56	18.65	SE / SE	40 @ 75.6	9x7	856074
High Selectivity Filter	140	60	22.4	BAL / BAL	40 @ 74.7	9.1x4.8	***856774****
High Selectivity IF Filter	140	64	17.8	SE / SE	40 @ 84	9x7	856020
High Selectivity IF Filter	140	72	21	SE / SE	40 @ 102	9x7	856314
High Selectivity IF Filter	140	1.5	12.1	SE and BAL	48 @ 143	9.1x4.8	856691
High Selectivity IF Filter	140	3	13.6	SE and BAL	46 @ 144	9.1x4.8	856692
High Selectivity IF Filter	140	6	11	BAL / BAL	39 @ 147	9.1x4.8	856693
High Selectivity IF Filter	140	7	13.6	SE and BAL	43 @ 147	9.1x4.8	856694
High Selectivity IF Filter	140	10	10	BAL / BAL	41 @ 152.5	9.1x4.8	856695
High Selectivity IF Filter	140	14	8.5	SE and BAL	43 @ 155	9.1x4.8	856696
High Selectivity IF Filter	140	20	9.8	BAL / BAL	40 @ 158.5	9.1x4.8	856697
High Selectivity IF Filter	140	28	18	SE and BAL	42 @ 168	9.1x4.8	856698
CDMA IF Filter	141	1.18	11.7	SE / SE	42.5 @ 2.5	19x6.5	855395
High Selectivity IF Filter	144	75	21.2	SE / SE	40 @ 91.81	9x7	856727
CDMA IF Filter	150	1.18	18.6	SE / BAL	30 @ 4.5	19x6.5	854833-1
CDMA IF Filter	150	8	12.1	SE / SE	35 @ 14.25	13.3x6.5	855678
CDMA IF Filter	153.6	3.75	12.04	SE / SE	45 @ 9.8	13.3x6.5	856048
TDSCDMA / WCDMA IF Filter	153.6	15	10	SE / SE	40 @ 25	13.3x6.5	856748
CDMA IF Filter	160	1.18	19.5	SE / BAL	30 @ 4.5	19x6.5	855049
Repeater IF Filter	161.5	25	22	SE / SE	50 @ 131	9x7	***855886****
WCDMA IF Filter	167	5	8	SE / SE	20 @ 11.8	9.1x4.8	856683
CDMA IF Filter	167.1	1.18	10.9	SE / SE	15 @ 2	19x6.5	855394
CDMA IF Filter	167.1	11	13.1	SE / SE	40 @ 16	13.3x6.5	855753
WCDMA IF Filter	168.5	20	8	SE / BAL	33 @ 190	5x5	856512
WCDMA IF Filter	168.96	3.84	11.5	SE / SE	30 @ 16	9.1x4.8	856320
GSM IF Filter	170.6	0.18	5	BAL / BAL	40 @ 1.6	9.1x4.8	856706
WCDMA IF Filter	172.8	8.84	12.5	SE / BAL	32 @ 16	7x5.5	856620
WCDMA IF Filter	172.8	20	8	SE / BAL	30 @ 194.3	5x5	856802
WCDMA IF Filter	172.8	21	8.2	BAL / BAL	50 @ 200	7x5.5	856893
WCDMA IF Filter	190	5.5	9.8	SE / BAL	30 @ 7.6	13.3x6.5	855529
WCDMA IF Filter	190	5	8	SE / SE	25 @ 9	5x5	855770
GSM IF Filter	190	0.2	4.2	BAL / BAL	30 @ 12	7x5.5	855625
GSM IF Filter	199	0.2	5.4	SE / SE	20 @ 1.2	9x7	856730
GSM IF Filter	199	0.2	6	SE / SE	45 @ 1.6	19x6.5	855131
GSM IF Filter	201	0.22	6.1	BAL / BAL	27 @ 0.8	13.3x6.5	856541
Cable IF Filter	202.75	1.2	6.6	SE / SE	40 @ 10	13.3x6.5	855068
GSM IF Filter	208	0.4	5.9	SE / SE	20 @ 2.4	9.1x4.8	856445
WCDMA IF Filter	208	3.84	11.5	BAL / BAL	17 @ 5.03	9.1x4.8	856496
GSM IF Filter	211	0.2	5.2	SE / SE	25 @ 0.8	13.3x6.5	856378
WCDMA IF Filter	219	20	9.6	BAL / BAL	35 @ 36	9x7	856795
WCDMA IF Filter	230	4	16.2	SE / SE	40 @ 10	13.3x6.5	855832
CDMA IF Filter	240	3.6	14.3	SE / SE	12 @ 5	13.3x6.5	855992
CDMA IF Filter	240	1.1	13	SE / SE	10 @ 1.8	19x6.5	856151
CDMA IF Filter	249.6	3.84	16.11	SE / SE	40 @ 11	7x5.5	855915
CDMA IF Filter	326.4	15	12.61	SE / SE	40 @ 25	7x5.5	855914
BWA / WiMAX IF Filter	330	5.45	18.26	SE / SE	50 @ 13.6	15.3x6.5	855730
WCDMA / LTE IF Filter	344	65	9.5	BAL / BAL	45 @ 66.6	5x5	***857004****
BWA / WiMAX IF Filter	350	1.7	13.7	SE / BAL	45 @ 6	13.3x6.5	855399
BWA / WiMAX IF Filter	350	1	8.2	SE / BAL	45 @ 15	7x5.5	855377

NOTES: **** = New***

SAW (cont.)

