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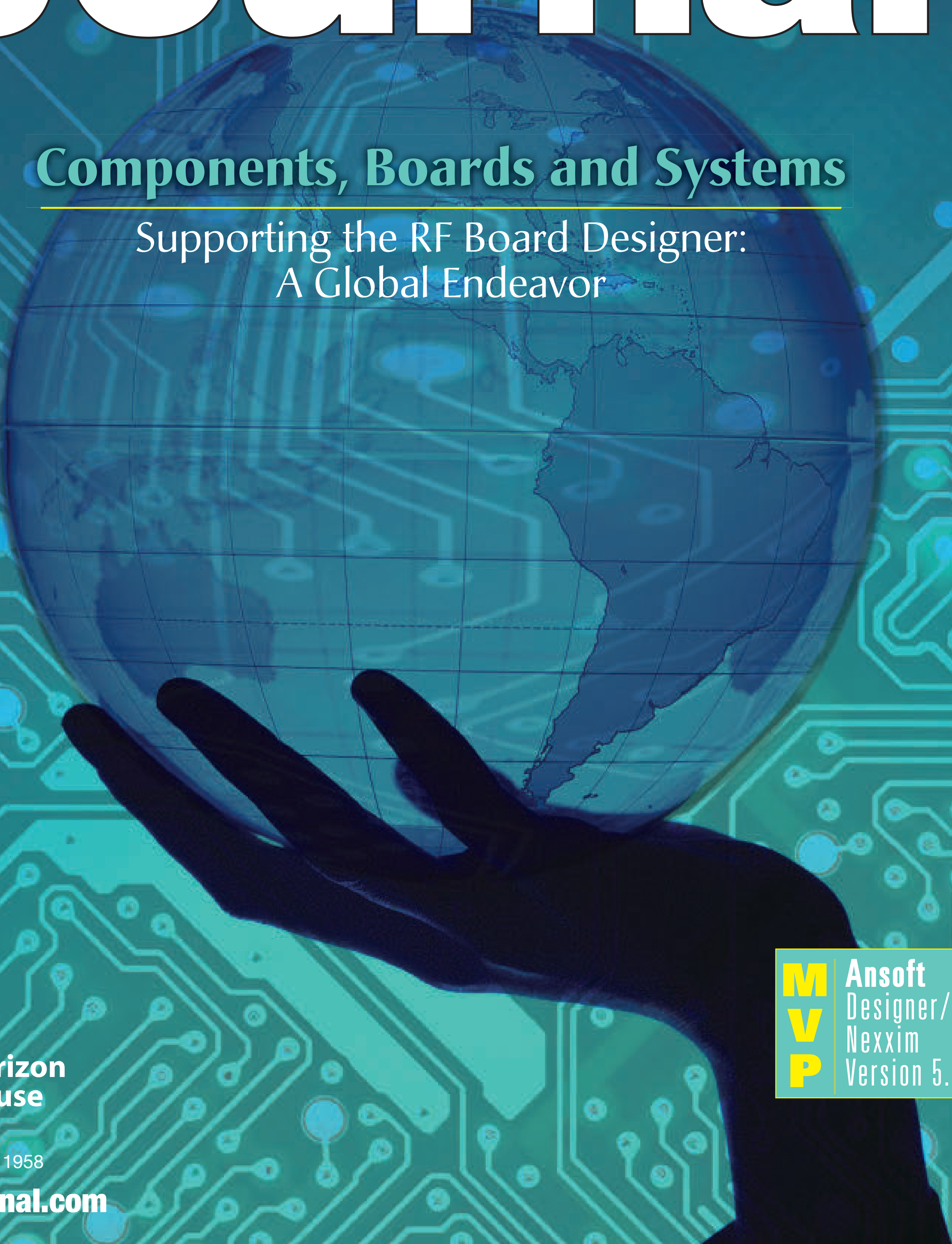
Microwave Journal



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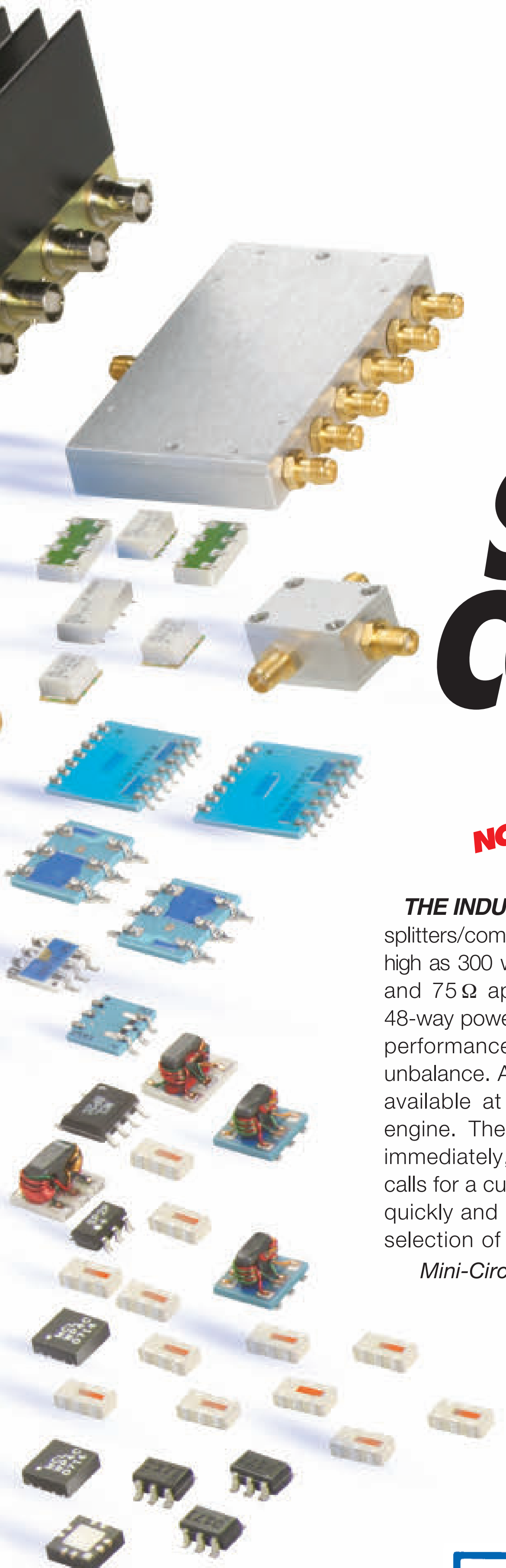


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FEATURES

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Dr. Florian Ramian, Rohde & Schwarz

Online Design Support and Evaluation Powered by Remote Simulation

Uwe Knorr, Transim

Semiconductor Obsolescence Leads to Gray Market Practices

Rochester Electronics

Executive Interview

Jim Rautio, Founder of **Sonnet Software**, talks about the humble beginnings of his company, converting microwave and high-speed engineers into EM believers, and why EM software always gives the wrong answer.

Expert Advice

Len Crane, Technical Marketing Manager at **Coilcraft**, has over 30 years of inductor design experience. He talks about a new interactive online inductor selection tool that helps engineers compare inductors and their critical performance data such as Q, equivalent series resistance and self-resonant frequency.

EDA Focus

DesignCon is an event for electronic design experts spanning chip, package, board, and system domains, addressing common issues in signal integrity, power management, interconnection, and design verification, which is why microwave design software is so widely used in this market. High speed board design certainly fits with this month's theme in MWJ; therefore, this month's EDA focus will look at EDA product announcements coming out of this show as part of our DesignCon coverage.

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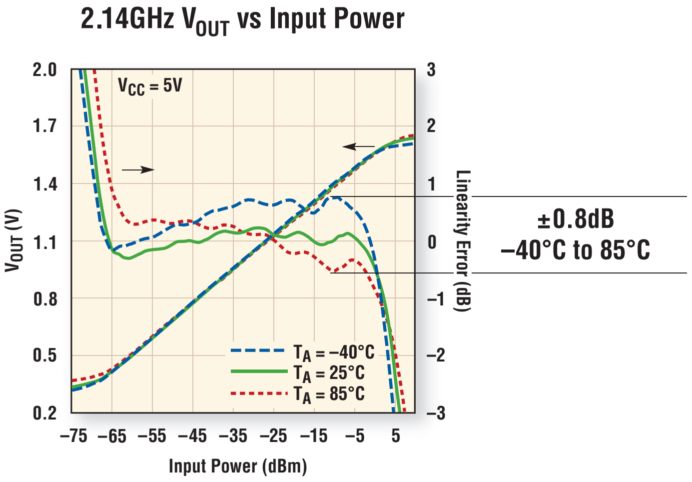

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COUNTING THE DAYS...

DAVID VYE, *MICROWAVE JOURNAL* EDITOR

Did you know that February was among the last two months (along with January) to be added to the Roman calendar? According to Wikipedia, the Romans originally considered winter to be a "month-less" period. NFL fans experience a similar feeling on the morning after the Super Bowl, which, coincidently, is in February. Maybe it's the time of year. As our astute readers are well aware, February with less than 30 days is not only the shortest month, it is the only one in which the number of days fluctuate every fourth year. Let's face it; time in February is short and unreliable. This month, more than any other, exemplifies how time is working against us, especially when a deadline is looming.

On the upside, February is the month we turn our editorial attention to the technology of printed circuit board design for RF and microwave applications. Over the years, we have published many papers on transmission line theory, techniques and applications in RF PCB, MIC, LTCC, SiP and hybrid design. As the technology and available mediums have evolved, we have reported on these advances and how innovative "off-chip" design has steadily improved performance, reduced size and cut costs. What we have not reported on so much, are the gory details of what it takes to tackle some of the very real engineering challenges in RF board design and product development. Since our readers sweat these details every day, we thought the time was right to put our spotlight on this often grueling experience.

When it comes to product development, time (or lack thereof) plays a central role. Engineering deadlines or what marketing folks refer to as "time to market" can become a real source of stress when some unforeseen problem brings a development project to a grinding halt. If the problem has been encountered before, engineers may find the solution quickly from among their bag of engineering tricks. Unfortunately, novel designs often yield novel challenges not readily solved with some previous work around. At this point one needs a bigger bag of tricks, usually acquired through the engineering process and experience. When a development project begins to resemble a research effort, time—that most precious commodity—is consumed at an alarming rate.

And yet, thanks to the component vendor eco-system, there are support networks readily in place that can provide near-instant design expertise. This is the subject of our cover article from Richardson Electronics, a real-life case study of their field application group working with an international customer on an engineering project with an extremely aggressive development cycle. As this case study demonstrates, sometimes it takes a global village to raise a product, especially when the clock is ticking.

Complimenting the intensive hands-on effort demonstrated by the Richardson Electronics field organization, this month at MWjournal.com we introduce our readers to Transim, a new online design services company that is entering the RF/microwave space. Transim works directly with the application groups of some major component vendors to create reference designs that can be simulated and modified directly on the component vendor's web site. By combining a powerful component search algorithm, interactive online schematic parameter entry, simulation and performance plotting with bill of materials generation, Transim partners with component vendors to offer a unique point of entry for design engineers to test out real components and submit a request for actual samples based on their results. This is a big leap from static data sheets and could change the way we initiate designs and are introduced to new components. Read all about it at www.mwjournal.com/transim.

We are also pleased to present Ansoft Designer/Nexxim version 5.0 as our MVP for the month of February. This high-frequency design software, which has been targeting advanced signal integrity and RFIC design applications for years, is now available in different product configurations to meet the specific needs of various RF/microwave applications. The capabilities that have made these products popular with the signal integrity world will serve our industry well as the lines between high-speed digital and microwave electronics blur, especially at the complex board level where both types of signals reside. Speaking of board simulations, we hear from Sonnet's Jim Rautio with a technical article on EM simulation of anisotropic substrates (co-authored with J. Reynolds and A. Horn III of Rogers Corp.) and in our monthly online executive interview.

Even though it's a short month, February has plenty of good content for our readers both in print and online; certainly enough to get us to March if not all the way to baseball's Opening Day.

MARCH 2010

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
28	1 **ARMMS RF and Microwave Society Conference** **Call for Papers** Deadline	2 ◄ **Georgia Tech Fixed-Point Signal Processing Systems** Atlanta, GA (March 2–5) ►	3 Georgia Tech	4	5	6
7	8	9 ◄ **EMV 2010 International Exhibition and Conference on Electromagnetic Compatibility** Düsseldorf, Germany (March 9–11) ►	10 ◄ **IWCE 2010** Las Vegas, NV (March 10–12) ► **Ansoft HFSS Training** San Jose, CA ANSOFT	11 Agilent Technologies ◄ **Agilent RF Interference Analysis Training** Englewood, CO (March 11–12) ►	12	13
14	15 ◄ SATELLITE 2010 National Harbor, MD (March 15–18) ► ◄ **GeMiC 2010 German Microwave Conference** Berlin, Germany (March 15–17) ►	16 **MWJ/Besser Webinar: RF/MW Power Amplifiers** Sponsored by: AWR, M/A-COM Technology Solutions	17	18 CST **CST EM STUDIO® Training** Darmstadt, Germany	19	20
21	22	23 The 2nd annual RF/Microwave Zone Pavilion *CTIA Wireless 2010, March 23-25, 2010,* Las Vegas Convention Center, Central Hall, Las Vegas, NV International CTIA WIRELESS 2010® A Division of CTIA–The Wireless Association®	24	25	26	27
28	29	30 ◄ **Georgia Tech Signal Processing Refresher** Atlanta, GA (March 30–April 1) ►	31	1	2	3

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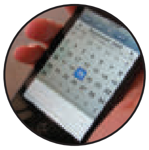

Coming Events

CALL FOR PAPERS

EuMW 2010
European Microwave Week
Deadline: February 7, 2010

ARMMS RF and Microwave Society Conference
Deadline: March 1, 2010

MILCOM 2010
Deadline: March 12, 2010

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FEBRUARY

GSMA Mobile World Congress
February 15–18, 2010 • Barcelona, Spain
www.mobileworldcongress.com

NATE 2010
National Association of Tower Erectors
February 15–18, 2010 • Orlando, FL
www.natehome.com

MARCH

EMV 2010
International Exhibition and Conference on Electromagnetic Compatibility
March 9–11, 2010 • Düsseldorf, Germany
www.e-emc.com

IWCE 2010
March 10–12, 2010 • Las Vegas, NV
www.iwceexpo.com

SATELLITE 2010
March 15–18, 2010 • Washington, DC
www.satellite2010.com

CTIA with RF/Microwave and M2M Zones
March 23–25, 2010 • Las Vegas, NV
www.ctiawireless.com

APRIL

WAMICON 2010
IEEE Wireless and Microwave Technology Conference
April 12–13, 2010 • Melbourne Beach, FL
www.wamicon.org

APEMC 2010
Asia-Pacific Symposium on Electromagnetic Compatibility
April 12–16, 2010 • Beijing, China
www.apemc2010.org

ARMMS RF and Microwave Society Conference
April 19–20, 2010 • Oxfordshire, UK
www.armms.org

MAY

MIE 2010 and ICMMT 2010
2010 Microwave Industry Exhibition in China (MIE 2010)

2010 International Conference on Microwave and Millimeter Wave Technology in China (ICMMT 2010)
May 8–11, 2010 • Chengdu, China
www.cnmw.org

Radar 2010
IEEE International Radar Conference
May 10–14, 2010 • Washington, DC
www.radar2010.com

RFIC 2010
IEEE Radio Frequency Integrated Circuits Symposium
May 23–25, 2010 • Anaheim, CA
www.rfic2010.org

IMS 2010
IEEE MTT-S International Microwave Symposium
May 23–28, 2010 • Anaheim, CA
www.ims2010.org

Microwave Journal OSD Online Show Daily

ARFTG 2010
75th ARFTG Microwave Measurement Conference
May 28, 2010 • Anaheim, CA
www.arftg.org

JULY

EMC 2010
IEEE International Symposium on Electromagnetic Compatibility
July 25–30, 2010 • Fort Lauderdale, FL
www.emc2010.org

SEPTEMBER

EuMW 2010
European Microwave Week
September 26–October 1, 2010
Paris, France
www.eumweek.com

Microwave Journal OSD Online Show Daily

OCTOBER

AMTA 2010
Antenna Measurement Techniques Association
October 10–15, 2010 • Atlanta, GA
www.amta2010.com

4G World
October 18–21, 2010 • Chicago, IL
https://4gworld.com

MILCOM 2010
October 31–November 3, 2010 • San Jose, CA
www.milcom.org

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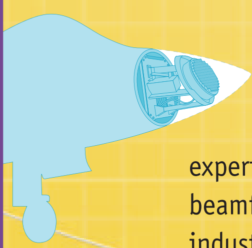

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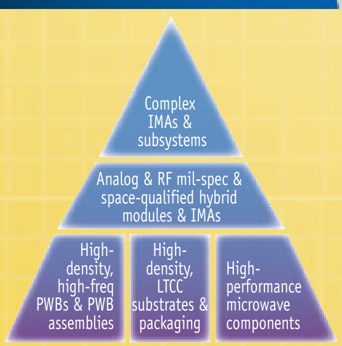

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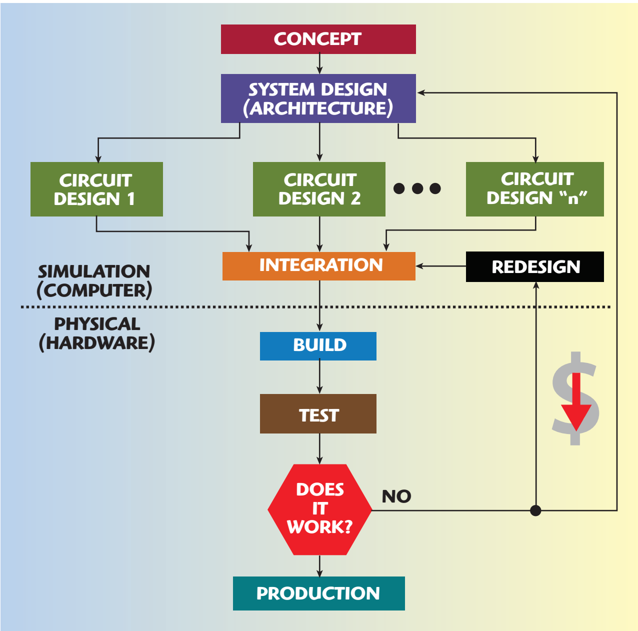
Cover Feature
Invited Paper

Field Support Streamlines Design and Development Cycles

There is little doubt that tomorrow will bring additional engineering design opportunities in the ever changing, ever expanding global RF and microwave applications arena. In the time it takes to read this paragraph, a new opportunity has been identified in Asia involving high-speed data, and one or two systems engineers have been tasked to come up with several solution concepts by the end of this month. If a workable, profitable business plan can be put together quickly, then one of these solutions could be in design by the middle of next month. In rapid fashion, a slightly larger engineering team will be assigned and the design phase will commence. Thus another engineering project begins. The engineering team's next few decisions will greatly impact the eventual time-to-market for the new product and the overall success or failure of the project. It is precisely at this point that experience is critical: The accrued knowledge of a component distributor's seasoned field support organization can act as an extension of this engineering team to help improve both the profitability and the success trajectory of the project.