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
WCDMA IF Filter	358.4	19.2	10.1	BAL / BAL	25 @ 375.4	7x5.5	856771
WCDMA IF Filter	358.4	24.8	9	BAL / BAL	30 @ 335.8	7x5.5	*856966**
WLAN IF Filter	374	17	8.5	SE / BAL	10 @ 33	7x5.5	855653
WLAN IF Filter	374	17	8.5	SE / BAL	35 @ 33	5x5	855898
WLAN IF Filter	374	17	9	SE / BAL	30 @ 33	3.8x3.8	856278
BWA / WiMAX IF Filter	374	10	9	BAL / BAL	10 @ 25	3.8x3.8	856466
WCDMA IF Filter	380	5.4	15.4	SE / BAL	30 @ 8.3	13.3x6.5	855530
BWA / WiMAX IF Filter	380	7	10	BAL / BAL	40 @ 20	7x5.5	856490
BWA / WiMAX IF Filter	380	10	8.7	BAL / BAL	40 @ 36	7x5.5	856631
WCDMA IF Filter	398	4.3	9.9	SE / SE	50 @ 36	9.1x4.8	855561
WCDMA / WiMAX IF Filter	398	15	7.5	SE / SE	30 @ 60	9.1x4.8	855559
BWA / WiMAX IF Filter	398	10	11.2	BAL / BAL	35 @ 388.5	5x5	856652
BWA / WiMAX IF Filter	426	5.16	18.02	SE / SE	50 @ 14	13.3x6.5	855731
WiBRO IF Filter	456	8.75	7.9	BAL / BAL	36 @ 443.25	5x5	856549
BWA / WiMAX IF Filter	456	10	8.3	BAL / BAL	37 @ 440	7x5.5	856672
BWA / WiMAX IF Filter	456	10	8.3	BAL / BAL	37 @ 440	5x5	856638
WCDMA IF Filter	456	19	10	BAL / BAL	25 @ 439	7x5.5	856687
General Purpose IF Filter	460	3.75	11.1	SE / SE	35 @ 8	7x5.5	856282
BWA / WiMAX IF Filter	464	3.5	10.6	BAL / BAL	53 @ 417	7x5.5	856623
FRS RF or GPS IF Filter	465	6	1.43	SE / SE	40 @ 445	3x3	856288
WiMAX IF Filter	467	10	3	SE / SE	40 @ 438	3.8x3.8	*856586**
BWA / WiMAX IF Filter	479.75	9	19.5	SE / SE	35 @ 22	7x5.5	855271
BWA / WiMAX IF Filter	479.75	23	9.8	BAL / BAL	35 @ 36	7x5.5	855272
Cable IF Filter	499.25	1	7	SE / SE	35 @ 6	9x7	855104
BWA / WiMAX IF Filter	520	6	10.8	SE / SE	30 @ 514	5x5	*856680**
BWA / WiMAX IF Filter	520	11	9.5	SE / SE	35 @ 506	5x5	*856625**
WLAN IF Filter	549.5	1	11.6	SE / SE	40 @ 547.4	9x7	*855985**
WLAN IF Filter	549.5	10	11.8	SE / SE	40 @ 536.5	7x5.5	*855959**
BWA / WiMAX IF Filter	580	10	10.7	BAL / BAL	40 @ 36	5x5	856665
RF Filter – Band 12 Uplink	707	18	1.5	SE / SE	9 @ 728	3x3	856884
Duplexer, Band 17	710 / 740	12 / 12	1.2 / 1.8	SE / BAL	–	2.5x2	856931
RF Filter – Band 12 Downlink	737	18	1.8	SE / SE	37 @ 708	3x3	856883
RF Filter – Band 13 Downlink	751.5	11	1.5	SE / SE	40 @ 776	3x3	*856794**
Duplexer, Band 13	751 / 782	9 / 9	2.3 / 1.8	SE / BAL	–	2.5x2	856879
WiMAX IF Filter	756	10	1.9	SE / SE	30 @ 727	3.8x3.8	*856690**
BWA IF Filter	756	20	0.9	SE / SE	30 @ 716	3.8x3.8	*856866**
RF Filter – Band 13 Uplink	781.5	11	1.5	SE / SE	38 @ 757	3x3	856764
RF Filter – Band 13 Uplink	782	10	1.52	SE / SE	15 @ 765	3x3	856844
BWA / WiMAX IF Filter	810	10	3.5	SE / SE	10 @ 31	3x3	856526
Duplexer, Band 20	806 / 847	30 / 30	2.5 / 3	SE / BAL	–	2.5x2	*856979**
Duplexer, BC10	833 / 878	32 / 32	2.5 / 2.5	SE / BAL	–	2.5x2	*856999**
RF Filter – Band 5 Uplink	836.5	25	2.7	SE / SE	28 @ 869	3x3	*856503**
RF Filter – Band 5 Uplink	836.5	25	2.7	SE / SE	28 @ 869	3x3	855729
RF Filter – Band 5 Uplink	836.5	25	2	SE / SE	10 @ 869	3x3	856704
RF Filter – Band 5 Uplink	836.5	25	1.9	SE / SE	35 @ 869	3x3	855821
Duplexer, Cell Band	836.5 / 881.5	25 / 25	1.9 / 1.9	SE / SE	–	3.8x3.8	856356
RF Filter – Band 20 Uplink	847	30	1.3	SE / SE	10 @ 882	3x3	*856932**
EU ISM 875 Band RF Filter	875	13	2.4	SE / SE	55 @ 849	2x1.5	*856963**
RF Filter – Band 5 Downlink	881.5	25	2.7	SE / SE	40 @ 849	3x3	855728
RF Filter – Band 5 Downlink	881.5	25	1.8	SE / SE	35 @ 849	3x3	855782
CDMA 2-in-1 Rx Filter	881.5 / 1960	25 / 60	1.6 / 2.2	SE / BAL	–	2x1.5	856565
RF Filter – Band 5 Downlink	881.5	25	2.7	SE / SE	40 @ 849	3x3	*856504**

NOTES: ** = New*

SAW (cont.)

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
Cell Band Delay Filter 450 NS	881.5	25	2.5	SE / BAL	–	7x5.5	856716
RF Filter – Band 8 Uplink	897.5	35	1.4	SE / SE	10 @ 984	3x3	856824
RF Filter – Band 8 Uplink	897.5	35	1.5	SE / SE	15 @ 930	3x3	856657
RF Filter – Band 8 Uplink	897.5	35	1.9	SE / SE	14 @ 930	3x3	856671
ISM 915 Band RF Filter	915	26	2.3	SE / SE	35 @ 882.5	2x1.5	856327
ISM 915 Band RF Filter	915	4.4	2.4	SE / SE	55 @ 849	3x3	856686
ISM 921.5 Band RF Filter	921.5	13	2.4	SE / SE	55 @ 825	2x1.5	***856905****
RF Filter – Band 8 Downlink	942.5	35	2	SE / SE	5 @ 915	3x3	855820
RF Filter – Band 8 Downlink	942.5	35	3.2	SE / SE	12 @ 915	3x3	855810
RF Filter – Band 8 Downlink	942.5	35	2.5	SE / SE	25 @ 915	3x3	856528
GSM Band Delay Filter, 450 ns	942.5	35	25.5	SE / SE	–	7x5.5	856766
WLAN IF Filter	970	9	24	SE / SE	35 @ 945	9.1x4.8	***856338****
WLAN IF Filter	970	18	24.7	SE / SE	35 @ 945	7x5.5	***856339****
Tuner IF Filter	1086	10	4	BAL / BAL	40 @ 1046	3x3	855964
Tuner IF Filter	1086	10	4	BAL / BAL	40 @ 1046	3x3	856330
Tuner IF Filter	1090	10	5	BAL / BAL	50 @ 1050	3.8x3.8	856096
WLAN IF Filter	1150	16	4.4	BAL / BAL	20 @ 1170	3x3	856256
GPS L5 RF Filter	1176	20	2.4	SE / SE	20 @ 1226	2x1.5	856440
Tuner IF Filter	1216	8	3.75	BAL / BAL	12 @ 24	3x3	856365
Tuner IF Filter	1220	10	4.5	BAL / BAL	30 @ 60	3x3	856298
Tuner IF Filter	1220	50	3.9	BAL / BAL	33 @ 96	3.8x3.8	856598
GPS L2 RF Filter	1227.6	20	1.1	SE / SE	27 @ 1152	2x1.5	856700
Tuner IF Filter	1250	96	6	BAL / BAL	44 @ 1152	3x3	856653
RF Filter – Band 11 Uplink	1445.4	35	1.25	SE / SE	20 @ 1495.9	3x3	***856928****
GPS RF Filter	1575.42	2	1.3	SE / SE	30 @ 1625	3x3	855969
GPS RF Filter	1575.42	2	1.25	SE / SE	30 @ 1624	2x1.5	856584
GPS RF Filter	1575.42	2	0.75	SE / SE	35 @ 1635	1.4x1.2	856561
GPS RF Filter	1575.42	2	1.1	SE / BAL	20 @ 1635	1.4x1.2	856576
GPS RF Filter	1575.42	2	1	SE / SE	27 @ 800	1.5x1.5	856463
GPS RF Filter	1575.42	2	0.5	SE / SE	20 @ Cell Bands	1.4x1.2	856756
GPS RF Filter	1575.42	2	0.7	SE / SE	27 @ 1700	1.5x1.5	856398
GPS RF Filter	1575.42	2	0.6	SE / SE	21 @ Cell Bands	1.4x1.2	856793
GPS RF Filter, Auto	1575.42	2	1.8	SE / SE	45 @ 1637	3x3	856039
GPS RF Filter, Auto	1575.42	2	1.3	SE / SE	45 @ 1640	3x3	856139
GPS / SDARS Diplexer	1575.42 / 2332.5	3 / 25	0.6 / 0.8	SE / SE	GPS Port: 40 @ 2332 SDARS Port: 36 @ 1572	3x3	***TQM2M9016****
RF Filter – Band 3 Uplink	1747.5	75	2	SE / SE	22 @ 1676	3x3	856654
RF Filter – Band 3 Downlink	1842.5	75	1.9	SE / SE	10 @ 1785	3x3	855860
RF Filter – Band 2 Uplink	1880	60	2.2	SE / SE	15 @ 1806	3x3	856705
RF Filter – Band 2 Uplink	1880	60	2.3	SE / SE	10 @ 1790	3x3	856880
RF Filter – Band 2 Uplink	1880	60	2.4	SE / SE	7 @ 1930	3x3	855849
RF Filter – Band 2 Uplink	1880	60	2.8	SE / SE	30 @ 1930	3x3	856530
Tuner IF Filter	1892	8	4.2	BAL / BAL	23 @ 1932	2.5x2	856236
RF Filter – Band 1 Uplink	1950	60	1.8	SE / SE	20 @ 2100	3x3	856678
RF Filter – Band 1 Uplink	1950	60	2.2	SE / SE	40 @ 2110	3x3	856532
RF Filter – Band 2 Downlink	1960	60	2.1	SE / SE	10.3 @ 1910	3x3	855817
RF Filter – Band 2 Downlink	1960	60	2.9	SE / SE	15 @ 1910	3x3	855859
RF Filter – Band 2 Downlink	1960	60	2.25	SE / SE	14 @ 1910	3x3	856531
Delay Filter, PCS 450 ns	1960	60	25	SE / BAL	–	7x5.5	856717
Delay Filter, UMTS 450 ns	2140	60	25	SE / BAL	–	7x5.5	856649
RF Filter – Band 1 Downlink	2140	60	2.3	SE / SE	25 @ 1980	3x3	856738
SDARS Filter	2332.5	45	1.7	SE / BAL	35 @ 2100	1.4x1.2	856604

NOTES: **** = New***

SAW (cont.)

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
Bluetooth® RF Filter	2441	83.5	2.8	SE / SE	26 @ 2200	3x3	855916
Bluetooth® RF Filter	2441	83.5	2	SE / SE	28 @ 2300	1.4x1.2	856539

NOTES: *** = New**

BAW

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
RF Filter	710	20	2	SE / SE	50 @ 140	3.81x2.54	880370
RF Filter, ISM	915	15	3.5	SE / SE	40 @ 35	6.35x4.57	880371
RF Filter	1030	15	2.5	SE / SE	40 @ 45	3.81x2.54	880367
RF Filter	1090	15	2.5	SE / SE	40 @ 45	3.81x2.54	880374
GPS RF Filter, L5	1176	28	2.75	SE / SE	40 @ 140	3.26x1.6	880364
GPS RF Filter, L2	1227	30	2.75	SE / SE	40 @ 140	3.26x1.6	880272
GPS RF Filter, L2	1227	15	1.5	SE / SE	40 @ 250	3.26x1.6	880366
GPS RF Filter, L2	1227	15	3	SE / SE	40 @ 45	3.81x2.54	880372
RF Filter	1280	20	3	SE / SE	40 @ 105	3.81x2.54	880368
GPS RF Filter, L3 / L4	1380	30	3	SE / SE	40 @ 160	3.26x1.6	880365
GPS RF Filter, L1	1575	30	3	SE / SE	40 @ 160	3.26x1.6	880273
GPS RF Filter, L1	1575	18	1.5	SE / SE	40 @ 350	3.26x1.6	880085
GPS RF Filter, L1	1575	25	3	SE / SE	40 @ 60	3.81x2.54	880373
RF Filter	2324	38	3	SE / SE	40 @ 150	3.81x2.54	880148
SDARS	2332.5	45	1.7	SE / BAL	35 @ 2100	1.4x1.2	856604
ISM Passband Filter for Coexistence	2436	72	2	SE / SE	20 @ 2495	1.7x1.3	885007
ISM Notch RF Filter for Coexistence	2440	72	1.5 (Out of Band IL)	SE / SE	25 @ 2440 (Notch Rej)	1.7x1.3	885008
ISM Notch RF Filter for Coexistence	2440	85	2 (Out of Band IL)	SE / SE	18 @ 2440 (Notch Rej)	1.7x1.3	885010
RF Filter, MMDS	2560	30	3	SE / SE	40 @ 150	3.81x2.54	880157
RF Filter, ISM	5775	100	4.5	SE / SE	20 @ 350	3.26x1.6	880369

GUIDE BY PRODUCT TYPE | Integrated Products

Automotive

Description	Frequency Bands	Features	Package Size (mm)	Part Number
QB GSM / GPRS Tx Module; PA / LPF / SP6T Switch	GSM850 / 900, DCS / PCS	High System Efficiency & Small Size	6x6x1.1	TQM6M4003
QB GSM / GPRS / EDGE-Polar PA Module	GSM850 / 900, DCS / PCS	-90 dBm Typ Rx Noise, +3 to +8 dBm Pin Nominal	5x5x1	TQM7M5012

GPS

Description	Frequency Bands	Features	Package Size (mm)	Part Number
GPS Filter-LNA-Filter Module	1575 MHz, GPS L1	Low Noise (1.56 dB) and High Gain (16 dB)	3x3x1	TQM640002

GSM / GPRS / EDGE

Description	Frequency Bands	Features	Package Size (mm)	Part Number
QB GSM / GPRS PA Module	GSM850 / 900, DCS / PCS	Low Band Ibatt < 1.5A @ Pcal w/PAE 55%	5x5x1	TQM7M4007

GSM / GPRS / EDGE (cont.)