▲ *Fig. 1 RF design process.*

An optimal RF design process (see ***Figure 1***) must include a "global perspective" for the project. The team will certainly have questions: How can we get help with architecture decisions? How many circuits should we design ourselves versus outsourcing? What are the best-fit critical parts for each circuit design? What are the ways to shorten our development time? How can we cost-optimize our designs while meeting all specifications? Who can help us to work simultaneously with part suppliers and end-customers on multiple continents? Partnering with a full-service, globally focused RF and microwave components distributor can help the team answer these questions and more.

Chris Marshall
and Bill Murphy
Richardson Electronics Ltd., LaFox, IL

IT TAKES A GLOBAL PERSPECTIVE TO SUCCEED THESE DAYS...

Even if a given design project is scaled to meet the needs of an application in just one country, the project team will benefit greatly by employing a global perspective. Knowledge of a novel application for an existing component or additional device characterization can often benefit engineers working on a completely different end product. Consider the challenge of searching through thousands of data sheets to find the best new technologies available for a specific circuit design. Are there reference designs and layouts available anywhere? Who can the team talk to about reliability concerns? Could a "development partner" be of help for prototyping… for testing… for supply chain… for manufacturing?

Think about it: At about the same time that the opportunity mentioned above presented itself in Asia, thousands of engineers are working worldwide on new RF and microwave circuit and component designs. Correspondingly, new information is just now becoming available. One of the keys to success is to make sure that the project team benefits from all this global information, global design support, global manufacturing and global supply chain logistics. The following case study highlights the benefits of this global perspective.

CASE STUDY: EXPERT SUPPORT HELPS THE PROJECT SUCCEED, STEP BY STEP

An engineering manager from a small company in Asia contacted the local office of Richardson Electronics. The engineering manager and his company had been contracted to design, develop and deliver production units of a multi-stage power amplifier circuit, specified over three different frequency ranges. Each of the three new PA units had been requested by the business team to be in preproduction within four months—a daunting challenge (all too common in today's marketplace, however). The engineering manager wanted to get as much help from the distributor's design support resources as possible, and a meeting was set up to discuss the alternative design approaches and component options. The detailed specifications were sent immediately to the local field sales engineer (FSE), as well as to the field applications engineer (FAE) located in their regional applications lab, in order to prepare for the initial design support session.

Step 1: Engage design support from a knowledgable and established global component distributor early in the design process

As is the case in many engineering companies today, the designers did not have access to a large, in-house component engineering department to provide them with support. The component distributor is most often called upon to fill this role, acting as an "expert-level" component engineering department. The distributor is able to provide current advice regarding where any given part might be in its product life cycle, which components were more widely available, new products about to be released, reliability history in similar operating conditions, and the like.

The distributor's FAE and FSE met initially with just the engineering manager and carefully reviewed the specifications and deliverables for each of the three power amplifiers. All were challenging designs in terms of meeting cost, performance and time-to-market goals. Two had significantly higher manufacturing quantity projections than the third, especially for the first 18 months of production. With the lower quantity unit, it was clear that the bills-of-materials (BOM) cost goals would be quite difficult to meet. The FAE asked the engineering manager about the possibility of focusing the design team on just the two higher-quantity PA units and looking to another supplier to customize an existing "off-the-shelf" design, in order to meet the project deliverables for the third PA. This would reduce the risk of the overall project.

Step 2: Brainstorm together looking at all alternatives, including "make versus buy" decisions when appropriate

The trade-offs included spending more on each individual unit and a small, up-front non-recurring expense (NRE) charged by the PA supplier to customize the design. The engineering manager was certain that his management would not approve this change and believed the team could complete all three designs within the allotted time and cost constraints.

The two next met with the small design team. Each of the three designers had completed a block diagram for their respective design. Each block diagram was discussed in turn, and the five worked together to consider the alternative device technologies—and corresponding circuit topologies—for each power amplifier design block. During this part of the discussion, specific RF power transistors were identified as possible candidates for each design, and the approximate cost, availability, and performance of each were evaluated against the overall project goals and performance requirements while still in the meeting.

Step 3: Evaluate together a number of circuit topology alternatives trading-off performance, cost and part availability

The application engineer not only had all of the latest published vendor information available to discuss, he also had knowledge of the newest parts and technologies that were just becoming available. One part was discarded, based on some recent returns from other customers that indicated a potential reliability problem. The design engineers were somewhat surprised to learn that some of their "preferred choices" had excessively long lead times and a couple had even recently been listed by the vendor as "not recommended for new designs," having been superseded by newer power transistors. Conversely, some newly released capacitors and low cost, high power terminations were stock items which could be delivered that same week.

Step 4: Make sure that the vendors recommended by the distributor are a good fit with your design tools, and that the proper modeling information is available for your use

The next topic to discuss was "simulations and computer modeling." It is important to match-up the design simulation tools used by the engineers with the types of models that can be provided by the individual vendors. A field application engineer has knowledge of the available models on a vendor-by-vendor basis, as well as what may not be published but could be obtained quickly on request. As a direct result of this discussion, the team was able to further refine the list of component options for each power amplifier.

The meeting moved forward with in-depth discussions regarding individual transistor and process cost trends, lead-time expectations, packaging alternatives, thermal management considerations, and quality/reliability field data. Trade-offs were discussed between cost and performance of the various transistor packaging alternatives. Plastic packaging was chosen as having acceptable electrical performance combined with low cost and stable lead times.

Near the end of this first meeting, the combined team settled on an LDMOS Doherty PA design driven by a high power driver. Each designer requested simulation models for two different power transistor alternatives as well as for multiple driver alternatives. These models were delivered to the team members electronically later the same day, while requests for samples and test fixtures were entered immediately for the most likely options. A second meeting was scheduled for two weeks later, with the goals established that simulations would be completed and preliminary BOM would be available for review.

During the next two weeks, the design team drew up initial schematics and simulated their power amplifier circuit designs using CAD tools. Support for the design team was provided as necessary by the applications engineer via phone calls and e-mails. In one case, a discussion needed to be facilitated between one of the PA designers and an engineer at one of the power transistor vendors. The designer's simulation was showing larger than acceptable inter-modulation distortion (IMD) at the output of the PA. A different biasing scheme was suggested by the vendor's engineer and this solved the problem immediately.

The second meeting was the first formal "design review" for the project. The preliminary BOMs had been e-mailed to the sales engineer two days before the meeting, giving him time to review all of the critical RF components in each design. It was time to start selecting specific components to move forward with building the prototypes.

Step 5: Preliminary BOM: Review together all critical RF components in the design

In this phase of development, certain areas should be explored:

- For each major RF part, is there a cheaper alternative available (with similar performance)? Are there more highly integrated or higher power options that may reduce the parts count and improve reliability?
- If simulated performance is marginal, is there a better performing part available?
- Are samples and (if needed) evaluation boards readily available for each key selected part?

During this design review meeting, it was apparent that one of the three PA designs (the one with the highest frequency range) had poorer performance margins than the other two. The power transistors seemed to be performing well in simulation and the engineer was not exactly certain how to improve the design. A more expensive transistor provided the additional margin needed (in simulation), but at a prohibitive cost. As the team reviewed his circuit, the field application engineer suggested that perhaps

some better performing coupling capacitors would increase the design margin (while still using the cheaper transistor). He suggested two specialized High-Q RF capacitors with tight tolerances, and the extra cost for these was much more acceptable than that of the transistor option. It was decided to try the capacitor solution on the bench. In fact, all three designs could benefit from the higher-grade coupling capacitors and the BOMs were altered accordingly.

Step 6: Procure component samples and other items required for physical design testing

The field application engineer worked with the engineering team to identify all the parts that could be sampled by the distributor and those parts that would have to be bought by the design company through other channels (low-end resistors, bypass capacitors, etc.). While the most critical parts had been ordered even before simulation was complete, some additional items were now requested on a rush basis, including engineering sample kits for the passive components that would allow for a quick replacement if a change from the simulated value was required.

Step 7: Circuit Testing Support: Verify design for core RF circuitry via physical testing

About two weeks later, after all of the sample parts, evaluation boards and test fixtures had been received by the designers, the testing commenced to verify the RF core circuitry. The testing went relatively smoothly, and the High-Q RF capacitors did address the required design margins. In each case, the PA circuit performed close to predictions, even with the lowest cost transistors in place. However, when the circuits were tested under the high temperature extreme, the PA with the highest frequency range was performing at a low margin and was a cause for concern. It was at this point the distributor's applications lab manager, an experienced power amplifier designer, was consulted. After a brief design review with the team via conference call, the application manager suggested that a slight change be made to the design. He noted that the transistor in question was simply bolted down to the PCB according to the supplier recommendations. Recently, however, a new, low-cost clamping device had become available on the market which provided a better "thermal ground" for the transistor. The application note for the clamping devices described improved thermal and (surprisingly) electrical performance for the transistor, including improved P1dB and IMD3 performance (especially at high temperature). A sample was shipped overnight to the designer, and the performance margins under high temperature improved to a satisfactory level (see ***Figure 2***).

Step 8: Prototype Build (Release prototype BOM, determine manufacturer and location for prototype build, order parts for prototypes)

The project moved forward to the prototype phase. The R&D company was not a manufacturer. Like most small design companies today, they used various manufacturers as needed to build their designs. In the past, they usually worked with one specific nearby manufacturer for both prototype builds and for smaller manufac-

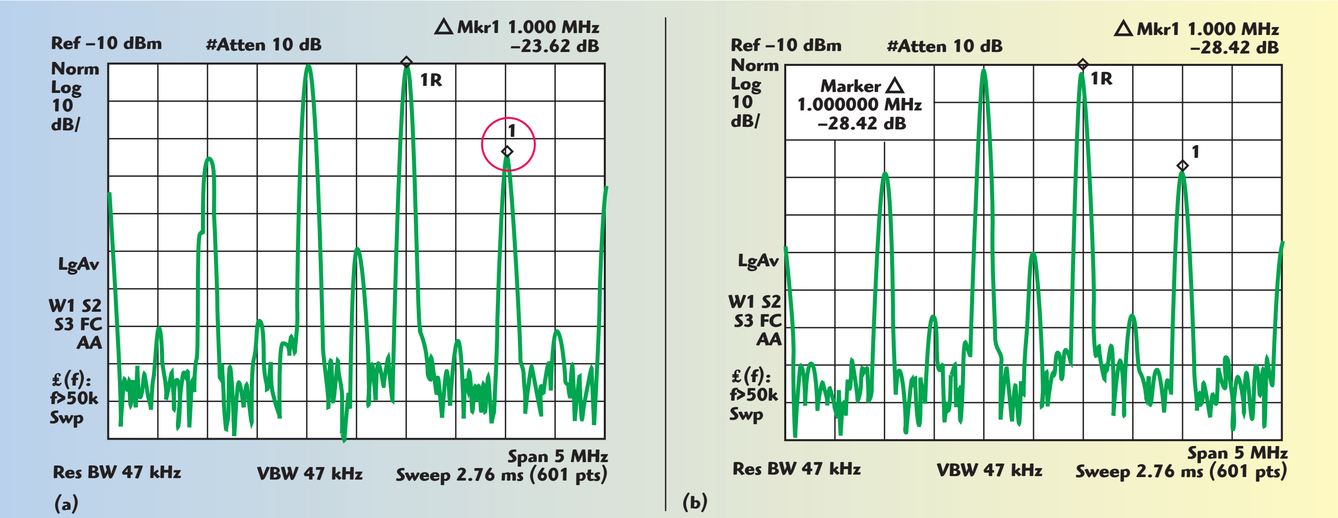


Fig. 2 IMD performance margin out of specification before clamping device (a) and within specification after clamping device (b).

turing runs. This time, however, their primary manufacturing resource was swamped and the lead time quoted for the build was not acceptable. The FAE suggested several other manufacturers known from past experience and offered to help to get an earlier "slot" for the build from one of them. The R&D company was a bit reluctant, mainly because the new manufacturer's facility was not located nearby and there were some language-barrier issues. The applications engineer set up a conference call with one of his colleagues located near the manufacturer and with the manufacturer's management team. In this way they convinced the customer that the new manufacturer would perform well, and the deal was struck for the prototype build. In the end, this saved approximately ten days for the project.

Step 9: Prototype Testing Support

After the PA prototypes were built and successfully lab-tested by the designers, the full system integration testing phase of the project began. The design team had scheduled time in their customer's in-house system integration testing lab for these purposes. During the first few days of testing, several minor issues were discovered with each of the PA prototype designs. The biggest issue was that when the PAs were tested (in turn) in the system, the system noise floor was rising up just a bit too high for specifications.

The problem seemed to be layout related. The team identified design changes to the ground plane near the driver MMIC and added an inexpensive choke and 2 bypass capacitors to the design. They were able to make these changes in the field to the prototypes, and the PAs passed system integration testing.

Step 10: Prepare for Manufacturing

Preparation for manufacturing had been on-going since the release of the prototype BOM. Parts had been ordered and stocked at the distributor based on the limited production forecast. Inventory was reserved specifically for the design company, in order to guarantee availability of parts for the first three months of production. This is another key point in the process. Working closely together, the design team and the distributor were able to meet the delivery needs of the end-customer. One of the keys was

the analysis earlier in the program, looking at lead time trends when key RF parts were being considered for the design. By carefully selecting parts that had adequate lead times, the design team and the distributor avoided some typical “back-end” problems related to parts availability.

Step 11: Manufacturing Support

In this case, the manufacturing support needed was fairly ordinary. Parts were ordered on time per the forecast and stock was available for the initial manufacturing runs of the three new power amplifiers. When the success of the project led to an earlier than expected jump in demand, components were pulled quickly from inventory in the US and Europe, arriving within three days. The key was the extensive communication and the close, step-by-step “tie-in” between the RF design company and the distributor. By working together closely, as would be the case if the designers worked with an in-house component engineering department, the designers and the distributor stayed in “lockstep” throughout each phase of the rapid development process, and each was able to make the best use of the information available to the two companies combined.

TRENDS IN THE ELECTRONIC SUPPLY CHAIN BUSINESS…

With the latest economic crisis, supply chains have become more tightly coupled than ever. CFOs everywhere, working on the basis of “cash is king,” have driven down inventories of finished goods and raw materials at every step in the channel. While not currently a widespread problem, selected products are going “on allocation,” and any fluctuation in demand can have a dramatic effect on their associated lead times.

Some of this is beneficial. Supply chain optimization does result in a lower cost at the end, and customers who are able to provide reasonably accurate forecasts and allow for the lead times will see a benefit. But for others, especially those dealing with end customers in China or Korea and may have to deliver product six weeks after winning a contract bid, identifying products that are likely to be in stock or that can be delivered quickly is key. Salespeople at global organizations can monitor and pull stock from local hubs in Europe, North America or Asia and deliver it anywhere in the world in one to three days. Distributors often rate their suppliers’ on-time delivery performance, and also invest heavily in new product inventories, even in anticipation of demand that is not forecasted. Some distributors also integrate data from their many customers’ material requirement planning (MRP) systems. Sample quantities of any new part, as well as evaluation boards and test fixtures, are maintained since that is often the critical element in a design win. Knowledge on everything from loading of supplier wafer fabs to lead times on ceramic packages for power transistors helps keep designers better informed of not only current lead times but future risk.

CONCLUSION: A GLOBAL PERSPECTIVE

It has always been an axiom that two

heads are better than one when trying to solve a problem. As demonstrated in the case study above, when it comes to design projects, two companies working together can indeed be a powerful approach to solving complex design problems and to streamlining the overall design and development process for RF and microwave systems. Each competent design team needs to work together with an equally knowledgeable supply team (i.e., a specialist global distributor) to bring a product to market on time.

During the early design phases, information flow is critical to success. Data sheets, design guides, application notes and part quotes need to be provided in a timely and efficient manner. Design alternatives need to be evaluated quickly, and component decisions made that trade-off time-to-market, cost and performance. Further into the design process, a given project's success or failure could ultimately hinge on the distributor's ability to work simultaneously (on behalf of the design team) with component suppliers and system manufacturers on several continents at once (see ***Figure 3***).

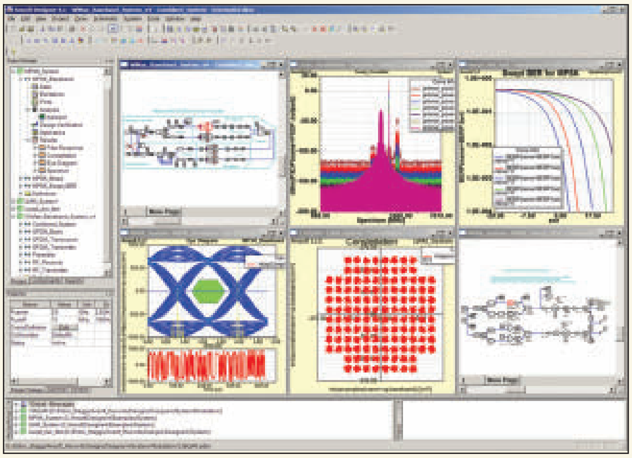
Fig. 3 Global perspective supply optimization.

Working with the best RF and microwave component and solutions suppliers around the globe, the distributor's field support team members are up-to-speed on the latest advances in the global wireless community. This global perspective is then used to provide the highly competent level of design support, on a step-by-step basis during the development, which has simply become the expectation for all design companies the world over. ■

Best Practices Note: At any stage of the design process, direct support between the design team and any given part vendor should be facilitated by the distributor. The distributor provides the customer with the proper contact at the factory saving time. The distributor also pre-qualifies the customer for the supplier, while eliminating most FAQs ahead of time, in order to make the best use of the supplier's limited resources.

Chris Marshall *received his BS degree in Electrical Engineering (BEng) from McGill University, Montreal, Canada, in 1973, and has held engineering, global marketing and business management positions in the semiconductor and telecom industries in Canada and the US. He is currently Vice President, RF and Microwave Components for Richardson Electronics Ltd., LaFox, IL.*

Bill Murphy *received his BS degree in Electrical Engineering (BSEE) from the University of Illinois at Urbana-Champaign in 1981, his MBA degree from the University of Chicago in 1984, and his MSEE degree from the Illinois Institute of Technology (IIT) in 1987. He is currently the Technical Marketing Manager for Richardson Electronics Ltd., LaFox, IL.*



ANSOFT DESIGNER/ NEXXIM VERSION 5.0

▲ *Fig. 1 March 2001* Microwave Journal *cover featuring Ansoft Designer.*

Ansoft Designer was introduced to the RF/microwave industry when "The New World of Communications Design Software" appeared as a cover feature in *Microwave Journal* back in March 2001 (see ***Figure 1***). Ansoft, now a division of ANSYS Inc., had developed a new design environment from the ground up, to integrate what had been separate circuit, system and planar EM simulation products. The product addressed high frequency design by offering a hierarchical approach to simulating complex distributed networks directly within the context of a circuit (including nonlinear devices, i.e. transistors and diodes) and/or system-level (behavioral models) analysis.