Description	Frequency Bands	Features	Package Size (mm)	Part Number
QB GSM / GPRS / EDGE-Linear HADRON II PA Module™	GSM850 / 900, DCS / PCS	Low Band Ibatt < 1.5A @ Pcal w/PAE 55%	5x5x1	TQM7M5005H
QB GSM / GPRS Tx Module; PA / LPF / SP6T	GSM900 / DCS or GSM850 / PCS	High Efficiency Broadband Tx, 4 Rx Ports	6x6x1	TQM6M4003
DB GSM / GPRS QUANTUM Tx Module™; PA / LPF / SP4T, Quad-Band Tx & Dual-Band Rx	GSM900 / DCS or GSM850 / PCS	High Efficiency Broadband Tx, 2 Rx Ports	6x6x1	***TQM6M4050****
DB GSM / GPRS QUANTUM Tx Module™; PA / LPF / SP4T, Quad-Band Tx & Dual-Band Rx	GSM900 / DCS or GSM850 / PCS	High Efficiency Broadband Tx, 2 Rx Ports	5x6x1	***TQM6M4068****
DB GSM / GPRS QUANTUM Tx Module™; PA / LPF / SP4T, Quad-Band Tx & Dual-Band Rx	GSM900 / DCS or GSM850 / PCS	High Efficiency Broadband Tx, 2 Rx Ports	6x6x1	TQM6M4048
QB GSM / GPRS QUANTUM Tx Module™; PA / LPF / SP6T	GSM850 / 900, DCS / PCS	High Efficiency Broadband Tx, 4 Rx Ports	6x6x1	TQM6M4049

NOTES: **** = New***

3G – CDMA / EV-DO, 4G – LTE

Description	Bands	Features	Package Size (mm)	Part Number
CDMA TRITIUM II PA-Duplexer Module™; SE Input w/Coupler	Cellular	2-Bit (Hi / Med / Lo Power Modes)	7x4x1.1	TQM613029
CDMA TRITIUM II PA-Duplexer Module™; SE Input w/Coupler	PCS	2-Bit (Hi / Med / Lo Power Modes)	7x4x1.1	TQM663029A
CDMA TRITIUM II PA-Duplexer Module™; SE Input w/Coupler	AWS	2-Bit (Hi / Med / Lo Power Modes)	7x4x1.1	TQM653029
CDMA SP3T Switch	Cellular / PCS / AWS	Antenna Routing	3x3x0.9	TQP4M3018
CDMA SP3T Switch	Cellular / PCS / AWS	Antenna Routing	2x2x0.57	TQP4M3019
LTE TRITON PA Module™, w/Coupler	Band 13	LTE, 2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM700013
CDMA TRITON PA Module™, w/Coupler	PCS	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM766012
CDMA TRITON PA Module™, w/Coupler	AWS	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM756014
CDMA TRITON PA Module™, w/Coupler	Cellular	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM716015
CDMA TRITON PA Module™, w/Coupler	PCS	1-Bit (Hi / Lo Power Modes)	3x3x0.9	TQM766062
CDMA TRITON PA Module™, w/Coupler	Cellular	1-Bit (Hi / Lo Power Modes)	3x3x0.9	TQM716065

3G – WCDMA / WGPRS / WEDGE, 4G – LTE

Description	Bands	Features	Package Size (mm)	Part Number
QB GSM / GPRS / EDGE-Polar HADRON II PA Module™	GSM850 / 900, DCS / PCS	-90 dBm Typ Rx Noise, +3 to +8 dBm Pin Nom	5x5x1	TQM7M5012H
QB GSM / GPRS / EDGE-Linear HADRON II PA Module™	GSM850 / 900, DCS / PCS	Input Power Controlled for GMSK & 8PSK	5x5x1	TQM7M5013
QB GSM / GPRS / EDGE-Polar HADRON II PA Module™	GSM850 / 900, DCS / PCS	+3 to +8 dBm Pin Nominal, Current Limiter	5x5x1	TQM7M5022
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 1	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM776011
WCDMA / HSUPA TRITON PA Module™, w/Coupler	PCS / Band 2	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM766012
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 4	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM756014
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 5	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM716015
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 8	2-Bit (Hi / Med / Lo Power Modes)	3x3x0.9	TQM726018
LTE PA Module, w/Coupler	Band 13	LTE 1-Bit (Hi / Lo Power Modes)	3x3x0.9	***TQM700013****
WCDMA / HSUPA TRITIUM III PA-Duplexer Module™; SE Input w/Coupler, Detector	Band 1	1-Bit (Hi / Lo Power Modes)	7x4.0x1.1	TQM676021
WCDMA / HSUPA TRITIUM III PA-Duplexer Module™; SE Input w/Coupler, Detector	Band 2	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM666022
WCDMA / HSUPA TRITIUM III PA-Duplexer Module™; SE Input w/Coupler, Detector	Band 4	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM656024
WCDMA / HSUPA TRITIUM III PA-Duplexer Module™; SE Input w/Coupler, Detector	Bands 5 and 6	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM616025
WCDMA / HSUPA TRITIUM III PA-Duplexer Module™; SE Input w/Coupler, Detector	Bands 5 and 6	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM616020

NOTES: **** = New***

3G – WCDMA / WGPRS / WEDGE, 4G – LTE (cont.)

Description	Bands	Features	Package Size (mm)	Part Number
WCDMA / HSUPA TRITIUM III PA-Duplexer Module™; SE Input w/Coupler, Detector	Band 8	1-Bit (Hi / Lo Power Modes)	7x4x1.1	TQM626028L
DB GSM / GPRS Tx Module: PA / LPF / SP6T WGPRS Switch w/Dual-Band WCDMA Antenna Pass-Through	GSM900 / DCS or GSM850 / PCS & 2 WCDMA Bands	Integrated DB GSM / GPRS & 2 WCDMA Antenna Switch Ports	5x6x1	***TQM6M9069****
QB GSM / GPRS / EDGE-Linear TRP QUANTUM II Tx Module™: PA / LPF / SP8T WEDGE Switch w/Quad-Band WCDMA Antenna Pass-Through	GSM850 / 900, DCS / PCS & WCDMA B1, B2, B5 / 6, B8	Integrated QB GSM / GPRS / EDGE PA & Antenna Switch Supporting WCDMA	7x7.5x1.1	TQM6M9014
Multi-Mode Quad-Band GMSK / EDGE / WCDMA TRIUMF PA Module	GSM850 / 900, DCS / PCS & WCDMA B1 & B8	2-Bit (Hi / Med / Lo Power Modes)	5x7.5x1	***TQM7M9023****
Multi-Mode Quad-Band GMSK / EDGE / WCDMA TRIUMF PA Module	GSM850 / 900, DCS / PCS & WCDMA B1 & B5	2-Bit (Hi / Med / Lo Power Modes)	5x7.5x1	***TQM7M9032****
Multi-Band WCDMA / HSUPA / HSPA+ / TRIUMF PA Module	High Bands 1,2,3,4,9,10 & Low Bands 5,6,8	1-Bit (Hi / Lo Power Modes); 1-Bit Band Specific Pout Adjust	5x4x0.9	***TQM7M9070****