Ansoft Designer incorporated a number of innovations into the design environment's user-interface, providing circuit designers with unprecedented access to the company's core competency in electromagnetic simulation. The so-called "Solver-on-Demand" feature allowed engineers to characterize passive interconnects in situ using the software's planar EM solver. Direct access of the planar solver to a parameterized physical design within the circuit simulation would change the role of an EM simulator from verification tool to a full-fledged design optimization tool.

The roadmap for Ansoft Designer called for developing dynamic links to Ansoft's other 3D electromagnetic simulation products (HFSS and SIwave) and replacing the circuit simulation technology (Serenade) with a new high-capacity

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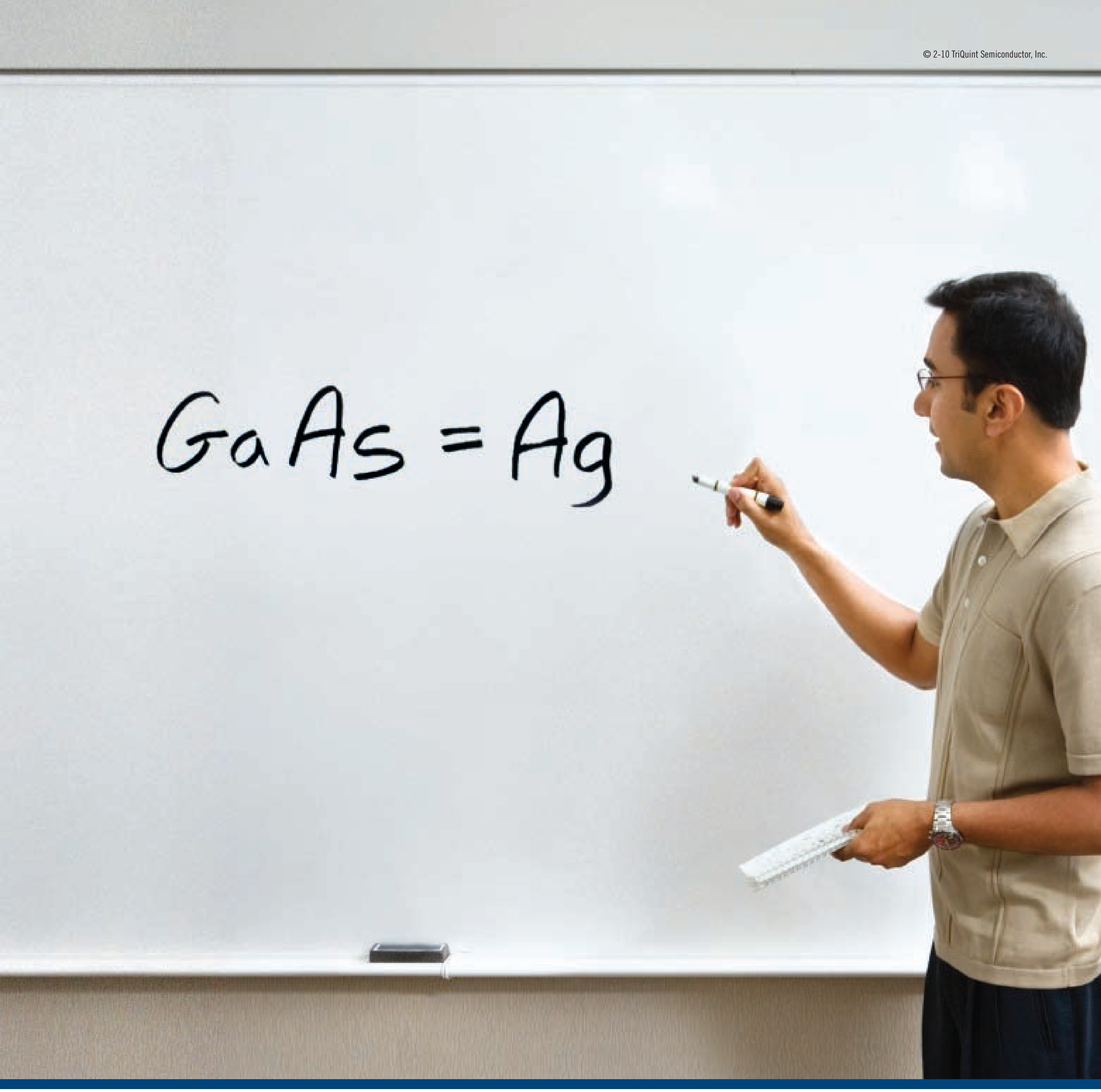
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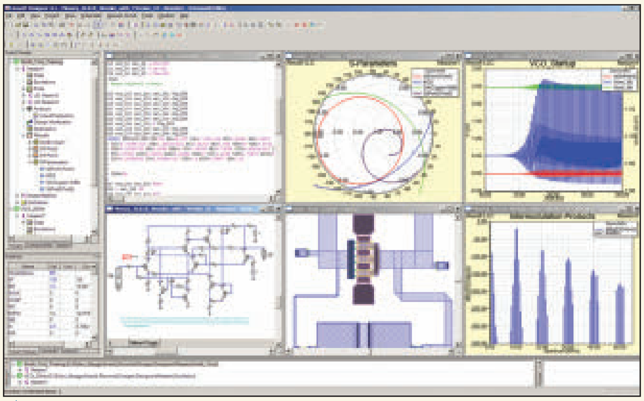
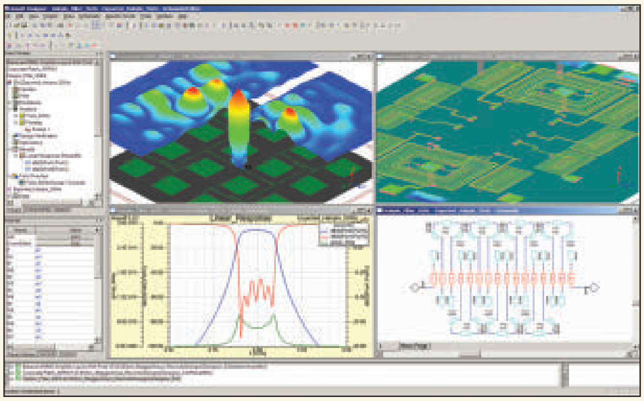


▲ *Fig. 2 DesignerRF Circuit with schematic, netlist and layout design views: linear, transient (time-domain) and nonlinear (frequency-domain) intermodulation simulations.*



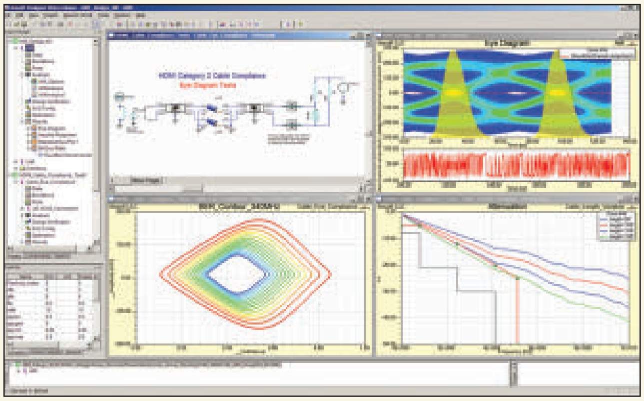
▲ *Fig. 3 Designer PlanarEM showing field plots (of MMIC with radiating on-chip inductors) and linear frequency response hairpin filter.*

circuit simulator developed by Ansoft called Nexxim, which was introduced in 2004. Combining the capabilities of HFSS and SIwave with Nexxim through the Ansoft Designer environment, Ansoft envisioned a solution for three specific application areas that required a set of tools capable of solving larger problems without sacrificing accuracy. The targeted applications included high-performance RF/microwave, Signal Integrity and RFIC designs that, due to the size and complexity of the passive structures, high transistor count and spectral density could not be addressed with existing simulation tools or had to be partitioned to reduce the problem size.

With the recent release of Ansoft Designer/Nexxim version 5.0, the company is expanding the product's focus beyond the needs of the most demanding, high-performance circuits in order to address a wider range of design problems. While the majority of high speed/frequency electronics require the functionality offered by the integration of circuit, system and EM simulators, many design problems do not. For instance, a planar antenna designer typically only needs an EM simulator, layout tool, optional schematic capture (depending if the design is based on a library of parts), design environment with plot generation and linear (and maybe transient) analyses. Unless the antenna is to be integrated with a power amplifier, the antenna designer will likely have no need for system-level or harmonic balance circuit simulation.

To address applications such as this, the product is now available in different suites with functionality bundled into sub-sets for specific design types, reducing potential gaps between tool capability and designer requirements. The three RF product suites are DesignerRF, DesignerRF Circuit and DesignerRF PlanarEM. The two product suites targeting signal integrity designs are DesignerSI and DesignerSI Circuit.

The DesignerRF product suite is tailored to the needs of engineers who design radio frequency integrated circuits (RFIC), monolithic microwave integrated circuits (MMIC), wireless transmission, system-on-chip (SoC), and other RF and microwave devices. Designers can choose between the full set of functions available with DesignerRF or targeted functionality with DesignerRF Circuit (no planar EM capability; see ***Figure 2***) or DesignerRF PlanarEM (no system or nonlinear circuit analyses; see ***Figure 3***). This bundling allows



▲ *Fig. 4 DesignerSI showing HDMI (category 2) cable compliance eye diagram test, bit error rate contours, and cable attenuation vs. length and frequency.*

companies with limited budgets to acquire just the necessary functionality for their particular product development needs. New enhancements for RF and microwave design include:

- System simulator integrated in circuit design with baseband and envelope simulation of advanced communication systems
- Filter synthesis tool that generates ideal and physical filters for circuit and EM tools
- Library expansion through downloadable vendor libraries as well as physical library expansion along with the latest active industry models
- EM improvements with design hierarchy, post-processing variables, thick conductor Q enhancements and parametric snapshot improvements with dynamic links

The DesignerSI product suite is ideal for engineers designing high-speed electronic interfaces including XAUI™, XFI, Serial ATA, PCI Express™, HDMI™, DDR, DDR2 and DDR3. Engineers using DesignerSI can leverage its optimization algorithms, design of experiments, tuning and post-processing capabilities for key signal-integrity metrics, such as time-domain reflectometry (TDR), bit-error-rate (BER), timing analysis and eye diagrams (see ***Figure 4***). All SI analyses can dynamically link to rigorous electromagnetic extraction. New signal integrity analysis features include:

- IBIS-AMI simulation: fully supports the latest IBIS standard, enabling fast behavioral modeling of electronic

systems with silicon vendor-supplied driver and receiver models

- QuickEye™ and VerifEye™ enhancements: separate rise/fall step responses, step response parallel processing, improved BER noise floor and enhanced jitter algorithms
- Design of experiments: large data handling, statistical eye plotting and text array variable support
- Reporter improvements: statistical eye, mixed mode reporting and network data explorer enhancements
- Model enhancements: S and W elements wizard, MATLAB™ models, S model caching and multi-source components

By focusing on the most challenging of high frequency design problems, Ansoft has developed a suite of products with impressive accuracy, capacity and speed. The performance of these combined products has made the Ansoft solution very widely used in the signal integrity community and niche RFIC applications. Since their initial release, the Ansoft Designer/Nexxim products have addressed these high-performance markets with regular, timely feature developments and product releases. With the new reconfigured product suites, the company is able to offer portions of this functionality which may be better aligned with the varied needs of the broader RF/microwave design community.

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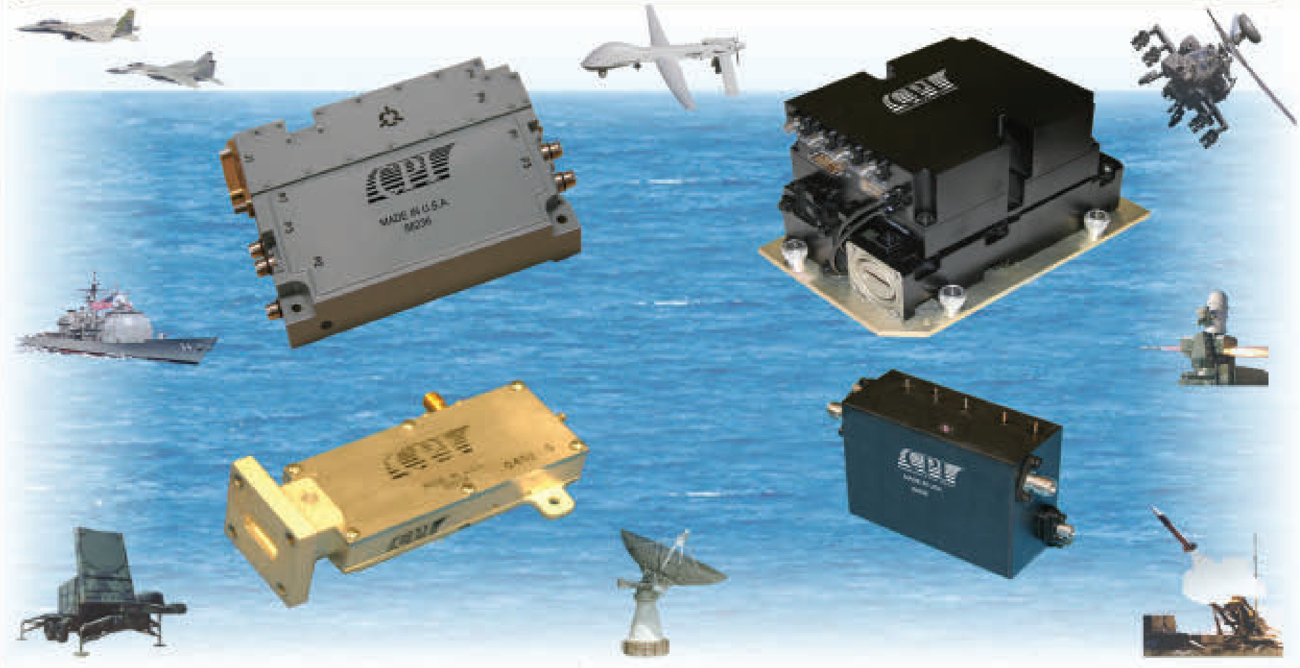

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Dan Massé, Associate Technical Editor

US Air Force/Lockheed Martin Team Complete Environmental Testing of Missile Warning Satellite

A joint US Air Force/Lockheed Martin-led team announced that it has successfully completed thermal vacuum testing of the first Space Based Infrared System (SBIRS) geosynchronous (GEO-1) satellite, one of the most significant program milestones that validates spacecraft performance in a simulated space environment. The US Air Force's SBIRS program is designed to provide early warning of missile launches, and simultaneously provide important capabilities to other missions, including missile defense, technical intelligence and battlespace awareness.

Conducted inside Lockheed Martin's Dual Entry Large Thermal Altitude (DELTA) chamber, the test verified spacecraft functionality and performance in a vacuum environment where the satellite was thoroughly tested at the extreme hot and cold temperatures it will experience in space. Thermal vacuum testing represents the last of several critical environmental test phases that validate the overall satellite design, quality of workmanship and survivability during space vehicle launching and on-orbit operations.

With the completion of spacecraft environmental testing, Lockheed Martin will now perform final factory work on the satellite and execute a series of integrated spacecraft and system tests to ensure the vehicle is ready for flight. The first SBIRS GEO spacecraft is planned for delivery to Cape Canaveral Air Force Station in late 2010, where it will then undergo final processing and preparation for launch aboard an Atlas V launch vehicle.

...the test verified spacecraft functionality and performance in a vacuum environment...

The SBIRS team is led by the Space Based Infrared Systems Wing at the US Air Force Space and Missile Systems Center, Los Angeles Air Force Base, CA. Lockheed Martin Space Systems Co., Sunnyvale, CA, is the SBIRS prime contractor, with Northrop Grumman Electronic Systems, Azusa, CA, as the payload integrator. Air Force Space Command operates the SBIRS system.

Raytheon Receives $1.1 B Order to Advance Taiwan's Patriot Capability

Raytheon Co. has received Foreign Military Sales contract awards totaling $1.1 B to fund new production of the combat-proven Patriot Air and Missile Defense System for Taiwan. The awards include ground-system hardware through an initial contract valued at $965.6 M and an initial spares contract valued at $134.4 M.

"The Patriot system is a vital element to providing superior integrated air and missile defense capabilities for the protection of Taiwan," said Daniel L. Smith, President of Raytheon Integrated Defense Systems (IDS). "Raytheon has provided advanced technology, innovation and support in Taiwan for more than 40 years, and we are honored to continue that partnership today and in the future."

The awards include ground-system hardware through an initial contract valued at $965.6 M...

The US Army Aviation and Missile Command, Redstone Arsenal, AL, issued the contract for new-production Patriot fire units that will include new advances in technology, improved man-machine interface and reduced life-cycle costs. Raytheon is the prime contractor for both domestic and international Patriot Air and Missile Defense Systems and system integrator for Patriot Advanced Capability-3 missiles. Work under these contracts will be performed at the Raytheon IDS Integrated Air Defense Center, Andover, MA; El Paso, TX; and Huntsville, AL. The company is supported by a global team of suppliers to the Patriot System.

Northrop Grumman Begins Full Rate Production of New Radar for B-2 Bomber

The nation's fleet of B-2 stealth bombers will all receive a new Northrop Grumman Corp.-developed radar system following the US Air Force's decision to authorize full-rate production of the units by the company's Radar Modernization Program (RMP). The decision, made by the assistant Secretary of the Air Force for Acquisition (acting), allows Northrop Grumman to begin fabrication of the balance of radar units needed to outfit the entire fleet. Those units will be produced as the final installment of the $468 M RMP contract awarded to the company by the Air Force in December 2008.

Northrop Grumman is the Air Force's prime contractor for the B-2, the flagship of the nation's long range arsenal, and one of the most survivable aircraft in the world.

"Putting this new radar on America's flight line helps ensure that the B-2 fleet is ready day or night to protect the nation's interests worldwide," said Dave Mazur, Vice President and B-2 Program Manager for Northrop Grumman. "The new radar also makes it easier for our modernization team to add additional mission capabilities to the jet in the future."

Northrop Grumman is currently producing radar units authorized under the RMP low rate initial production program, added Mazur. The company is also installing radar

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Northrop Grumman is the Air Force's prime contractor for the B-2...

units in operational B-2s as part of the RMP system development and demonstration phase. The B-2 radar modernization program replaces the aircraft's original radar system with one that incorporates technology improvements that have occurred since the B-2 was originally designed in the early 1980s. Raytheon Space & Airborne Systems, El Segundo, CA, developed the new radar hardware under contract to Northrop Grumman. The units include a new advanced electronically scanned array antenna, a power supply and a modified receiver/exciter.

Harris Receives Order to Provide HF Radio Systems to US DoD

Harris Corp., an international communications and information technology company, has received a $228 M order from the US Marine Corps to provide Falcon II AN/VRC-104 high-frequency radio systems for use in US Department of Defense (DoD) MRAP-All Terrain Vehicles (M-ATV). The contract was awarded by the US Marine Corps–Systems Command on behalf of the Joint MRAP Vehicle Program.

"The Department of Defense will use the AN/VRC-104 radio system to provide reliable, secure beyond line-of-sight terrestrial communications for this new class of armored vehicle," said Steve Marschilok, President, Department of Defense Business, Harris RF Communications. "Beyond line-of-sight communications—such as HF and tactical satellite—are essential in Afghanistan because of its mountainous terrain. M-ATVs are playing a crucial role in the Afghanistan war, and we're pleased the DoD has again recognized our radios are the best choice for this urgent and important mission."

"Beyond line-of-sight communications ...are essential in Afghanistan because of its mountainous terrain"

The AN/VRC-104 is a vehicular transceiver/amplifier that includes the AN/PRC-150(C), the only Type-1 certified HF radio available today. Harris HF radios are in widespread use by all branches of the US Department of Defense and allies around the world. Harris was recognized previously by the DoD for outstanding performance in delivering more than 10,000 radio systems to the original MRAP program.

Richard Mumford, International Editor

SANITAS Project to Strengthen German Competitiveness

The SANITAS ("Enabling safer systems by a new collaborative verification methodology across the entire value chain") project, which aims to strengthen German competitiveness by developing processes and verification methods for more flexible and secure automated manufacturing, has been launched by leading German companies. Under the project management of Infineon Technologies there are nine partners—research institutes and companies from the semiconductor, automotive and industrial automation sectors—that will work to complete research by September 2012.

The SANITAS project is being funded by the German Federal Ministry of Education and Research (BMBF) to the sum of about €7.3 M as part of the German government's High-tech Strategy and its Information and Communication Technology 2020 (ICT 2020) Program, which aims, among other things, to extend the development of electronic systems as 'enabling' technology for electronics.

The work carried out within the SANITAS project will create a basis for increasing the flexibility of complex microelectronics-aided systems, for example, in production automation and automotive electronics. One goal is to develop a collaborative verification methodology that can be applied beginning as early as in the development phase of system components and carried through the entire value-added chain; from the semiconductor provider to the system manufacturer whose production facilities use the newly developed chips. The benefit of the verification methodology is that faults can be detected even before production of the system components.

...SANITAS project will create a basis for increasing the flexibility of complex microelectronics-aided systems...

The project partners will work on new modelling processes that should allow suppliers to develop virtual reference models of their components. Using these models, system manufacturers can 'assemble' their production systems on a computer to test and correct them before actually constructing the systems. The developed methods are also intended for use in areas other than industrial automation, for example, in the communication and automotive sectors.

Key Milestone Observed by ALMA

After more than ten years of design and construction by scientists and engineers across the globe, the Atacama Large Millimetre/submillimetre Array (ALMA) has passed a key milestone, known as 'phase closure', crucial for the high quality images that will be the trademark of this new tool for astronomy. Engineers and astronomers have, for the first time, successfully linked three of the observatory's antennas at the 5,000 m elevation observing site in northern Chile.

The three-antenna linkup is a critical step towards the observatory's operations as an interferometer

ALMA, an international astronomy facility, is a partnership of Europe, North America and East Asia in cooperation with the Republic of Chile. The successful linking of the antenna trio was a key test of the full electronic and software system now being installed, and its success anticipates the future capabilities of the observatory. When complete, ALMA will have at least 66 high-tech antennas operating together as an 'interferometer', working as a single, huge telescope, with an effective diameter exceeding 10 miles, probing the sky in the millimetre and submillimetre wavelengths of light.

The combination of the signals received at the individual antennas is crucial to achieve images of astronomical sources of unprecedented quality at its designed observing wavelengths. The three-antenna linkup is a critical step towards the observatory's operations as an interferometer. Although the first, successful measurements employing just two antennas were obtained at the ALMA high site from October 2009, the addition of the third antenna is a leap of vital importance into the future of the observatory. Several additional antennas will be installed on the Chajnantor plateau over the next year and beyond, allowing astronomers to start producing early scientific results with the ALMA system around 2011.

ARTHUR Radar System for Italian Army

Defence and security company Saab has signed a contract valued at approximately €46 M for the sale of its ARTHUR Weapon Locating System (WLS) to the Italian Army. The order was obtained in collaboration with the Italian partner Selex Sistemi Integrati, who will supply the command and communications solution, while Saab will supply the radar system.

The contract, which is a basic order with the opportunity for future expansion, also comprises associated logistics with training, installation and support. Delivery is scheduled to take place over the next three years

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"Highly-functional weapon locating systems have become an increasingly important component in peacekeeping missions…"

and the Italian Army will be using the system for international assignments.

The ARTHUR radar system locates incoming enemy projectiles and missiles. The system provides information about the firing position and point of impact, and can simultaneously direct countermeasures. It therefore contributes to increased protection for friendly forces and the civilian population.

Commenting on the significance of the deployment of the radar system, Lennart Joelsson, Business Unit Manager, Saab Microwave Systems, said, "Highly-functional weapon locating systems have become an increasingly important component in peacekeeping missions throughout the world, both for ensuring that peace accords are being upheld, and for the protection of own personnel."

Motorola Sells MIRS to Altice

Motorola Inc. has signed a definitive agreement to sell its Israel-based Motorola Integrated Radio System (MIRS) to the Altice Group, a European investor in media and telecommunications. Utilizing Motorola's iDEN technology, MIRS provides telecommunications solutions to a wide range of customers in Israel including health services, fire and rescue, and transportation.

"We are confident MIRS is a good fit for the Altice Group"

Currently serving approximately 500,000 subscribers, MIRS was established in 1998 and has been a subsidiary of Motorola's Enterprise Mobility Solutions business, which serves both commercial enterprises and government and public safety customers around the world.

Gene Delaney, President of Motorola Enterprise Mobility Solutions, stated, "We are confident MIRS is a good fit for the Altice Group, an investor in media and telecommunications companies who has experience in pursuing growth opportunities in Israel's communication industry."

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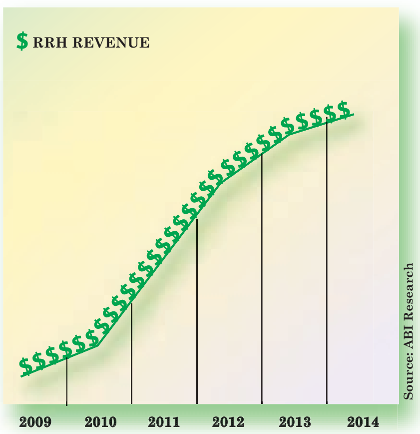
Market Watch

The end-of-life for a semiconductor product can leave OEMs of systems with long lifecycles scrambling for a supply of vital parts, forcing them into a difficult procurement situation. Some have turned to the so-called "gray market", a term that refers to the fraudulent manufacturing and distribution of counterfeit semiconductors. The danger of the gray market is that there is no guarantee of a continuous supply, authenticity, quality or reliability of the parts. One alternative is to redesign the component out of the system, but this can be costly or impossible if the original design team is no longer intact.

The ideal solution would be to find a drop-in replacement from a contractually-licensed manufacturer and authorized distributor. OEMs should be aware that such a service does exist. **Rochester Electronics** provides continuing manufacturing and customer support for semiconductor products that are being discontinued by the original manufacturer. As part of the Extension-of-Life™ process, the company acquires the original manufacturer's remaining inventory, including packaged devices, finished devices, die, intellectual property, tooling, test programs and test equipment, to provide continuous supply and extend the life of many semiconductor series. Semiconductor manufacturers such as AMD, Analog Devices, Fairchild, Freescale, Intel, Intersil, National, Texas Instruments and many others have authorized Rochester to provide continued manufacturing of devices that are no longer produced by the original manufacturer. Read more at www.mwjournal.com/Rochester.

Billion Dollar Market for Remote Radio Heads in 2014

The demands of cost reduction and greater efficiency in cellular base station design are leading to a rapidly growing market for remote radio heads. According to a new study from ABI Research, this market is on track to exceed a value of $1 B in 2014. Cellular base stations are now undergoing a design revolution; the trend is towards "distributed base stations" in which the RF portion (along with suitable processing and an optical interface) is placed into a weatherproof box mounted on the tower near the antennas. This is the remote radio head.



REMOTE RADIO HEADS REVENUE 2009–2014

Reducing operating costs is especially important now, so the remote radio head has become an integral part of these new distributed base stations. Remote radio heads are also very 'smart': almost all are software-controlled and can be configured remotely to handle a variety of technologies within a given air interface family. The result: greater efficiency, lower power consumption, and the possibility of placement in locations with coverage issues. A single distributed base station can even have multiple remote radio heads for MIMO operation.

To learn more about the remote radio heads market and how it may affect business models now and in the future, visit ABI Research's "Remote Radio Heads" study, which examines the ways in which radio heads will capture an increasing share within the BTS marketplace. It includes shipments and revenue forecasts for 2009-2014 segmented by air interface, as well as ASP and vendor market share data. It is part of the Mobile Networks Research Service.

Wi-Fi Becomes Multimedia Interface of Choice for Consumer Entertainment Devices

Wi-Fi has taken the entertainment device market by storm, with cameras, gaming devices (handheld and consoles), and personal media players (PMP) incorporating the technology within the past few years, reports In-Stat. Wi-Fi enabled entertainment device shipments will increase from 108.8 million in 2009 to 177.3 million in 2013.

Wi-Fi enabled entertainment device shipments will increase... to 177.3 million in 2013

"While a growing number of entertainment devices have Wi-Fi embedded, most product categories only have a few players—often with a single company dominating the market," says Victoria Fodale, In-Stat Analyst. "For gaming consoles and gaming devices, Nintendo dominates the market, selling 79 percent of Wi-Fi enabled consoles and 87 percent of Wi-Fi enabled handheld devices in 2009."

Recent research by In-Stat found the following:

- Although the Apple iPod Touch clearly has the dominant Wi-Fi-enabled PMP market share, many vendors have offerings in the space including Archos, Chumby Industries, Com One, Commodore International, Cowon, Creative, Dell, Haier, iriver, Logitech, Microsoft, Mintpass, Nokia, Philips, Polaroid, Revo, SanDisk, Sangean, Sirius, Slacker, Sony, Toshiba and Venzero.
- Nikon shipped 91 percent of Wi-Fi-enabled cameras in H1 2009.
- For the past several years all gaming consoles have had Wi-

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Fi embedded, which is a trend that will continue throughout the forecast period. The most significant variance in handhelds will be the type of Wi-Fi embedded. Beginning in 2010, these devices will begin shipping with 802.11n, while previously all devices were being shipped with 802.11b.

The research, "Wi-Fi in Entertainment Devices: Wi-Fi Becomes the Multimedia Interface of Choice," covers the worldwide market for entertainment devices with embedded Wi-Fi capability. It includes:

- Examination of the market for Wi-Fi in entertainment devices including drivers and barriers.
- Market share analysis of the gaming device market.
- Forecasts of worldwide WLAN chipset shipments and revenues through 2013.
- Profiles of major market players, including Microsoft, Nintendo, Sony, Apple, SanDisk, Nikon and Panasonic.

RFaxis' WLAN RFeIC and High Gain Antenna to Boost B-Link's Solutions

RFaxis, a fabless semiconductor company focused on innovative, next-generation RF solutions for the wireless connectivity markets, announced that B-Link Electronic Ltd. has selected RFaxis' RFX2402 and RFX2402H RF Front-end Integrated Circuits (RFeIC™), along with the new RFaxis high-gain antenna solution, for integration into the B-Link family of WLAN products.

B-Link, established in 1997 and based in Shenzhen, China, is an ISO 9001:2000 electronics OEM with in-house R&D and design functions that innovates at a rate of one new product every quarter. B-Link's manufacturing and quality control facilities enable eight production lines, a portfolio of over 500 connectivity products and a broad line of popular WLAN solutions that serve global high volume demand in Asia, North America, South America, EMEA and Australia.

> *"B-Link... innovates at a rate of one new product every quarter"*

The fully integrated RFaxis RFX2402 RFeIC comes complete on a single silicon die with a linear power amplifier that delivers state-of-the-art EVM power, a low-noise amplifier, a TX/RX switching circuit, a power detector, harmonic filters and impedance matching.

The RFaxis high-gain/high-power solution for B-Link includes the RFaxis RFX2402H RFeIC designed for WLAN client devices, such as USB dongles, as well as server devices, such as wireless routers and access points. By leveraging the RFX2402H high power and high sensitivity attributes together with an optimally matched RFaxis high-gain/omni-directional antenna, this total RFaxis front-end solution enables a highly reliable wireless connection over extended distances for any mobile WLAN device.

AROUND THE CIRCUIT

Jennifer DiMarco, Staff Editor

INDUSTRY NEWS

Crane Co., a diversified manufacturer of highly engineered industrial products, and **Merrimac Industries Inc.**, a leader in the design and manufacture of RF microwave components, assemblies and micro-multifunction modules, announced that they have signed a definitive agreement for the acquisition of Merrimac by Crane. Crane will pay $16.00 cash per share of common stock of Merrimac and associated common stock purchase rights. Under the terms of the agreement, Crane will commence a tender offer to acquire all of the outstanding shares of common stock of Merrimac, and this transaction, which is subject to the satisfaction of customary conditions, is expected to close in the first quarter of 2010. This transaction is valued at approximately $52 M and represents a 40 percent premium to Merrimac shareholders based on the closing value of its common stock on December 22, 2009, and a premium of 70 percent based on Merrimac's most recent 20-day average closing price. The agreement has been approved by the boards of directors of both companies.

Cree Inc. announced that it has acquired a portfolio of patents and patent applications related to semi-insulating silicon carbide (SiC) material and power device technology from Daimler AG. The portfolio consists of approximately 20 patent families, including issued patents in the United States, Germany, Japan and China.

Analog Devices Inc. (ADI) has successfully completed operational improvements to lower cost and achieve greater wafer fabrication efficiencies for its proprietary analog, mixed-signal and MEMS manufacturing process technologies. The improvements to plants in Wilmington, MA, which were completed November 1, and Limerick, Ireland, finalized earlier last year, were part of a previously announced multi-year plan to ensure ADI's customers have access to cost-effective and flexible global manufacturing infrastructure.

Cadence Design Systems Inc. announced that **Fairchild Semiconductor** has named Cadence as its primary EDA partner following the signing of a multi-year agreement for key Cadence® mixed-signal technology. Fairchild selected Cadence for its proven ability to provide an interoperable, mixed-signal design and verification solution using Cadence Virtuoso®, Encounter®, Incisive® and Allegro® technologies.

Nitronex and **Modelithics** have announced a collaboration to create state-of-the-art nonlinear models for Nitronex's high power gallium nitride (GaN) devices. Combining the Modelithics team's 35+ years of modeling experience with Nitronex's industry-leading GaN power devices will allow power amplifier designers to achieve best-in-class performance with faster time to market. Initial models will focus on Nitronex's new thermally improved products targeting broadband and high efficiency amplifiers for the military communications, electronic warfare and radar markets.

Agilent Technologies Inc. announced that **Simplay Labs LLC**, the company operating four of the eight global HDMI Authorized Test Centers (ATC), has selected Agilent Technologies as its High-Definition Multimedia Interface (HDMI) test solution provider. Agilent's test solution meets, or exceeds, the requirements of the HDMI Compliance Test Specification (CTS) Version 1.4 and is listed as recommended test equipment. The Agilent test solution addresses four sectors: source testing, sink testing, media physical layer evaluation and protocol test. The test solution was designed to reduce development costs while providing accurate test results with greater flexibility.

TT electronics has restructured its North American sales operations to create an integrated sales and marketing team to represent the company's component business units to its customers. The new TT electronics North American Sales Operation will be responsible for the sales and marketing of BI Technologies, IRC Inc., OPTEK Technology, Semelab and Welwyn Components products in the Americas.

Cobham is significantly enhancing its existing presence in India through the establishment of a wholly owned subsidiary, Cobham India Private Ltd. With offices in New Delhi and Bangalore, Cobham India Private Ltd. will open during the first quarter of 2010.

Dynawave® Inc. has announced that it has expanded its capabilities and product line by now manufacturing low loss bulk cables to be used with its connectors and cable assemblies in RF and microwave applications. The company, in business since 1985, designs and manufactures a variety of products, including connectors, cable assemblies and now bulk cable covering frequency ranges from DC up to 65 GHz.

Epoxies Etc. announced the completion of a new R&D and Quality Control Laboratory. The new equipment in the laboratory increases the company's testing capabilities as it continues to develop new epoxy, urethane and silicone systems. This expansion allows Epoxies Etc. to diversify and expand its product offerings to meet customer needs and the needs of an ever-changing manufacturing environment.

Empower RF Systems, a manufacturer and provider of solid-state power amplifiers and amplifier-based solutions, celebrated the tenth anniversary of the company and also announced the appointment of Barry Phelps as CEO. Entrepreneur and founder of Empower, Efraim (Effi) Bainvoll, is President of the company and will be leading projects fo-

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cused on nurturing strong, existing technologies and creating new PA solutions for evolving systems requirements.

RF Micro Devices Inc. (RFMD) announced that RFMD has commenced pre-production shipments of high-performance gallium nitride (GaN)-based CATV hybrid amplifiers to a major US-based cable television (CATV) equipment provider. RFMD's GaN CATV hybrid amplifiers provide industry-leading RF output levels, and cable operators using RFMD's GaN can reduce the number of amplifiers required in emerging architectures, also known as N+1 architectures, and achieve up to 20 percent cost savings in fiber deep networks.

DragonWave Inc., a supplier of packet microwave radio systems for mobile and access networks, announced that **Videotron**, a wholly owned subsidiary of Quebecor Media Inc., will be deploying the Horizon Compact packet microwave solution to deliver high capacity backhaul for its HSPA network, bringing consumers and small businesses advanced mobile communications services in several major Canadian markets.

Laser Services Inc., an ISO and AS-9100 registered precision laser cutting, drilling, scribing, etching and welding job shop, is celebrating its 30th anniversary. Laser Services offers a variety of unique design and manufacturing advantages to engineers and technicians in the RF/microwave, medical device, semiconductor, test and measurement, aerospace, military, and electronics industries, among others.

CONTRACTS

Raytheon Co. announced it has received Foreign Military Sales contract awards totaling $1.1 B to fund new production of the Patriot Air and Missile Defense System for Taiwan. The awards include ground-system hardware through an initial contract valued at $965.6 M and an initial spares contract valued at $134.4 M. Raytheon is the prime contractor for both domestic and international Patriot Air and Missile Defense Systems and system integrator for Patriot Advanced Capability-3 missiles. Work on the contract will be performed in Andover, MA; El Paso, TX; and Huntsville, AL.

Harris Corp., an international communications and information technology company, has received a $228 M order from the US Marine Corps to provide Falcon II AN/VRC-104 high frequency radio systems for use in US Department of Defense (DoD) MRAP-All Terrain Vehicles (M-ATV). The contract was awarded by the US Marine Corps - Systems Command on behalf of the Joint MRAP Vehicle Program.