NOTES: **** = New***

WLAN & Bluetooth® for Handsets

Description	Bands	Features	Package Size (mm)	Part Number
5 GHz WLAN PA MMIC	802.11 a	ETSLP-16 Package	3x3x0.45	TQP787011
2.4 GHz WLAN LNA + SP3T Switch MMIC w/WLAN Tx & Bluetooth® Paths	802.11 b, g	LNA Bypass, ETSLP-12 Package	1.5x1.5x0.55	TQP879001A
2.4 GHz WLAN PA + Switch MMIC w/WLAN Rx Balun & Bluetooth® Path	802.11 b, g, n	ETSLP-16 Package, Coupler / Detector	3x3x0.45	TQM679002A
2.4 GHz and 5 GHz WLAN PA + Switch MMIC w/WLAN Rx Baluns & Bluetooth® Path	802.11 a, b, g, n	ETSLP-24 Package, Coupler / Detector	4x4x0.45	TQP6M9002

WLAN & Bluetooth® for Wireless Data & Personal Media Devices

Description	Bands	Features	Package Size (mm)	Part Number
5 GHz WLAN PA MMIC	802.11 a	ETSLP-16 Package	3x3x0.45	TQP787011
2.4 GHz WLAN LNA + SP3T Switch MMIC w/WLAN Tx & Bluetooth® Paths	802.11 b, g	LNA Bypass, ETSLP-12 Package	1.5x1.5x0.55	TQP879001A
2.4 GHz WLAN PA + Switch MMIC w/WLAN Rx Balun & Bluetooth® Path	802.11 b, g, n	ETSLP-16 Package, Coupler / Detector	3x3x0.45	TQM679002A
2.4 GHz & 5 GHz WLAN PA + Switch MMIC w/WLAN Rx Baluns & Bluetooth® Path	802.11 a, b, g, n	ETSLP-24 Package, Coupler / Detector	4x4x0.45	TQP6M9002
Bluetooth® EDR v2.0 Class 1 PA MMIC	2.4 to 2.5 GHz ISM Band	STSLP-12 Package	2x2x0.57	TQP770001