Giga-tronics Inc. announced that it has received three orders valued at $5.1 M for microwave components from a major aircraft manufacturer. The award for high performance specialty filters based upon the company's fast switching YIG technology will be fulfilled by Giga-tronics' Microsource component subsidiary located in Santa Rosa, CA. One order valued at $1.8 M will be delivered by the end of the fiscal year, in March 2010.

SprayCool®, a leader in advanced thermal management and environmental isolation products for the military, announced that it was selected by **Sierra Nevada Corp.** (SNC) to supply its liquid cooled enclosure to support their Electronic Support Measure (ESM) system on the US Navy's Broad Area Maritime Surveillance Unmanned Aircraft System (BAMS UAS). The current development program was awarded to Northrop Grumman in April of 2008, and Sierra Nevada is working with Northrop Grumman to provide the ESM system.

NEW MARKET ENTRIES

Murata Electronics North America introduced the new LQH88P_38 series of power inductors, marking Murata's entrance into the large form factor power inductor market. The inductors support up to an 8A rated current and measure 8 × 8 mm with a low profile of 3.8 mm. This new inductor series is designed for DC-DC converters that are utilized in flat screen televisions, set-top boxes, digital recording devices, wireless base stations and other electronic applications.

Peregrine Semiconductor Corp., a supplier of high performance RF CMOS and mixed-signal communications ICs, announced the first pair in a series of new SPDT RF switches addressing the needs of wireless infrastructure, 2.4 GHz Industrial, Scientific and Medical (ISM), and broadband applications for fiber optics and Multichannel Multipoint Distribution Service (MMDS). The PE4250 and PE4251 are the result of a joint design and development activity with long-standing partner OKI Electric Ltd. (Tokyo). Product engineers from both OKI and Peregrine collaborated to develop leading-edge design techniques to meet market demands, resulting in the latest high-performance UltraCMOS™ Silicon-on-Sapphire RFICs.

PERSONNEL

ANSYS Inc., an innovator of simulation software and technologies designed to optimize product development processes, announced that **Joshua Fredberg** has joined the ANSYS senior management team as the Vice President of Marketing. Fredberg will play an integral role in furthering the company's vision and strategy, enhancing ANSYS global marketing initiatives, and leading all aspects of the company's branding. Fredberg brings a rich, diverse background in engineering and technology to the ANSYS leadership team. Before joining ANSYS, Fredberg was Senior Vice President of Product and Market Strategy at Parametric Technology Corp. (PTC), where he worked on industry strategy, marketing and business development. Prior to joining PTC, he held leadership roles with both ARIBA and Andersen Consulting Strategic Services.

Nitronex, a leader in the design and manufacture of gallium nitride (GaN)-based RF solutions for high perfor-

mance applications in the defense, communications, and industrial and scientific markets, has named **Edwin Chen** as Director of Sales and Business Development for the Asia Pacific region. Chen has over 15 years experience in mobile and broadband communications, as well as infrastructure base station sales and business development. He also brings 10 years of experience in leading field sales, technical resources and channel partner teams in the Asia Pacific region.

REP APPOINTMENTS

RFMW Ltd. and **NXP Semiconductors** announced a distribution agreement for the Americas. NXP is a manufacturer of high performance RF and microwave semiconductors. RFMW Ltd. is a specialized distributor providing customers and suppliers with focused distribution of RF and microwave components as well as specialized component-engineering support. According to the agreement, RFMW will distribute NXP's broad portfolio of RF and microwave products including RF wideband transistors, RF power transistors, RF small-signal FETs, RF diodes and RF amplifiers.

Mouser Electronics Inc. announced that it is now the sole catalog distributor for **TriQuint Semiconductor**, an RF products manufacturer and foundry services provider. The entire TriQuint RF product line is available from Mouser and includes amplifiers, control products, discrete transistors (FET), filters and duplexers, frequency converters, integrated products, passives, RFID modules and semiconductors, as well as standard RF products. TriQuint Semiconductor recently acquired two companies, WJ Communications and TriAccess Technologies, whose products continue to be offered by Mouser.

ESM Cable Corp., a manufacturer of high performance RF cable assemblies, announced the appointment of **MC Microwave Inc.** as the company's northern California and northern Nevada representative. MC Microwave Inc. brings 26 years of sales expertise to a RF and microwave cable assembly supplier with decades of experience and an established reputation. Visit ESM Cable Corp.'s website at www.esmcablecorp.com or MC Microwave's website at www.mcmicrowave.com.

The Micromanipulator Co. announced its partnership with **Teltec Semiconductor Pacific Ltd.** for sales and service representation in Taiwan, and the People's Republic of China.

Allied Electronics has signed a distribution agreement with **International Resistive Co.** (IRC), a TT electronics company, to distribute its resistive solutions. Allied will carry IRC's complete line of resistive product solutions, which includes a comprehensive range of current sense resistors, precision discretes and networks, passive components and power resistors.

SETTING STRATEGIES FOR PLANAR DIVIDERS/ COMBINERS

In building a strategy for effective integrated-circuit design, it is important to understand the characteristics of different RF and microwave planar dividers/combiners. Optimization of the design process for dividers and combiners can reduce unnecessary costs and design iterations, thus allowing designers time to improve the quality of the product. The design process includes various stages from analysis of requirements to final design documentation, balancing and trading-off factors such as electrical performance, size, cost, etc.

DEFINITIONS OF DIVIDERS/COMBINERS

Dividers and combiners are used frequently in RF and microwave integrated circuits as separate components or as parts of devices such as attenuators, phase shifters, mixers, amplifiers, modulators, high power transmitters and beam forming networks for antenna arrays.[1] A reciprocal divider can provide an equal or unequal power split between two or more channels. Because of their reciprocity, these circuits may also be employed to combine a number of oscillators or amplifiers to a single port. However, the combining mode has some particularities. To get lossless combining, input signals should be coherent and of equal amplitudes.

The major parameters that define planar RF and microwave dividers/combiners are bandwidth (BW), power division (m), relative output phases ($\Delta\varphi$), phase imbalance, amplitude imbalance, insertion loss (IL), matching (VSWR) or return loss (RL), isolation (ISO), power handling capacity, total number of inputs/outputs, integration level and cost. Insertion loss is the ratio (in decibels) of input power to output power with reflectionless terminations connected to the ports of the divider/combiner. The insertion loss of a printed divider/combiner is a combination of conductor loss, dielectric loss, isolation loss and mismatching loss. The relative phase difference can be quadrature ($\Delta\varphi = 90°$) or in-phase/out-of-phase ($\Delta\varphi = 0°$ or 180°). The divider/combiner bandwidth is the range of frequencies for which a parameter falls within a specified limit with respect to certain characteristics.

Dividers/combiners can be classified according to the following performance characteristics:

- narrow band (less than 20 percent) or broadband (greater than 20 percent)
- in-phase/out-of-phase or quadrature outputs
- number of outputs: two, three, four, etc.
- distributed, lumped-element, or combination of both
- equal or unequal power division
- fixed or tunable power division

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Model	Frequency Range (GHz)	Attenuation Range (dB)	Notes
150-11	dc-18.0	0-11/1	
150-75-3	dc-18.0	0-75/5	
150-70	dc-18.0	0-70/10	
150-70-1	dc-18.0	0-70/10	
151-11	dc-4.0	0-11/1	
152-90-3	dc-26.5	0-90/10	
150T-11	dc-18.0	0-11/1	◆
150T-15	dc-18.0	0-15/1	◆
150T-31	dc-18.0	0-31/1	◆
150T-62	dc-18.0	0-62/2	◆
150T-70	dc-18.0	0-70/10	◆
150T-75	dc-18.0	0-75/5	◆
150T-110	dc-18.0	0-110/10	◆
151T-110	dc-4.0	0-110/10	◆
152T-55	dc-26.5	0-55/5	◆
153-70	dc-40	0-70/10	New
153-110	dc-40	0-110/10	New

Model	Frequency Range (GHz)	Attenuation Range (dB)	Notes
3200-1	dc-2.0	0-127/1	
3200-2	dc-2.0	0-63.75/.25	
3200-1E-2	dc-3.0	0-127/1	
3200-2E-2	dc-3.0	0-63.75/.25	
3201-1	dc-2.0	0-31/1	
3201-2	dc-2.0	0-120/10	
3206-1	dc-2.0	0-63/1	
3200T-1	dc-2.0	0-127/1	◆
3206T-1	dc-2.0	0-63/1	◆
3250T-63	dc-1.0	0-63/1	◆ X
3406-55	dc-6.0	0-55/1	New
3408-55.75	dc-6.0	0-55.75/0.25	New
3408-103	dc-6.0	0-103/1	New
4216-63	0.8-3.0	0-63/1	
4218-127	0.8-3.0	0-127/1	
4238-103	.01-2.5	0-103/1	

Notes: ◆ SmartStep® Control Circuitry, X = 75 Ohm Model
For a complete list of available models/designs, visit our website @ www.aeroflex.com/weinschel-programmables

Visit http://mwj.hotims.com/28485-5 or use RS# 5 at www.mwjournal.com/info

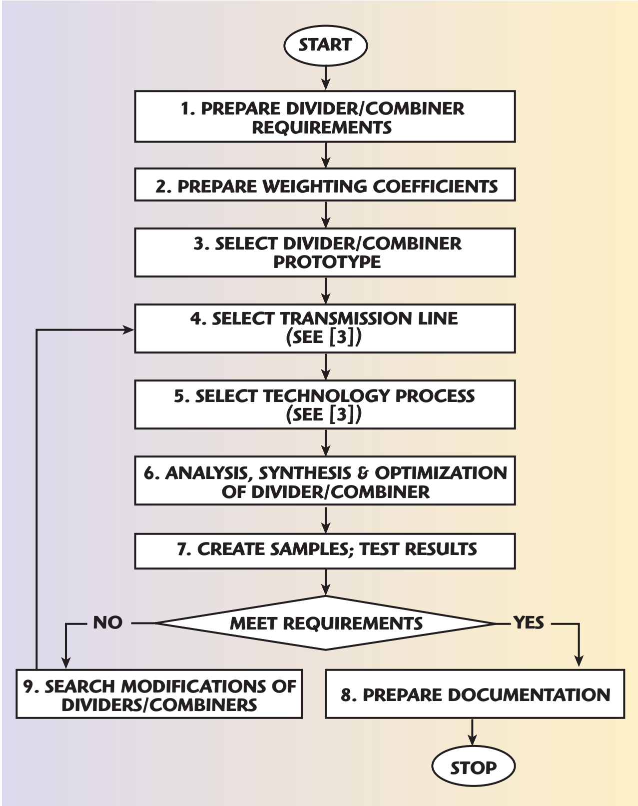
PLANAR DIVIDER/COMBINER DESIGN FLOW AND OPTIMIZATION

Figure 1 illustrates the design flow of a planar divider/combiner. The definition of the system level specification is the first step in the design flow. This involves both the system level requirements, which are applied directly to a divider/combiner, and the derived requirements, which depend on system requirements. Divider/combiner specifications include electrical, cost, size and other requirements. RF specification also includes margin for manufacturing tolerances, environmental conditions and performance degradation over a system's life.

For all requirements, a designer has to choose consecutive integer values of weighting coefficients k_i corresponding to each parameter (step 2), with k = 1 for the most important parameter. The maximum value of k can be less than or equal to the number of parameters, depending on whether some parameters are considered to have the same importance or not. Selection of a divider/combiner prototype (step 3) must take into account the corresponding weighting coefficients. The final selection of a divider/combiner prototype can be made by analysis of a circle diagram.[2] The optimum prototype should have the minimum area between real and goal performance. For the selected prototype, transmission line (step 4) and technology process (step 5) should be defined. For minimum cost, most dividers/combiners use microstrip lines. However, for lower loss, a stripline or a suspended stripline design is desirable. The design strategy of a printed transmission line type was described previously.[2] The type of optimal transmission line depends on many different factors, including the technology process. Sometimes the divider/combiner prototype does not satisfy the requirements. In this case a new modified circuit should be selected (step 9) to satisfy divider/combiner requirements.

The search procedure for the optimum prototype was described in a previous article.[2] The synthesis of a planar divider/combiner is based on both system requirements and derived requirements. The synthesis results are the physical dimensions of a divider/combiner and the lumped element values, if necessary. Analysis of a printed divider/combiner entails definition of electrical performance with the known physical dimensions. An electromagnetic simulation may be used to create an S-parameter model for a divider/combiner. Dividers/combiners, symmetrical with respect to one or two planes, are frequently implemented in RF and microwave devices. A mirror-reflection method[3] is widely used for analyzing symmetrical networks. In the RF and microwave technique, the analysis of a divider/combiner using matrix representation is very popular. The following procedure of analysis and calculation of a symmetric divider/combiner is recommended:[3]

- Determine the transfer matrices of the two-port networks (symmetrical parts of a divider/combiner) for both even- and odd-mode excitation. In the case of a cascade connection of two-port networks, the transfer matrix is equal to the product of the transfer matrices of the components
- Determine the most important scattering element of the divider/combiner. For example, let us say it is S_{11}, which characterizes the input matching

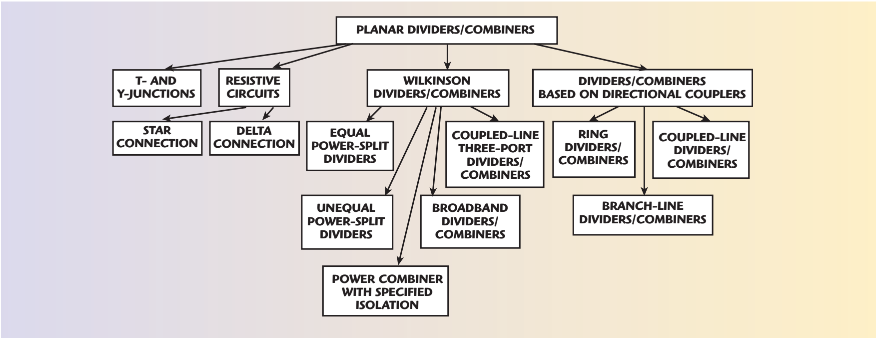


▲ *Fig. 1 Planar divider/combiner design flow.*

- Determine the relationship among admittances (or impedances) of the line segments of the divider/combiner from the condition of perfect matching: $S_{11} = 0$
- Calculate the remaining elements of the scattering matrix accounting for the found relationships among admittances
- Determine the characteristics of the divider/combiner

The parameters of the divider/combiner can be simulated using the ADS program. In this case, the designer has to set up variable parameters that can be used to optimize a divider/combiner. Analysis of manufacturing tolerances should be considered to avoid excessive manufacturing cost. For high frequency dividers/combiners, this analysis is especially critical.

Trade-off analysis of a planar divider/combiner includes criteria determined from specifications. The trade-off design includes the following contradictory characteristics: cost vs. tolerances; cost vs. thermal characteristics; cost vs. reliability; cost vs. loss; integration index vs. cost; integration index vs. tolerances; size vs. Q-factor; size vs. tolerances; size vs. maximum power; bandwidth vs. amplitude balance and quantity of sections. The principal trade-off is between frequency range, insertion loss and amplitude balance. The most contradictory requirements are size vs. loss. The integration quality of the divider/combiner is characterized by the following parameters: volume V (inches or centimeters cubed), minimum of dissipated losses A_0 (in dB) within the bandwidth, bandwidth ($\Delta f / f_0$) in percent and the number of sections. The relationship between these controversial parameters is described by the integration index.[3]



▲ *Fig. 2 The four main types of planar dividers/combiners.*

The final documentation (step 8) of the optimized planar divider/combiner should include the following issues:

- Type of planar divider/combiner
- Main performance: frequency range, bandwidth, power split, isolation, impedance, return loss, insertion loss, maximum power, relative phase difference between output signals, phase and amplitude imbalance
- Drawing with physical dimensions
- Technology process used
- Packaging (package material, technology process, hermetic or non-hermetic, housing physical dimensions)
- Tolerance analysis results
- Thermal analysis results
- Reliability analysis results
- Cost analysis

TYPES OF PLANAR DIVIDERS/ COMBINERS

More than 100 different types of power dividers/combiners have been developed over the past four decades, often in quest of additional bandwidth, lower loss, smaller size, greater isolation, or other performance advantages. In this section, the main types of planar dividers/combiners and their modifications are considered. The main four types of planar dividers/ combiners include (see ***Figure 2***):

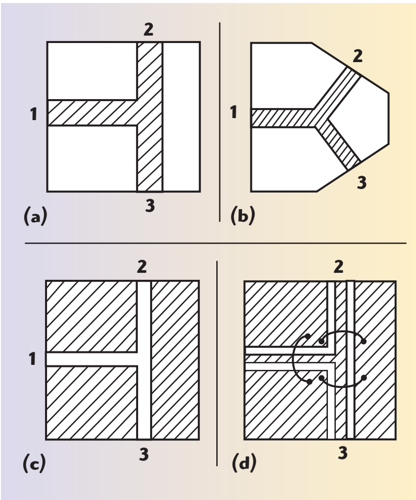
- T- and Y-junction circuits
- resistive three-port circuits
- Wilkinson dividers/combiners
- four-port circuits based on directional couplers

The simplest planar three-port divider is analogous to coax and waveguide T-junction. To improve the matching, the lines can be connected at 120° to each other. Circuits connected in this way are called Y-junctions. T- and Y-junctions can have a series or a parallel connection of one input and two outputs. In a series planar connection, the signal splits out of phase; in a parallel connection, it splits in-phase between two outputs. The simple three-port network structure of T- and Y-junctions has two significant drawbacks: the absence of isolation between output ports and the imperfect matching of all ports. A lossless, reciprocal three-port circuit can be physically matched at only two ports. In the transmit direction, the divider input has an excellent VSWR,

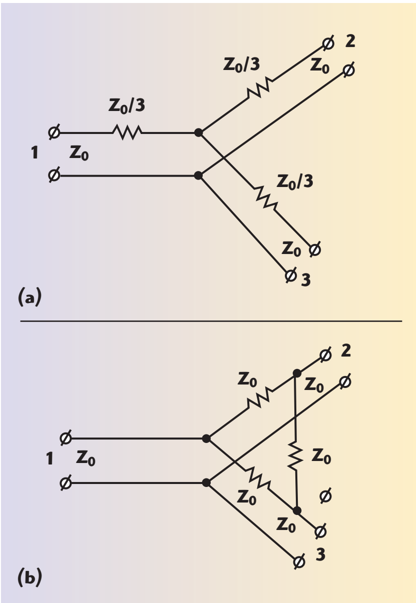
typically less than 1.15:1. In the receive direction (combiner mode), the VSWR is not as good. Microstrip T- and Y-junctions are shown in ***Figures 3a*** and ***3b***. The T-junction of three slotlines is displayed in ***Figure 3c***. ***Figure 3d*** shows the coplanar waveguide T-junction for an in-phase power divider.

The basic structures of a resistive three-port divider are shown in ***Figure 4***. One version has resistors in the form of a star (or "wye") (see ***Figure 4a***); the other is in the form of a delta (see ***Figure 4b***). The resistive three-port divider can be matched at all ports. The given resistor values will ensure that each port is impedance matched to Z_0. Any mismatching on one output will be reflected to the other output. The resistive power divider can work over many octaves. In fact, there are commercially available resistive dividers that cover DC to 40 GHz. In addition to their broad frequency range, they are very compact because they include only lumped elements. The resistive power divider suffers some serious drawbacks. In the resistive divider, half of the input power is dissipated. Another disadvantage is the lack of isolation between output ports. Even though it is not lossless, isolation is still not achieved. The isolation of a resistive divider is equal to its insertion loss (6 dB). Also, the problem with the resistive divider/combiner is the power-handling capability of the internal balancing resistor.

N-way resistive dividers can be easily developed from the star divid-



▲ *Fig. 3 Simple three-port networks: (a) T-junction, (b) Y-junction, (c) T-slotline junction and (d) T-coplanar waveguide junction.*



▲ *Fig. 4 Resistive three-port dividers: (a) star and (b) delta.*

er. The appropriate resistors for an N-port star divider are found by the equation:

$$R = Z_0(N-1)/(N+1) \qquad (1)$$

For example, a three-way divider needs resistors of $Z_0/2$, while a four-way divider needs resistors of $3Z_0/5$ and so on.

The Wilkinson divider (see ***Figure 5***)[3-5] provides matching of all three ports, low loss, in-phase split and high isolation between output ports. The Wilkinson divider/combiner has a small resistor that limits its ability to combine any signals of higher power than that of the resistor, which is rated for several watts. Perfect matching of all divider ports and perfect isolation between output divider ports are obtained if

$$Y_1 = \frac{1}{\sqrt{2}}, Y_2 = 1 \qquad (2)$$

$$z_1 = z_0\sqrt{2}, R_2 = 2z_0 \qquad (3)$$

where R_2 is the resistance of the lumped element resistor; $Y_1=Z_0/Z_1$ is the normalized admittance of line segment of length l; z_0 is the characteristic impedance of the input /output port lines; $Y_2=2z_0/R_2$ is twice the normalized admittance of resistor R_2.

As opposed to the reciprocal T- or Y-junction, the Wilkinson divider can be matched at all ports simultaneously because this three-port circuit uses a lossy element (resistor R_2). The Wilkinson divider is a network with outputs whose phase relationship is 0°. The real divider characteristics deviate from the ideal, due to manufacture tolerances, losses, discontinuities, and mismatching of terminations, as well as the physical quality of the resistor. The influence of these different factors on the parameters of the divider was examined by Paral and Moynihan.[3] For combining two or more oscillators, the Wilkinson combiner sometimes requires specified isolation between input ports to provide mutual synchronization between oscillators.[3] Such a combiner with specified oscillation between ports 1 and 2 can be realized (see ***Figure 5b***) with a variable resistor $R_2 \neq 2z_0$. The isolation value for this network is

$$C_{23} = 20\log\left|\frac{2(1+Y_2)}{Y_2-1}\right| dB$$

For perfect matching of ports 1 and 2, it is necessary that $Y_1 = 1/\sqrt{2Y_2}$.

The Wilkinson divider with unequal power-split ratio $m=P_1/P_2 \neq 1$ (see ***Figure 5c***)[3,4,6] consists of two quarter-wave segments 1-2 and 1-3 of different impedances

$$Z_2 = \frac{z_2}{z_0} = m^{1/4}(1+m)^{1/2}, Z_3 =$$

$$\frac{z_3}{z_0} = \frac{(1+m)^{1/2}}{m^{3/2}}$$

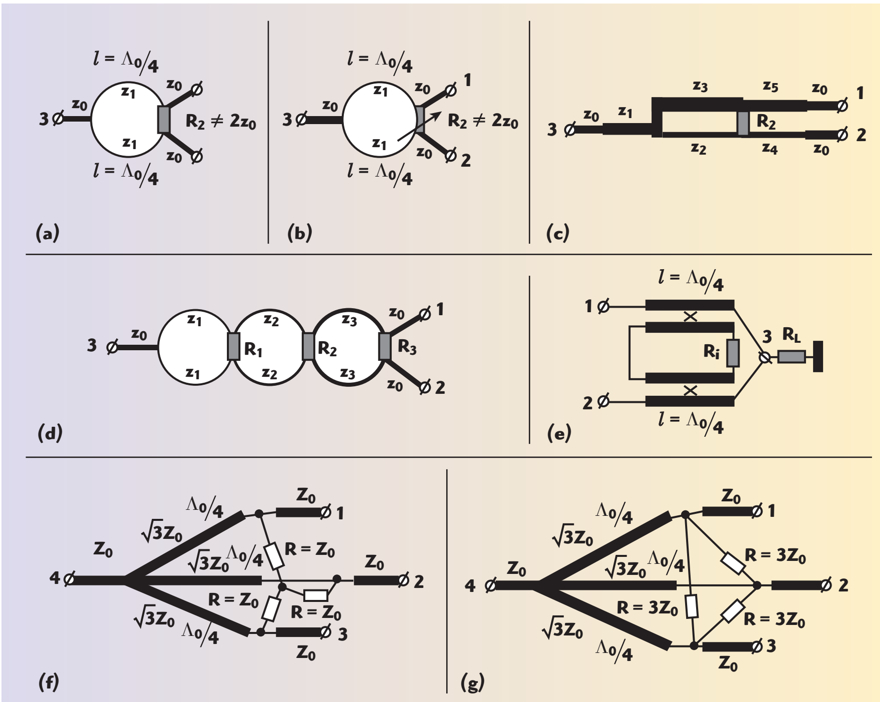
and lumped resistor $R_2 = \frac{1+m}{m^{1/2}}$.

Due to the quarter-wave length segments, the Wilkinson divider bandwidth is limited to approximately 20 percent. Some applications require broadband Wilkinson dividers. ***Figure 5d*** illustrates the broadband version of a narrow band cascading of the Wilkinson power divider. Each section must have quarter-wave segments of different characteristic impedance, and each resistor must have a different value. The two-section divider has an octave bandwidth. It is possible to build a broadband divider from 2 to 18 GHz using more than two sections. As a general rule, the greater the bandwidth the more sections are added to the design. However, as the number of sections increases, the insertion loss and the complexity of the device also increase.

Another broadband resistive divider/combiner is based on coupled transmission lines.[3,7,8] The simplest version of the coupled transmission line two-way power divider/combiner is shown in ***Figure 5e***.[8] It consists of two identical quarter-wavelength coupled lines positioned with respect to common ground, load resistor R_L and isolating resistor R_i.

Dividers/combiners with more than two inputs/outputs are used in antenna arrays, in combining networks, etc. A three-way Wilkinson divider/combiner with "star-resistor" configuration is shown in ***Figure 5f***. The arms have an impedance of $\sqrt{3}Z_0$ and the resistor value is equal to the input impedance. ***Figure 5g*** shows a three-way Wilkinson divider/combiner with the "delta" resistor configuration. The arms again have an impedance of $\sqrt{3}Z_0$, but now the resistors have an impedance of $3Z_0$. A disadvantage of an N-way (N>2) divider/combiner is the fact that this network requires crossovers for the lumped element resistors that makes fabrication difficult in planar implementation.

A directional coupler is a reciprocal four-port circuit, which provides two different amplitude outputs when a signal is applied to its input. This definition of a directional coupler suggests its possible use for splitting power from one port between two other



▲ *Fig. 5 Wilkinson dividers/combiners.*

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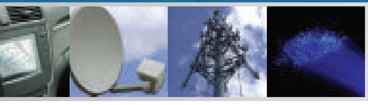

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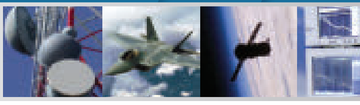

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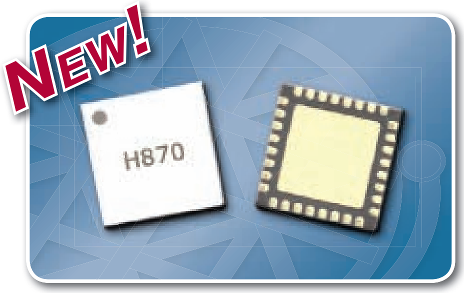

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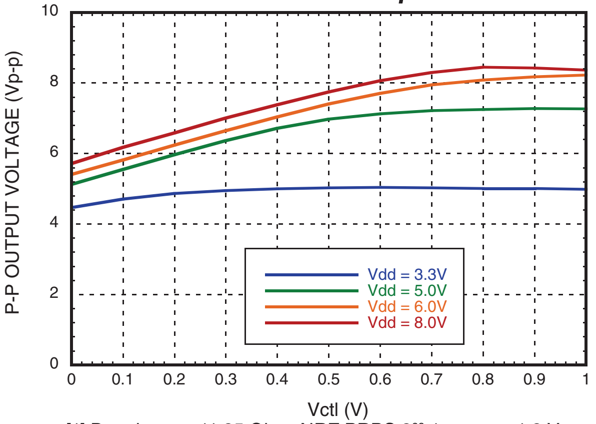
- Low DC Power Consumption
  1W for Vout = 8Vp-p @ Vdd = 7V
- Cross Point Adjustment
- 32 Lead 5x5mm SMT Package: 25mm²

Peak-to-Peak Output Voltage vs. Vctl @ 11.25 Gbps [1]



[1] Data input = 11.25 Gbps NRZ PRBS 2^{23}-1 pattern, 1.2 Vp-p.

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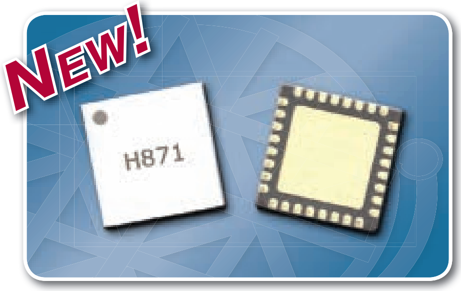
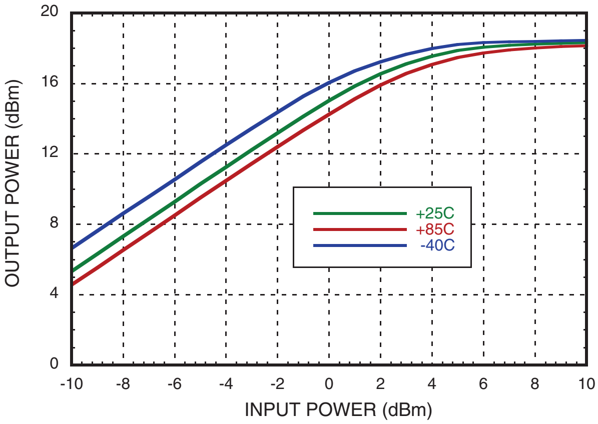


- Wide Supply Range: 5V to 8V
- Adjustable Output Amplitude: 4Vp-p
- Low Additive RMS Jitter: <300fs
- Low DC Power Consumption
  0.25W for Vout = 2.5Vp-p @ Vdd = 5V
- Cross Point Adjustment
- 32 Lead 5x5mm SMT Package: 25mm²

Output Power vs. Input Power @ 10 GHz, Vdd = 8V



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ports. The dividers and the combiners based on the ring directional coupler are shown in ***Figure 6***. A matched ballast termination R_4 (see ***Figure 6a***) is "ballast" only from the structural point of view. The admittances of the ring power divider/combiner are[3]

$$y_1 = y_0\sqrt{\frac{m}{m+1}},\ y_2 = y_0\sqrt{\frac{m}{m+1}} \quad (4)$$

where $m = P_2/P_3 = \left(y_1/y_2\right)^2$ is the power split ratio of the ring divider.

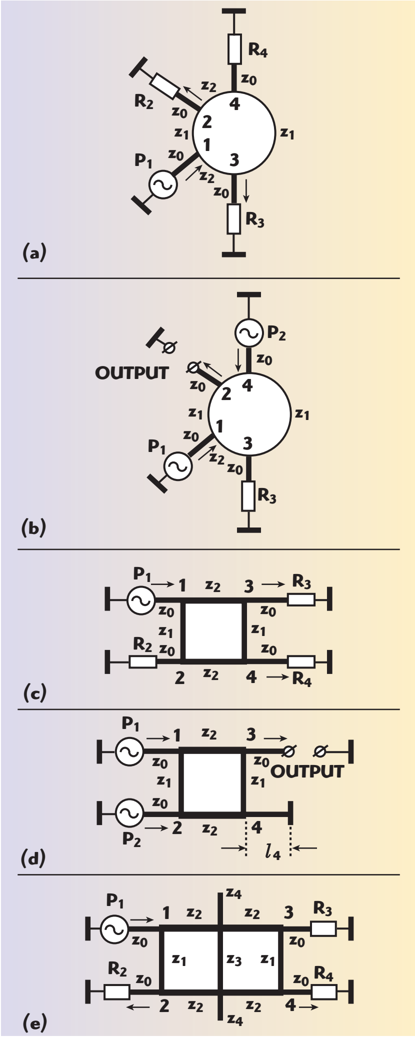
The divider and the combiner based on a two-branch directional coupler are shown in ***Figures 6c*** and ***6d***, respectively. The normalized admittances are

$$Y_1^2 = \frac{1}{m}, Y_2^2 = \frac{m+1}{m}, \quad (5)$$

$$\text{where } m = \frac{P_3}{P_4} = \frac{1}{Y_1^2} = \frac{1}{Y_2^2 - 1}$$

From Equations 1 and 2, the admittances of ring and two-branch dividers can be determined. For m > 3, it is difficult to realize the corresponding ratio of admittances; therefore, the maximum practical power split used is m = 3. The main advantage of the quadrature hybrid is to isolate the input port from its two outputs if the load's VSWR, magnitude and phase of reflection signals are identical. That is why the quadrature-combined circuit appears to be well-matched.

In the circuit shown in Figure 6d, equal quadrature signals of two identical-frequency oscillators connected to ports 1 and 2 of a 3 dB two-branch coupler are combined. In the ideal case, the combined power appears only on port 3, while port 4 is isolated. If conditions of equal power, phase quadrature and equal frequencies are not satisfied, then an unbalanced signal appears on port 4. Due to a specially introduced mismatching element (short or open segments l_4 of adjustable length), the unbalanced signal is reflected from the end of line l_4 and travels into the two oscillators for mutual synchronization. In some applications, coherent addition of signals is not a requirement; for example, where n signals of different frequencies are applied to a device with a single output port (multiplexer).



▲ *Fig. 6 Directional couplers used as divider/combiner.*

The three-branch divider with power split regulation is shown in ***Figure 6e***. Two reactances (open or short stubs) are connected to the center branch. If port 1 (or port 3) is the input, the power split between ports 2 and 4 depends on the stub length. For perfect matching at the mid-frequency band, the normalized characteristic admittances Y_1, Y_2 and Y_3 are given as

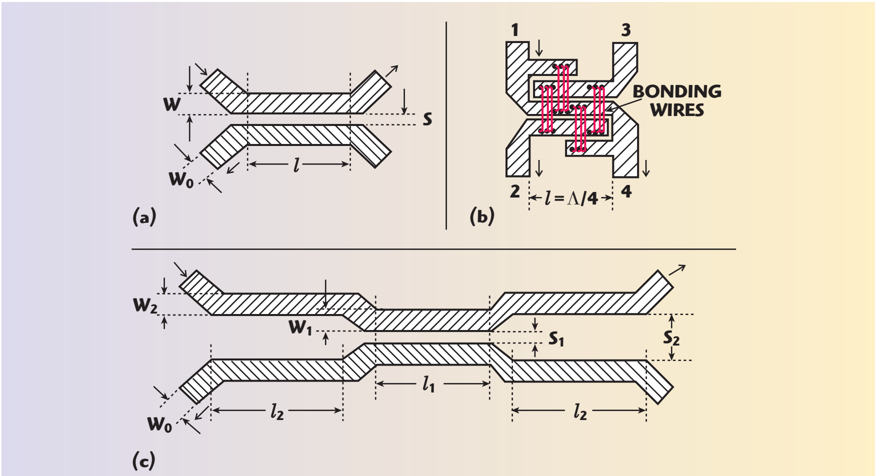
$$Y_1 = 1, Y_2^2 - Y_3 = 0, \quad (6)$$

where

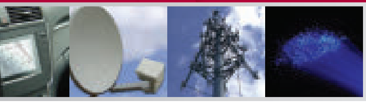
$$Y_1 = Z_0/Z_1, Y_2 = Z_0/Z_2, Y_3 = Z_0/Z_3$$

The dividers/combiners based on directional couplers have an advantage over T- and Y-junctions: the split power ratio m is proportional to the square of the ratio of admittances, which gives more room for increasing m. However, a decrease in admittance and a corresponding decrease in the width of the conductor of the microstrip line lead to increased losses. The branch-line dividers/combiners are effective for planar fabrication of balanced circuits because the output ports of the network are on the same side.