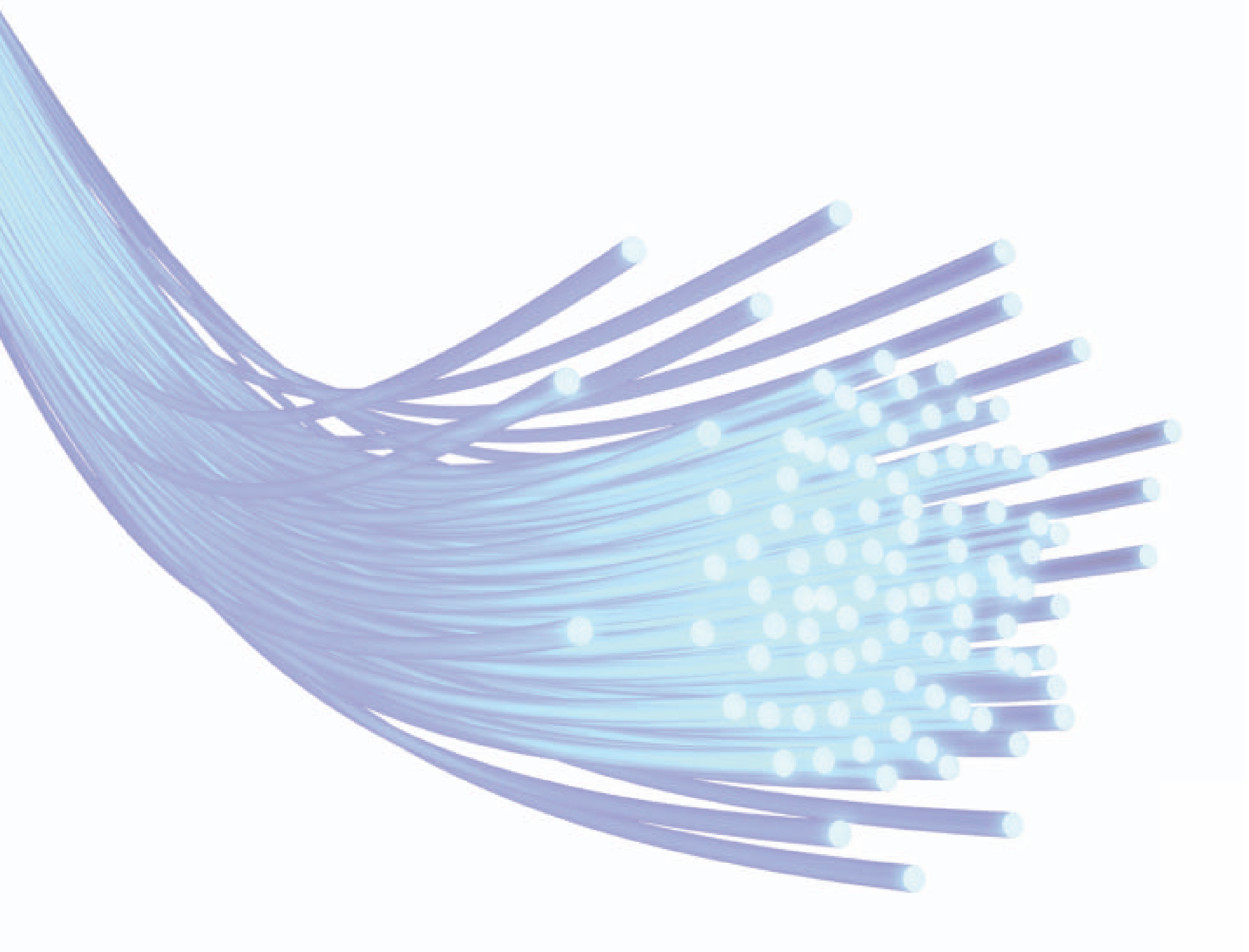
UHF RFID

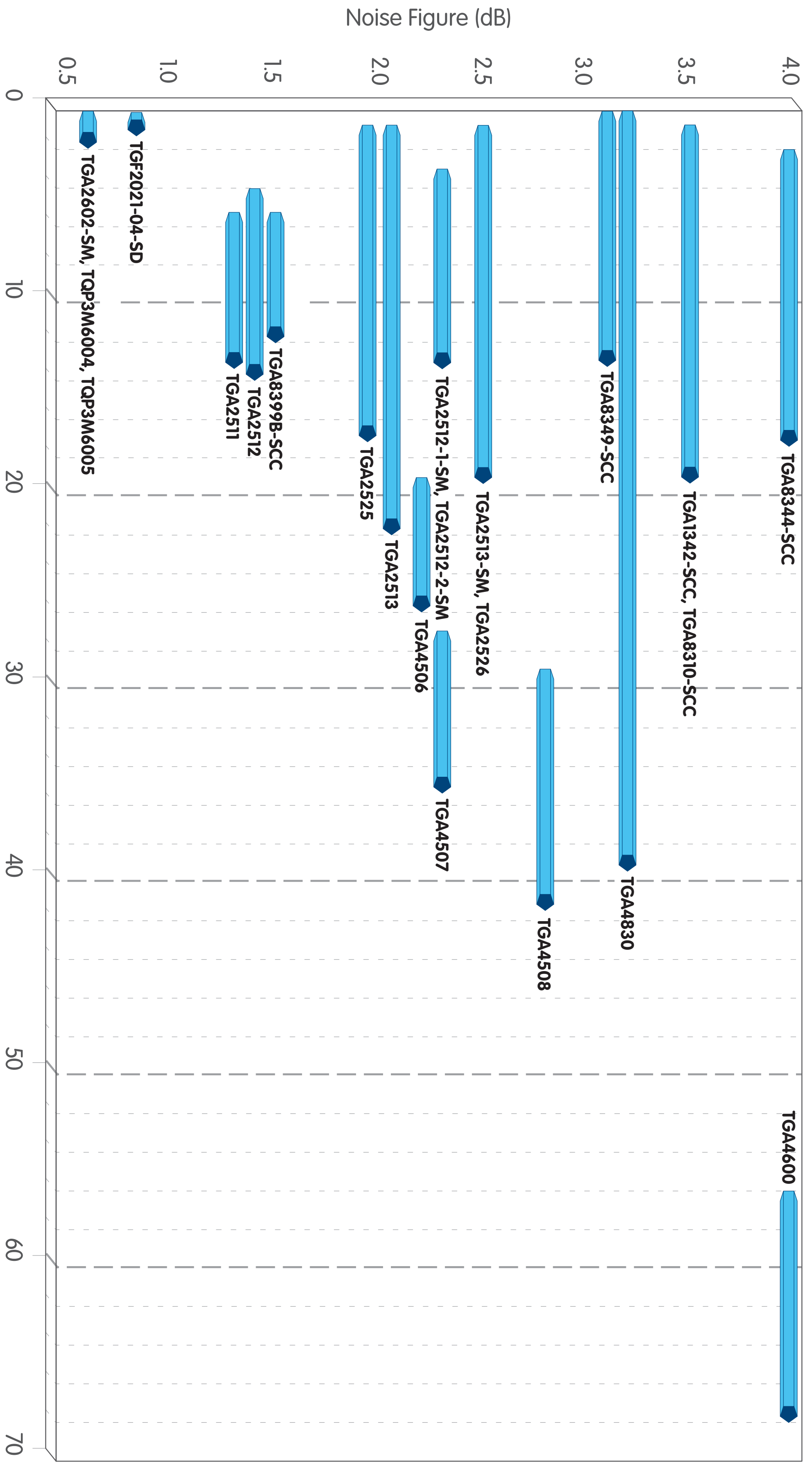
Description	Frequency (MHz)	Channels / Spacing (kHz)	Max Output Power (W)	Protocol Support	Region of Operation	Interface	Part Number
Reader PCMCIA Form Factor Module (ETSI 302.208)	865.7 - 867.5	4 / 600	1	ISO18000-6B & -6C	Europe	Serial TTL	WJR7081
Reader PCMCIA Form Factor Module (FCC Pt 15)	902.75 - 927.25	50 / 500	1	ISO18000-6C	N. America	Serial TTL	WJR7000
Embedded Reader Mod (FCC Pt 15)	902.75 - 927.25	50 / 500	1	ISO18000-6B & -6C	N. America	Serial TTL	WJM3000
Embedded Reader Mod (FCC Pt 15)	902.75 - 927.25	50 / 500	0.25	ISO18000-6B & -6C	N. America	Serial TTL	WJM1000
PCMCIA Form Factor Module	910.6 - 913.4	15 / 200	1	ISO18000-6B & -6C	Korea	Serial TTL	WJR7090
PCMCIA Reader Module (FCC Pt 15)	902.75 - 927.25	50 / 500	0.5	ISO18000-6B & -6C	N. America	PCMCIA	WJR6000

Amplifiers

Description	Frequency (GHz)	Power (Vpp or dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style (mm)	Part Number
9.9 - 12.5Gb/s 3V - 7V Driver	DC - 13	3 - 7Vpp	32	–	3.3 - 5 / 115	8x8 QFN	TGA4956-SM
9.9 - 12.5 Gb/s Modulator Driver	DC - 16	3 - 10Vpp	35	2.5	5.5 - 8 / 210	11.4x8.9 SL	TGA4953-SL
9.9 - 12.5 Gb/s Modulator Driver	DC - 16	3 - 9Vpp	35	2.5	5.5 - 8 / 210	11.4x8.9 SL	TGA4954-SL
12.5 Gb/s NRZ Driver	DC - 18	3 - 11Vpp	16	–	8 / 285	Die	TGA4807
12.5 Gb/s NRZ Driver	DC - 18	6 - 8Vpp	16	3.5	5 - 8 / 70 - 175	Die	TGA1328-SCC
12.5 Gb/s NRZ Driver	DC - 18	4 - 8Vpp	16	3.5	8 / 175	8.9x8.9 SL	TGA8652-SL
15 Gb/s 10V Linear Modulator Driver	DC - 20	3 - 10Vpp	22	–	7 / 280	6x6 QFN	TGA4826-SM
40 & 100 Gb/s 8Vpp SE Driver	DC - 30	3 - 9Vpp	32	–	6 - 7 / 270	14.4x7 SL	TGA4943-SL
Wideband Driver (40 Gb/s)	DC - 35	4Vpp	12	–	5 / 135	Die	TGA4832
LNA / Gain Block (40 Gb/s)	DC - 40	11.5	13	3.2	5 / 50	Die	TGA4830
45 Gb/s 8Vpp SE Driver	DC - 35	5 - 9Vpp	30	–	6 - 7 / 300	14.4x7 SL	**TGA4942-SL****
45 Gb/s 10Vpp Diff In / Out Driver	DC - 50	6 - 10Vpp Diff	27 Diff	–	5 - 6 / 500	Die	**TGA4958-SL****
32 Gb/s 9Vpp Diff In / Out Driver	DC - 35	6 - 9Vpp Diff	25 Diff	–	5 - 6 / 500	SL	**TGA4959-SL****
43 Gb/s Driver	DC - 78	3.5Vpp	8	5	6 / 82	Die	TGA4803
10.7 - 12.5 Gb/s Linear Modulator Driver	30 kHz - 8	12.5Vpp	20	–	8 / 310	8x8 QFN	TGA4823-2-SM