A coupled-line directional coupler (see ***Figure 7***) can be used for broadband power division or combining. The planar edge-coupled-line coupler cannot be implemented for a power division m < 10 because of etching tolerances. The 3 dB broadband Lange directional coupler (see ***Figure 7b***) is used for equal power division (m = 1). The divider based on the single-section coupled line directional coupler is limited in bandwidth due to the quarter-wave length section. Bandwidth can be increased by using multiple sections (see ***Figure 7c***). The disadvantage of couplers used for dividers or combiners is the complexity of the



▲ *Fig. 7 Coupled-line directional couplers.*



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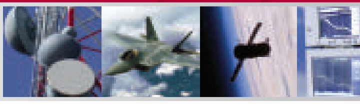

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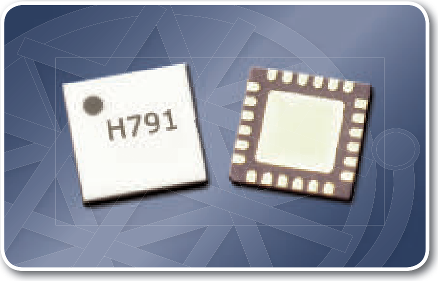

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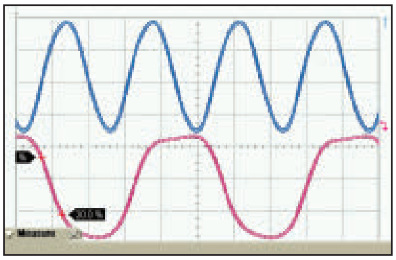
Output Signal

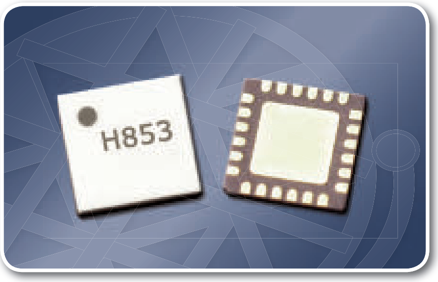


	Current	Minimum	Maximum	Total Count
Rise Time (/2)	12.00 ps	12.00 ps	12.67 ps	50
Fall Time (/2)	12.67 ps	12.67 ps	13.33 ps	51
Rise Time (/4)	16.67 ps	16.00 ps	16.67 ps	51
Fall Time (/4)	16.67 ps	16.67 ps	16.67 ps	51

Vertical Scale (/2)	65 mV/div
Vertical Scale (/4)	80 mV/div
Horizontal Scale	30.0.ps/div

Test Conditions:
CK/2 and CK/4 outputs are presented on an Infinium 86100C
Input Clock Frequency = 28 GHz
Vin = -6 dBm

HMC853LC4B - 28 Gbps D-Type Flip Flop w/ Programmable Output Voltage



- *Differential & Single-Ended Operation*
- *Fast Rise / Fall Times: 15 / 14 ps*
- *Low Power Consumption: 240mW*
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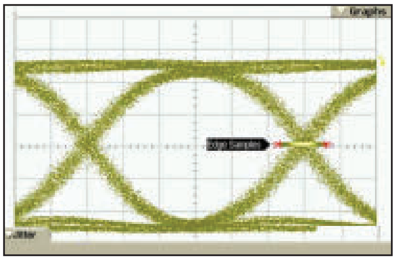
- *Single Supply: -3.3V*

Eye Diagram @ 25 Gbps



Parameter	Conditions
Bit Rate	24.9900 Gbps
Pattern Length	127 Bits
DJ (d-d)	2.0 ps
Vertical Scale	100 mV / div
Time Scale	6.7 ps / div

Test Conditions:
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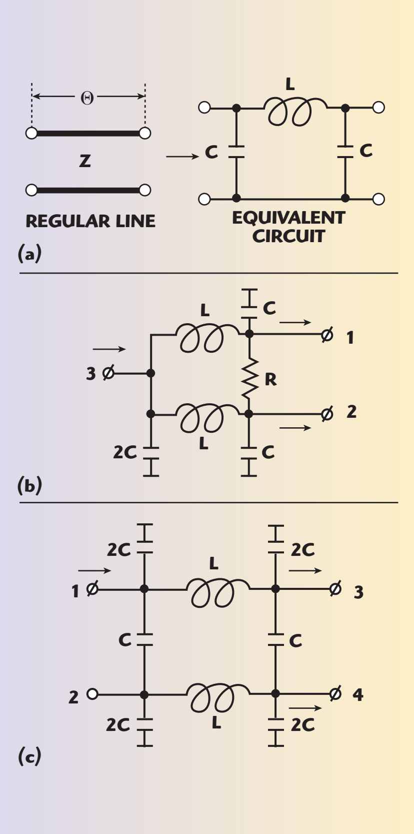

Fig. 8 Lumped element Wilkinson dividers.

circuit. The advantages of these couplers are convenience of adjustment and good electrical characteristics.

Consider lumped-element dividers/combiners. Choosing between distributed-element and lumped-element designs depends on several factors.[9] Some of these include size, insertion loss, frequency and cost. For example, lower-frequency RF components are often based on lumped-element components. Higher-frequency designs (2 to 30 GHz) can use distributed elements. The distributed Wilkinson divider and dividers based on directional couplers can be converted into the lumped element π network (see ***Figure 8***). For the center frequency f_0, the quarter-wavelength segment with characteristic impedance z has the π-section lumped element equivalent with series inductance L, as well as two shunt capacitances C[3] with the following values:

$$L = \frac{z}{2\pi f_0}, C = \frac{z}{2\pi f_0 z} \qquad (7)$$

Figure 8b illustrates the lumped element Wilkinson divider. A

TABLE I

COMPARISON OF DIFFERENT DIVIDERS/COMBINERS

Type	T- and Y- junction	three-port resistive circuit	Wilkinson circuit	directional coupler
Bandwidth	up to three octaves	DC to 40 GHz	up to 5 octaves (with many sections)	up to 3 octaves (coupled-line)
Power Division (m)	1...2		1...2	1...100
Power	very high (up to 700 W)	low (few watts)	low (few watts)	high (up to 200 W)
Dissipated Losses	very low (dependent on transmission line loss)	high (dependent on number of ports)	~0.3 dB (for two-way)	~0.2 dB
VSWR	input: 1.15:1 output: poor	1.25:1	1.3:1	1.2:1
Isolation	poor	good with many ports	~20 dB	~25 to 30 dB
Size	very small	small	small	moderate

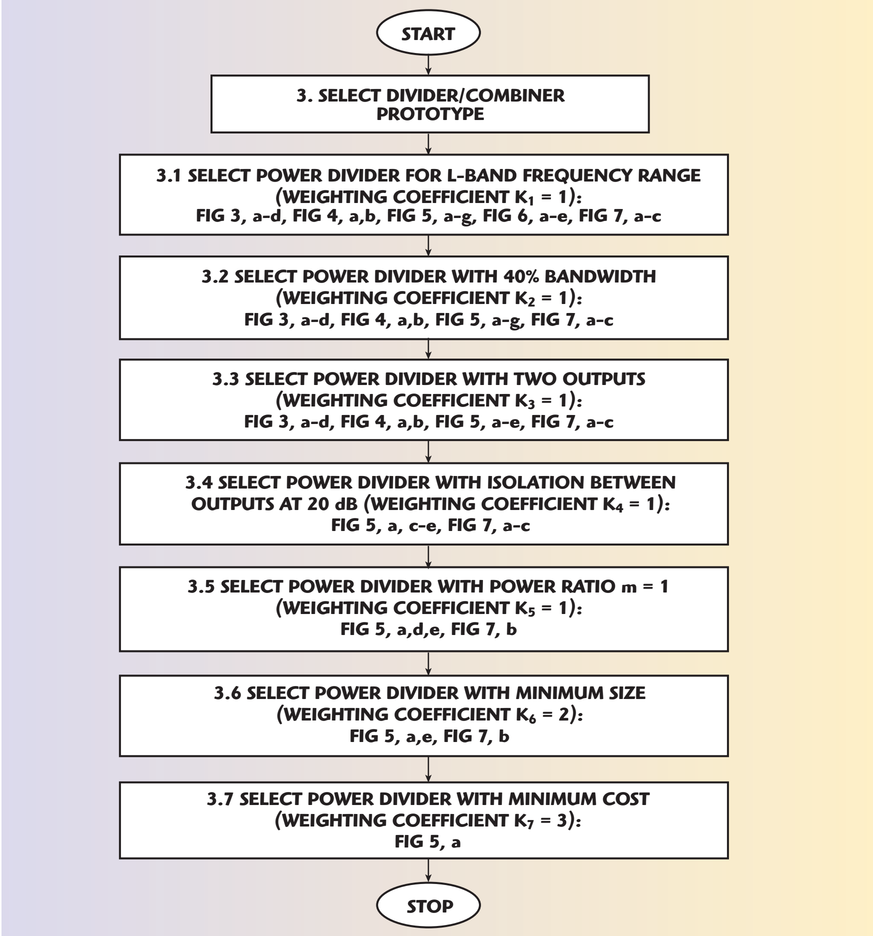

Fig. 9 Design flow for selection of a planar divider.

lumped-element layout is much smaller than the distributed layout (see Figure 5a). For this example, the π arrangement was chosen to reduce the number of lossy inductors as compared to the T-equivalent.[3] The input shunt capacitors (port 3) are combined into a single capacitor yielding two inductors, one shunt capacitor at each port, and the 100 Ω isolation resistor. The bandwidth of a lumped-element Wilkinson divider is approximately half that of the microstrip distributed version.

Figure 8c shows the lumped element divider based on the two-branch directional coupler.[10,11] The bandwidth performance of this divider is narrower, due to parasitic elements in the models of capacitors and inductors. ***Table 1*** compares the performance of different dividers/combiners.

The major differences between using the Wilkinson divider/combiner versus the branch-line hybrid is that the input match of the Wilkinson circuit depends on the match at the other two ports. However, it is much easier to get wider bandwidth with the Wilkinson divider/combiner than with the two-branch circuit. Choosing between the divider based on the directional coupler or on the Wilkinson circuit is a matter of the power levels of input/output signals. Wilkinson dividers have small resistors mounted on PCB, which limits their ability to operate with signals higher than the value of the resistor power. The divider based on directional couplers has external loads to absorb power, so it is applicable to powers of several hundred watts. The power split $m \geq 3$ is difficult to realize in the resistive three-port dividers and dividers based on the ring and branch-line directional couplers. The limiting factor here is the impossibility of manufacturing narrow printed conductors of high impedance segments.

Figure 9 shows an example of the design flow for the selection of a planar divider prototype. In this example, the divider requirements and their weighting coefficients include: the frequency range is L-band with the weighting coefficient of the highest importance ($k_1 = 1$); 30 percent bandwidth with the weighting coefficient of the highest importance ($k_2 = 1$); the total number of outputs = two, with the weighting coefficient $k_3 = 1$ of the highest importance; the isolation between outputs at 20 dB, with the most important weighting coefficient $k_4 = 1$; power ratio $m = 1$ with the most important weighting coefficient $k_5 = 1$; minimum size with the weighting coefficient $k_6 = 2$; minimum cost with the weighting coefficient $k_7 = 3$. The selection of a directional coupler prototype starts with satisfying the most critical requirements with weighting coefficients $k_1 = k_2 = k_3 = k_4 = k_5 = 1$ (step 3.1, 3.2, 3.3, 3.4, 3.5), and then the less critical requirements with $k_6 = 2$ (step 3.6) and $k_7 = 3$ (step 3.7). The design flow shows that the optimum divider prototype for the above specifications is the simple Wilkinson divider (see Figure 5a).

APPLICATIONS OF DIVIDERS/ COMBINERS

Figure 10 illustrates different configurations of a reflection-type phase shifter. In the phase shifter shown in ***Figure 10a***, the two output ports are terminated with voltage variable capacitors to ground. The divider splits the input signal of equal amplitude with a phase difference of 90°. Then the signals are reflected from the capacitors back to the hybrid and combined at the output port 2. If the magnitudes and angles of reflection signals are equal, there will be two reflection signals that are equal in amplitude and in phase quadrature. These signals will combine at the isolated port 2 and will cancel at the input port 1. This reflection-type phase shifter provides a voltage variable phase shift between 0° and close to -180°. The power divider including the two-branch divider/combiner and two reflected loads with shunt diodes D1 and D2 is shown in ***Figure 10b.***[3,4] An input signal is divided by the quadrature divider among the two ports. The diodes are biased in the same state (forward or reverse biased). The input signal is divided into two quadrature components with equal amplitudes on the output ports. Turning the diodes ON or OFF changes the total path length for both reflected waves by Δφ, producing a phase shift of Δφ at output 2. ***Figure 10c*** illustrates a reflection-type phase shifter using a divider/combiner based on the Lange coupler and varactor diodes D1 and D2. The ideal varactor diode is a variable capacitor with the capacitance value changing as a function of the DC bias.

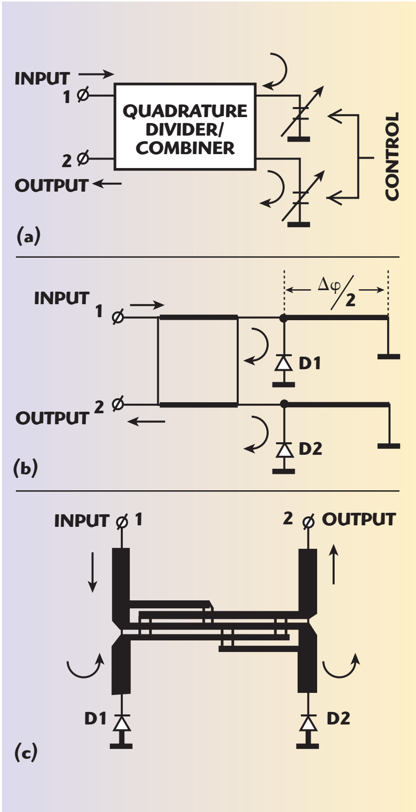

Fig. 10 Reflection-type phase shifters.

Figure 11 illustrates different combiner circuits based on directional couplers. The chain structure of the combiner of ***Figure 11a*** includes the series connection of three ring directional couplers. The couplers are connected by connecting lines between one output/input of one divider/combiner with one input/output of the next divider/combiner. This

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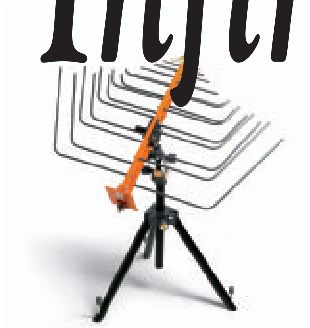

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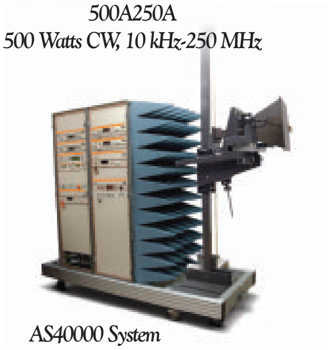

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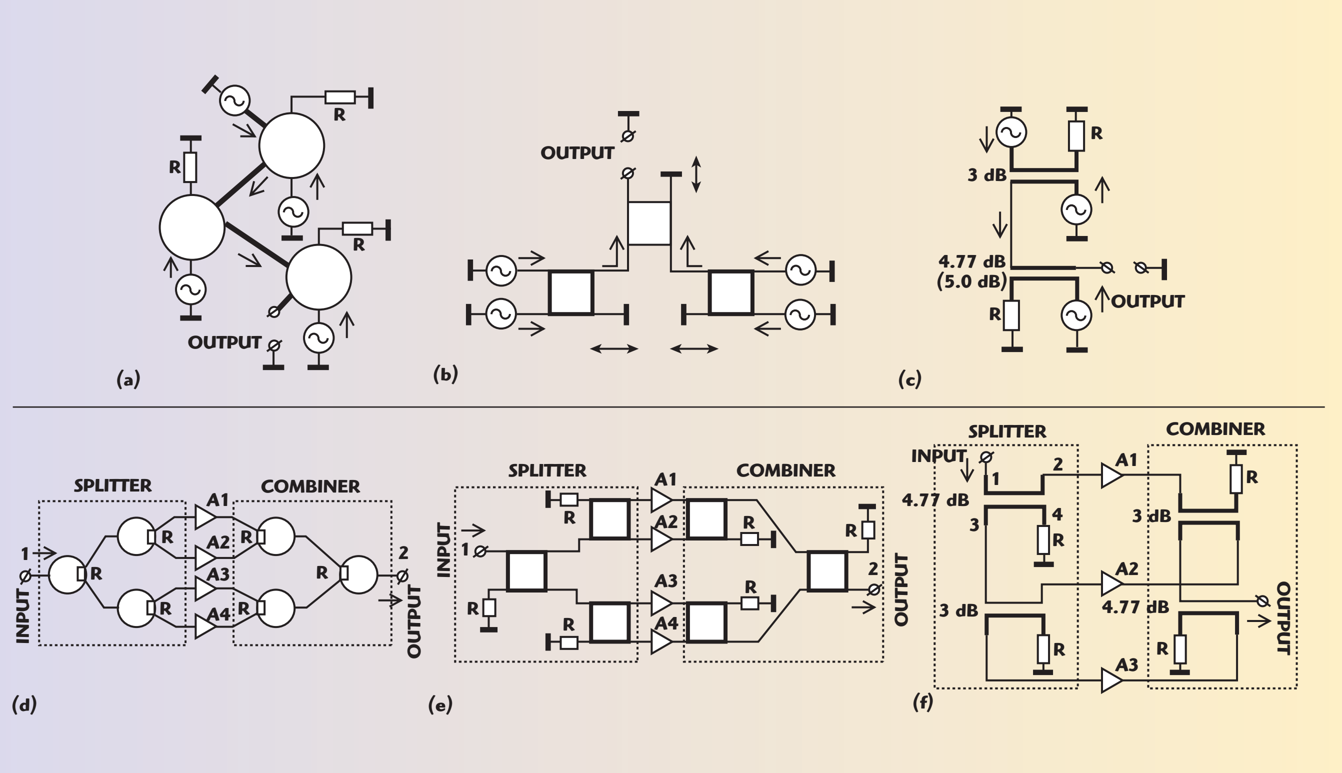

Fig. 11 Combiner circuits using directional couplers.

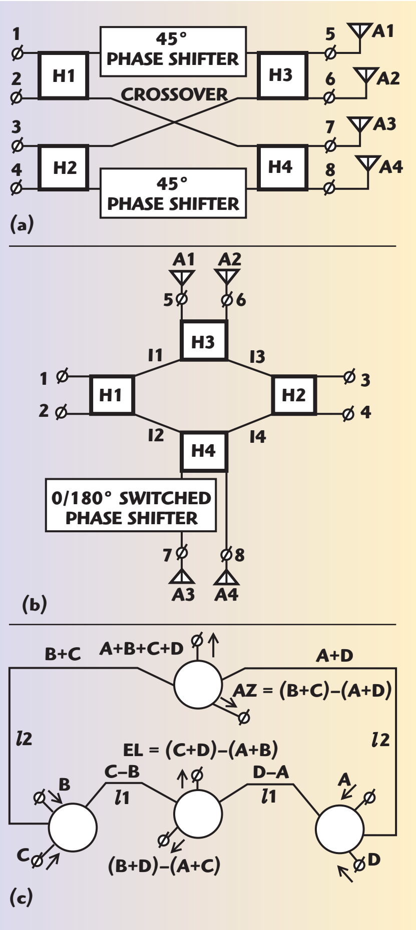

Fig. 12 Monopulse networks.

network can be used as a combiner of four oscillators.[3] The characteristic impedances of the different ring segments are determined in accordance with the oscillator power ratio. The network of ***Figure 11b*** ensures the power combining of four oscillators using three two-branch couplers. Adjustable segments (short or open lines with variable length) provides mutual coupling between oscillators to implement mutual synchronization between oscillators.[3] The schematic of a 3:1 combiner (see ***Figure 11c***), including a network of 3.0 dB and 4.77 dB couplers, provides 4.8 dB loss in each signal path (33 percent split). Due to losses in the three-way combiner, higher coupler values, such as 5.0 dB, are actually better suited for this function.

Different balanced amplifier schematics with power dividers/combiners are shown in ***Figures 11d***, ***e*** and ***f***. The use of splitting and combining in the balanced amplifiers comes from the need to replace one high power amplifier with two or more less expensive amplifiers. Figure 11d illustrates a balanced power amplifier including a four-way divider, a four-way combiner and four low power amplifiers. The input divider and the output combiner use Wilkinson dividers/combiners. The input divider splits the input power equally between the four output ports. The output combiner recombines the output signals from the amplifiers. To minimize balance differences between the splitting and the combining circuits, the same circuits can be used for both functions. The most important parameter of this circuit is the power loss after amplification. The loss of actual dividers/combiners differs from the ideal, due to the mismatching of all ports, transmission line loss, discontinuities, as well as manufacture tolerances.