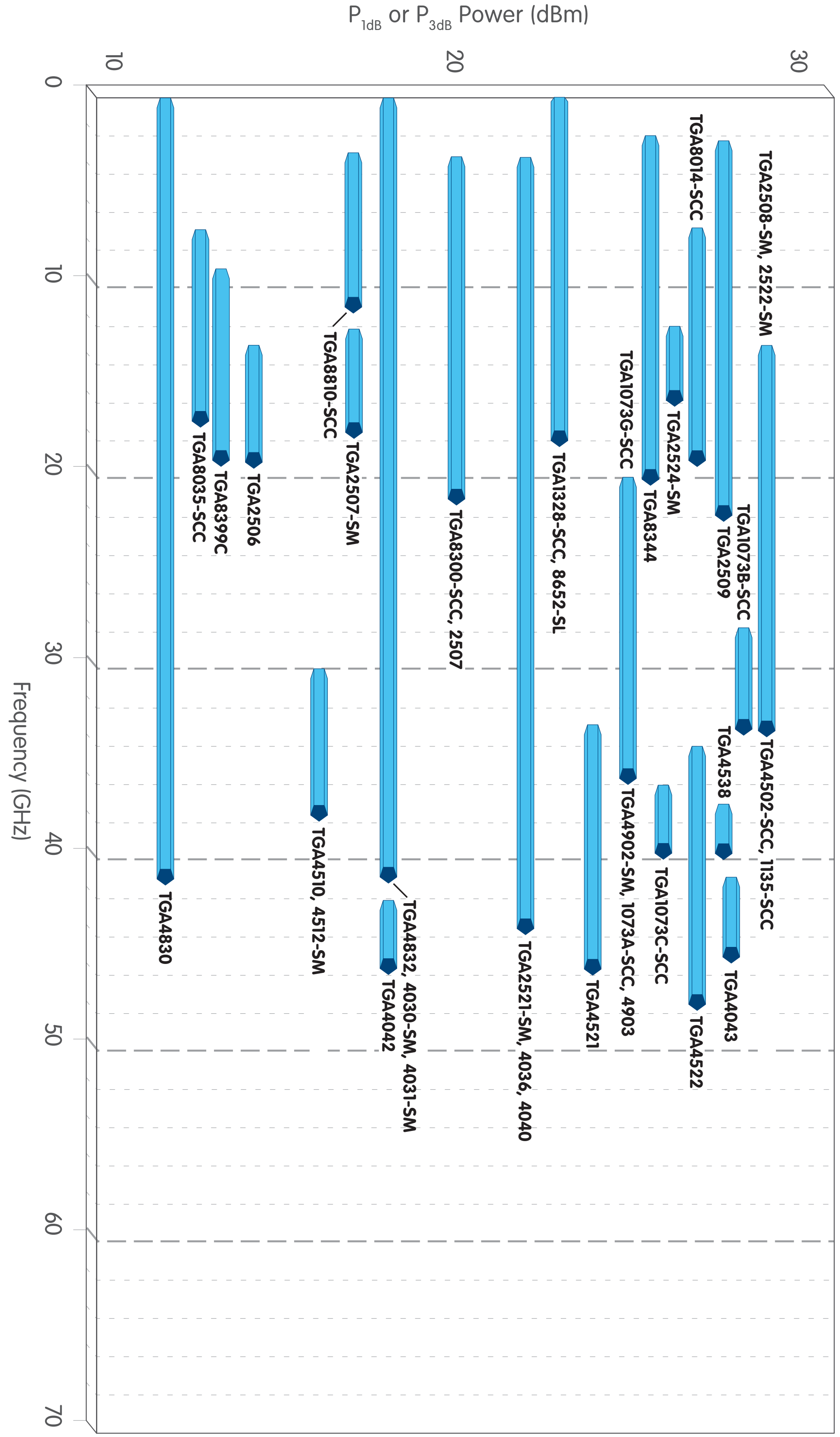
NOTES: **** = Coming Soon**, SE = Single-Ended





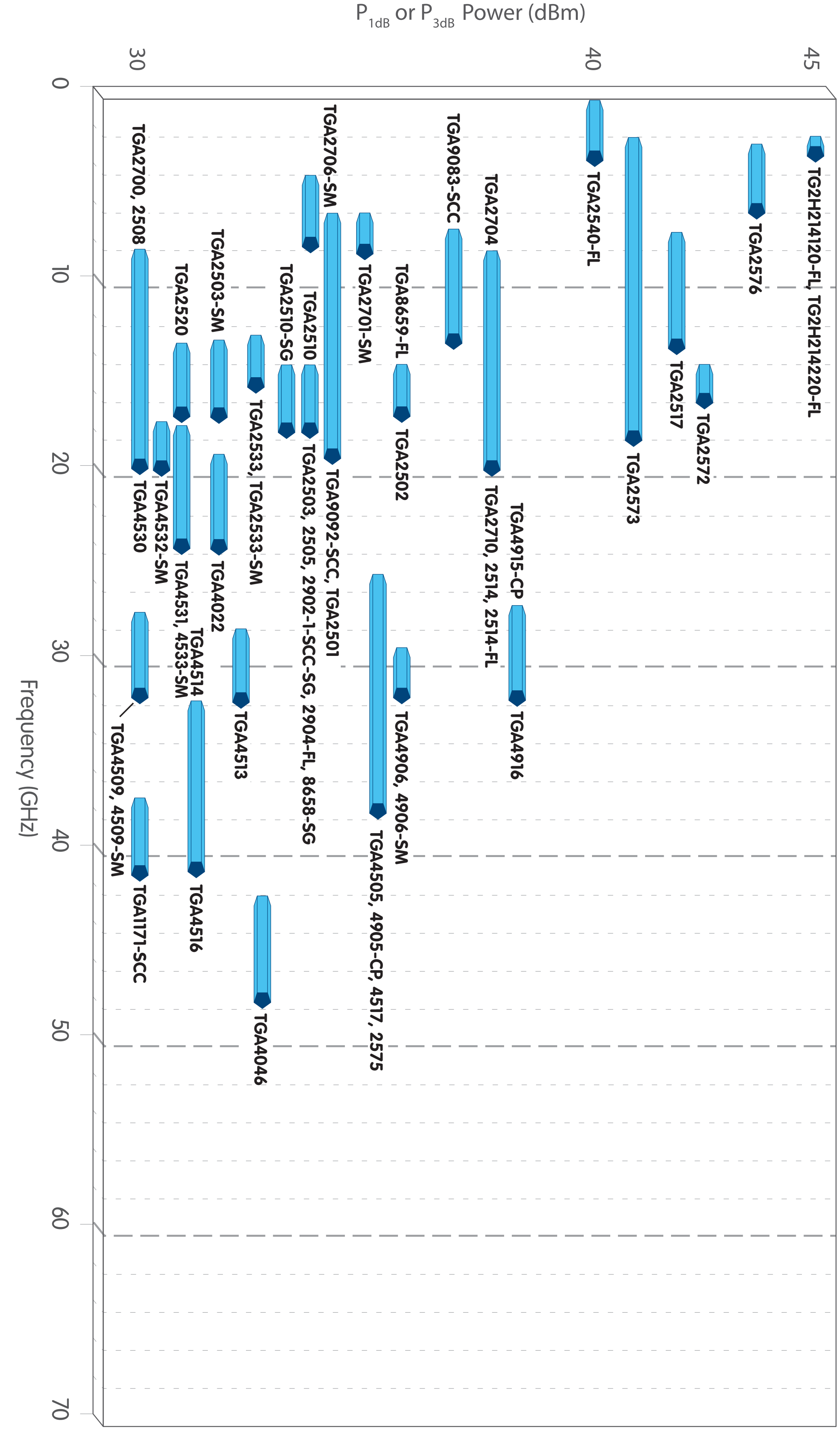
Selected Low Noise Amplifiers, LNA Noise Figure vs. Frequency

For a complete list of low noise amplifiers, please refer to page 28.



Selected Less Than 1W Higher Frequency Amplifiers, Power vs. Frequency

For a complete list of less than 1W amplifiers, please refer to pages 24 and 25.



Selected More Than 1W Higher Frequency Amplifiers, Power vs. Frequency

For a complete list of more than 1W amplifiers, please refer to pages 25 and 26.

PACKAGING

For detailed information on TriQuint product packaging, please visit our website at **www.triquint.com/prodserv.**

ORDERING

TriQuint products can be purchased through:

- ***TriQuint Field Sales Offices:***
  We have regional sales offices across the globe to work closely with you on your next TriQuint product purchase. To identify the closest regional sales office, please go to our website at **www.triquint.com/sales.**
- ***Local Sales Representatives:***
  Local sales representatives are skilled at examining application needs from a variety of angles to aid the design process. Their insight and specialized experience, paired with your goals, can find the combination of products that best meet overall objectives. Since these representatives work with a variety of customers in many different design environments, their experience can be valuable in determining the right 'fit' for your particular application. To locate a sales representative, please visit our website at **www.triquint.com/sales.**
- ***Distributors - Buy / Resale Reps:***
  TriQuint products can be purchased from any one of the distributors or buy / resale reps listed on our website at **www.triquint.com/sales.**

TERMS & CONDITIONS

For a complete listing of TriQuint terms and conditions of sale, please visit our website at **www.triquint.com/sales.**

EXPORT COMPLIANCE

Virtually all products TriQuint offers for sale as detailed in the Product Selection Guide are available for export in compliance with US government regulations. Please contact your TriQuint salesperson for details.

PRODUCT SUPPORT

- ***Product Data Sheets and Literature:***
  Detailed information on our products including datasheets and other literature can be found on the TriQuint website at **www.triquint.com/prodserv.**
- ***Applications Support:***
  Detailed product support information can be found on the TriQuint website at **www.triquint.com/prodserv.**

RELIABILITY PROGRAMS

Our programs are in line with JEDEC and other industry standards.

ENVIRONMENTAL POLICY

TriQuint Semiconductor is committed to managing environmental matters as an integral part of our business, complying with all applicable laws, regulations and other requirements, preventing pollution and continually improving.

ENVIRONMENTAL SYSTEMS

- ISO-14001:2004 (Select Sites)

QUALITY POLICY

The people of TriQuint Semiconductor are committed to continuous improvement, quality, reliability and customer satisfaction in everything we do.

QUALITY SYSTEMS

- ISO-9001:2008 Certified (Select Sites)
- ISO / TS 16949:2009 Certified (Select Sites)
- ISO / AS9100 Certified (Select Sites)

QUALITY TOOLS UTILIZED

- Design Failure Mode & Effects Analysis (DFMEA)
- Process Failure Mode & Effects Analysis (PFMEA)
- Process Control Plan (PCP)
- Production Part Approval Process (PPAP)
- Eight Discipline Problem Solving (8-D)
- Real Time Statistical Process Control (SPC)
- Measurement System Analysis (MSA)
- Advanced Product Quality Planning (APQP)

For further details on TriQuint quality information, please visit our website at **www.triquint.com/company/quality.**

PRODUCT COMPLIANCE POLICIES

TriQuint is committed to meeting all global product environmental regulations that affect its products. These regulations include:

- Directive 2002 / 95 / EC (RoHS Directive)
- Management Methods for Control of Pollution Caused by Electronic Information Products (China RoHS)
- Directive 94 / 62 / EC (Packaging Directive)
- Directive 2006 / 122 / EC (PFOS Directive)
- Regulation (EC) No 1907 / 2006 (REACH Regulation)
- Commission Decision 2009 / 251 / EC {[Dimethylfumarate (DMF) Ban]}

All active TriQuint commercial standard products are compliant with these directives. Contact TriQuint for the RoHS compliance status of custom products, military products and products manufactured prior to June 2006. All new product designs are halogen-free since late 2008. TriQuint does not use any REACH Substances of Very High Concern (SVHCs) in its products or packaging materials (as of May 2011). Also, TriQuint is committed to complying with Section 1502 (Conflict Minerals) of the Dodd-Frank Wall Street Regulation and Consumer Protection Act. We are actively surveying our supply chain to ensure that our products are "Conflict Free".

In addition to being compliant with the above product compliance laws and regulations, TriQuint participates in the following customer programs:

- Sony Green Partner
- Samsung Eco-Partner

Please contact TriQuint at **rohs_info@tqs.com** for any product compliance information requests. For further details on TriQuint environmental, health & safety information, please visit our website at **www.triquint.com/company/ehs.**

NOTICE

The data provided in this selection guide is subject to change without notice. TriQuint reserves the right to make changes to specifications and other information at any time.

TriQuint SEMICONDUCTOR

Connecting the Digital World to the Global Network®

Below is a List of our Authorized Channel Partners:

RichardsonRFPD An Arrow Company

MOUSER ELECTRONICS a tti company

RFMW

AVNET 安富利电子元件

JORJIN TECHNOLOGIES

tecnomic

MARUBUN CORPORATION

Versatech

To find out who is authorized in your area, visit **www.triquint.com/sales.**

OREGON, UNITED STATES
Phone: +1.503.615.9000
Facsimile: +1.503.615.8900
E-mail: infoamericas@tqs.com

TEXAS, UNITED STATES
Phone: +1.972.994.8200
Facsimile: +1.972.994.8504
E-mail: infoamericas@tqs.com

FLORIDA, UNITED STATES
Phone: +1.407.886.8860
Facsimile: +1.407.886.7061
E-mail: infoamericas@tqs.com

EUROPE / MID EAST / AFRICA
Phone: +49.89.99628.2600
Facsimile: +49.89.99628.2699
E-mail: infoemea@tqs.com

CHINA
Phone: +86.21.5011.7290
Facsimile: +86.21.5011.7295
E-mail: infoasia@tqs.com

TAIWAN
Phone: +886.2.2758.3066
Facsimile: +886.2.2758.3185
E-mail: infoasia@tqs.com

KOREA
Phone: +82.31.788.7231
Facsimile: +82.31.788.7245
E-mail: infoasia@tqs.com

JAPAN
Phone: +81.3.5449.7105
Facsimile: +81.3.5449.3021
E-mail: infoasia@tqs.com

Visit **www.triquint.com/subscribe** and register for TriQuint product and process updates.