Another form of circuit loss is defocusing, which can be defined as the amount of power that is directed to circuit termination instead of to the circuit output port (see Figure 11e). This power is directed to termination R due to amplitude and phase balance errors introduced by the dividers/combiners and the amplifiers. The main advantage of the quadrature hybrid of Figure 11e is the isolation of the input port from its two outputs, if the load's VSWR, magnitude and phase of the reflect-

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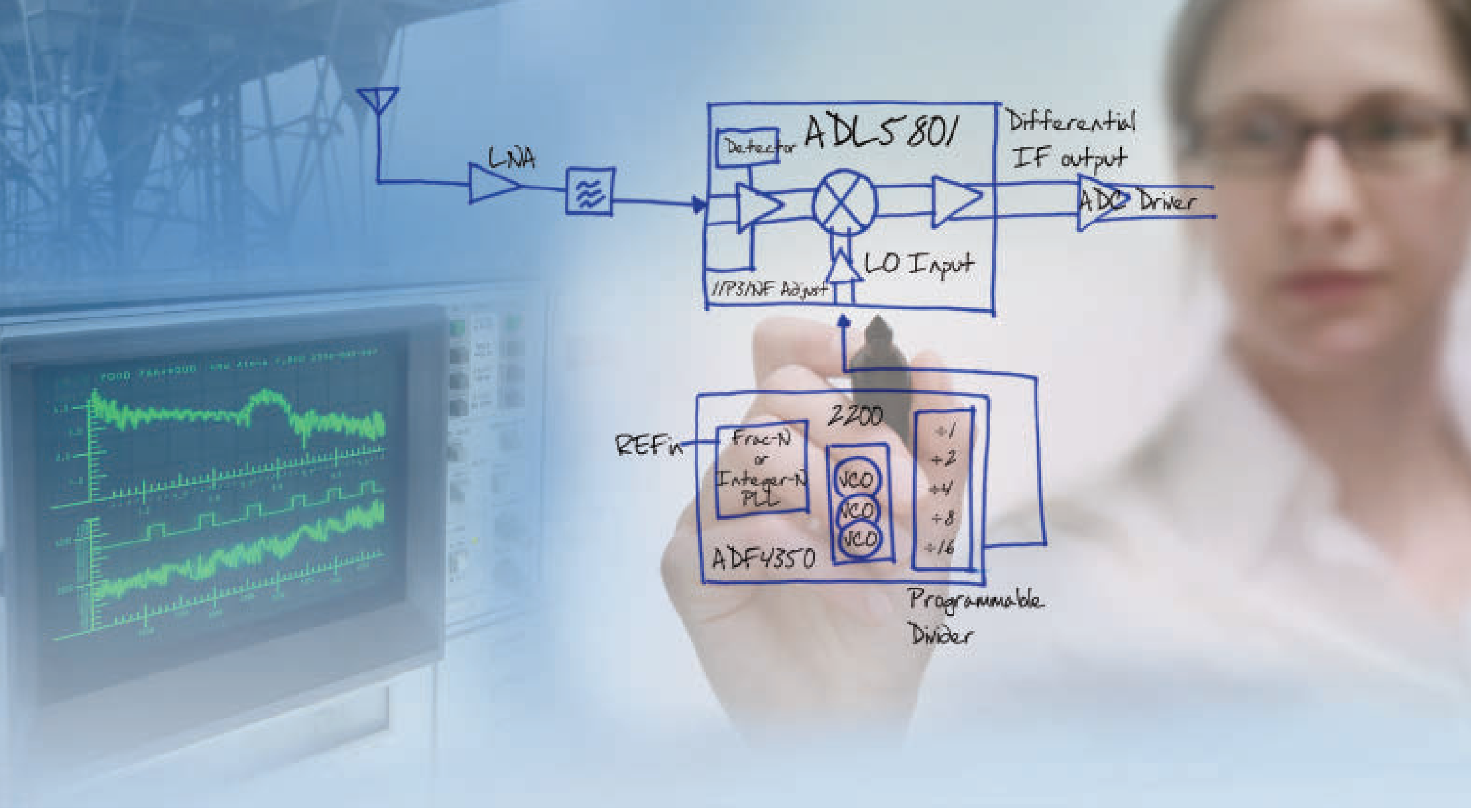

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ed signals are identical. The power amplifier chain structure with three amplifiers (see Figure 11f) includes a three-way divider consisting of a 3 dB coupled line coupler, a 4.77 dB coupled line coupler, and a combiner consisting of a 4.77 dB coupler and a 3 dB coupler. The electrical parameters of the three-way divider and combiner should have very strong magnitude and phase relationships between the three channels in order to provide a high PA efficiency. Also, the insertion loss of the divider and combiner is very critical. For the 4.77 dB coupler of the divider, the voltage transfer coefficients[3] are

$$\frac{U_1}{U_2} = \frac{-1-\left(\Gamma_2 S_{12}^2 + \Gamma_3 S_{13}^2\right)}{-\left(1+\Gamma_2\right)S_{12}}; \qquad (8)$$

$$\frac{U_1}{U_3} = \frac{-1-\left(\Gamma_2 S_{12}^2 + \Gamma_3 S_{13}^2\right)}{-\left(1+\Gamma_3\right)S_{13}}$$

where Γ_2, Γ_3 are the reflection coefficients of the coupler loads in port 2 and port 3, respectively.

The conventional RF eight-port beam forming network based on four hybrid dividers/combiners is used for determining both azimuth and elevation information in monopulse radar systems. The monopulse networks (see ***Figure 12***) provide connection of four inputs/outputs 1, 2, 3 and 4 to output/input ports 5, 6, 7 and 8, which can be connected to four antenna elements. These eight-port hybrid matrices provide equal amplitudes and specific relative phases for the four antenna monopoles to form the directional antenna pattern.[12] ***Figure 12a*** illustrates a Butler matrix,[13] including four two-branch hybrids H1, H2, H3, H4 and two 45° phase shifters. Four antenna elements connected to ports 5, 6, 7 and 8 provide four antenna beams in the desired directions.

The amplitude monopulse network (see ***Figure 12b***)[12] includes four dividers/combiners and a switched 0°/180° phase shifter, connected in series. This 4 x 4 matrix should be asymmetrical to take into account the losses of the switched phase shifter to provide an amplitude balance at all four antenna terminals 5, 6, 7 and 8. Therefore, hybrids H1, H2 and H4 should have unequal power ratio m (see Equation 2), depending on the phase shifter loss. The direct connection of the four two-branch hybrids (without an additional connection line between them) makes the bandwidth of the 4 x 4 matrix slightly narrower than the bandwidth of the single two-branch hybrid due to undesirable interaction between the four hybrids. When the four hybrids H1, H2, H3 and H3 are connected using quarter-wavelength transmission lines (invertors I1, I2, I3 and I4) (see Figure 12b), the quality of the circuit is improved.[12] ***Figure 12c*** illustrates a monopulse comparator circuit using dividers/combiners based on the 0°/180° hybrid rings. If the four input ports with signals A, B, C and D are connected to four antenna elements, the output signal (C+D) - (A+B) is proportional to the elevation angle and the output signal (B+D) - (A+C) is proportional to the azimuth angle. ■

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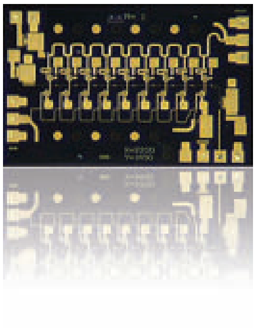

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SDA-2000	DC to 22	12	5.3	27	38	8.0	410	Die, 3.1 x 1.45 x 0.102
SDA-3000	DC to 24	16	2.1	23	34	8.0	160	Die, 3.1 x 1.45 x 0.102
SDA-4000	DC to 26	14	3.0	19	29	5.0	160	Die, 3.1 x 1.45 x 0.102
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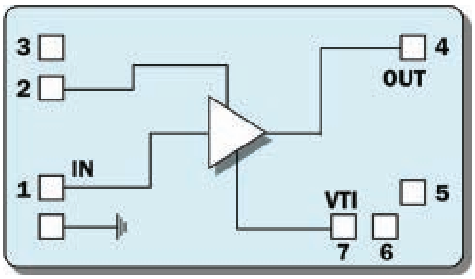

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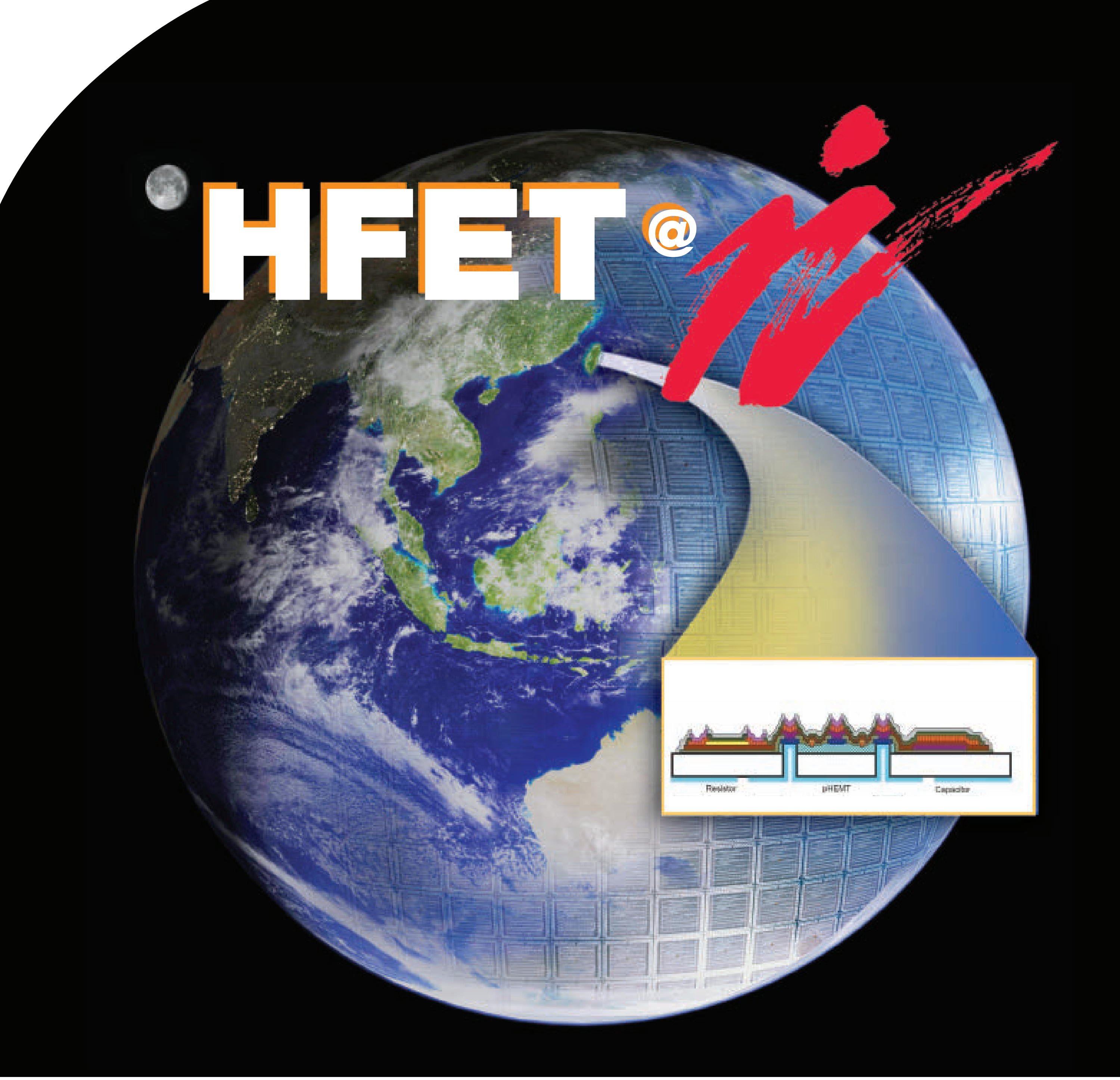
Leo G. Maloratsky *received his MSEE degree from the Moscow Aviation Institute and his PhD degree from the Moscow Institute of Communications in 1962 and 1967, respectively. From 1962 to 1992, he was involved in the research, development and production of RF and microwave integrated circuits at the Electrotechnical Institute and was an assistant professor at the Moscow Institute of Radioelectronics. From 1992 to 1997, he was a staff engineer at Allied Signal. From 1997 to 2008, he was a principal engineer at Rockwell Collins, where he worked on RF and microwave integrated circuits for avionics systems. He joined Aerospace Electronics Co. in 2008.*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THE DISTANCES CHART: A NEW APPROACH TO SPURS CALCULATION

A new method for mixer spurs calculation is presented, which has been found easier and more straightforward to use than the traditional spurs chart approach when dealing with the frequency plan optimization in broadband double conversion transceivers suitable for applications as multiband, multistandard and Software Defined Radio (SDR). Instead of plotting the spurs at the mixer's output, it shows the distance from the wanted RF input to other unfiltered input frequencies (named RFmn interferers) that will appear, through the mixing process, at a minimum "guard" distance—user specified—from the borders of the IF output band. The main benefit of this method, as compared to the spur chart, is that the LO sweep is implicit in the results and the spur lines are static, thus permitting the optimization of the RF and IF filter bands and the LO sweep band. This method assumes that the IF is a design variable and that a second conversion is used to get to/from a lower IF frequency more suitable for A/D or D/A conversion.

When dealing with frequency conversion processes, it is necessary to know the type and level of the non-desired spurs appearing at the output of the frequency conversion device. Power level calculations rely on mixer behavior (that is the nonlinear transfer function from V_{in} to V_{out}) that is dependant on specific mixer technology and design.

These levels are commonly referred to the level of the wanted output signal and are expressed as rejections in decibels (positive values) or gains (negative values). Analytical expressions for intermodulation product (IMP) suppressions can be found[1] for the case of doubly balanced diode ring mixers; they take into account the balun imbalances, diode mismatches and diode turn-on voltages. The proper setting of these parameters can require a deep knowledge of the internal mixer circuitry and technology, not often available.

The rejections to IMPs are also dependant on the relative levels of oscillator and input signals and they vary with frequency. Many manufacturers of microwave mixers provide spur rejection tables in their datasheets, corresponding to conversions between a mid-to-high RF and a low IF, usually of 100 MHz. In conversions to/from much higher intermediate frequencies, as those considered in this study, it may be necessary to obtain new spur tables from measurement, prior to their use in a microwave simulator. Also in a first approach, the analytical results from Henderson[1] could be used.

Regardless of the output spectrum component levels in a particular frequency conversion, their frequency values can be obtained in

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a much more generic way: All the convolutions between harmonics of the oscillator and input signals will appear at the mixer output. Thus, for single tone RF and LO inputs to a mixer, the IF output will consist of a set of spectral lines with positive frequencies expressed as |mRF ± nLO|, that will be named $|IF_{mn}|$ spurs. For the three common frequency conversion types—RF+LO, LO-RF and RF-LO—the desired output signals correspond to IF_{11}, IF_{-11} and IF_{1-1}.

THE CONVERSION FREQUENCY PLAN

The proper choice of IF and LO values can greatly simplify the filtering requirements in a converter design, produce high robustness to interferences in receiver applications, or high output spectral purity in transmitters, and allow for a reduced number of filters and minimum values of local oscillator frequencies, while covering a broad RF band with a wide IF bandwidth. These aspects become particularly important in converter applications requiring wide IF bandwidths and broad RF bands, like in multiband and multistandard transceivers and SDRs.[2]

Figure 1 shows the datasheet spur table for the mixer HMC141 from Hittite Microwave Corp. This table represents the mixer rejection to the feedthrough harmonics (the nLO (m = 0) and mRF (n = 0) signals) and the IMPs of the form |mRF + nLO|. The suppressions are given in dBc below the desired output signal (equal to 0 dBc). The test conditions are single tone RF and LO and conversion to low IF (100 MHz in this case). The spur tables are always referred to specific input and LO signal power levels.

An optimum frequency plan for the conversion represented by the above table will keep the low order IMPs (those with m≤2 and n≤4) away from the IF band to be rejected by filtering, and will leave only high order spurs (m≥3) appearing at the desired output band as they are well rejected by the mixer. This is a necessary limitation if broadband RF filtering is to be implemented in order to reduce the filter count, and its direct consequence is that the mixer rejections to those spurs must be equal to or higher than the dynamic range specified for the converter. This imposes an important requirement for mixer selection.

THE CLASSICAL SPURS CHART METHOD

The Spurs Chart is a plot, on the IF/RF plane, of the mixer output frequencies as a function of the single input RF tone frequency for a fixed LO value. The |mRF+nLO| products appear as straight lines, crossing the y-axis (IF) at ±nLO with a slope ±m in the x-axis (RF); (m, n) being integer numbers m≥1 and n≥0.

	nLO				
mRF	0	1	2	3	4
0	XX	3	7	3	35
1	3	0	17	25	32
2	72	64	59	59	74
3	76	76	71	72	76
4	74	76	77	77	77

RF = 6 GHz @ –10 dBm
LO = 6.1 GHz @ +20 dBm
All values in dBc relative to the IF power level.
Measured as downconverter.

The frequency plan makes these IMPs falling out-of-band. They can be rejected by filtering.

These IMPs are not excluded by the frequency plan. Many of them will fall inside the frequency band of interest.

▲ *Fig. 1 M × N spurious at IF port for Hittite's HMC141.*

In order to study the spurs appearing at the mixer output when the LO is swept to translate into IF a portion of the input band in a receiver with broad RF filtering (or to translate the IF into the broad RF band in a transmitter), several steps must be performed trying different values for LO, IF and the RF filter pass band, until the most harmful IMPs are kept outside the mixer output and at a safe distance that will make their rejection effective by practical filtering.

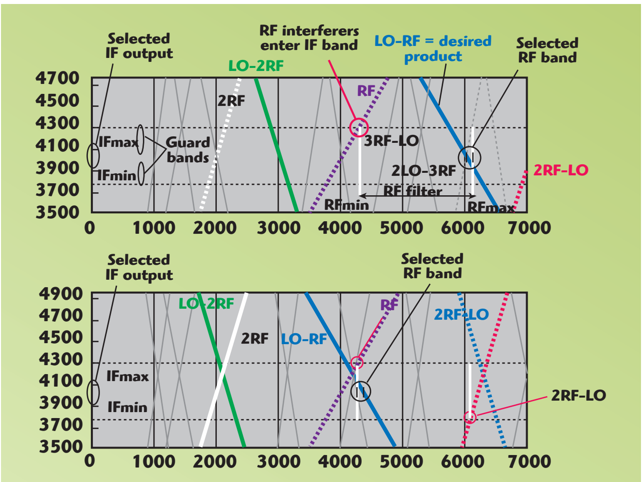
The former process can be tedious and inefficient as the represented spur lines change for every LO setting and many different frequency plans are possible, making it very difficult to find the optimum values for the RF bandwidth, LO band and the IF. An example for an LO sweep is given in ***Figure 2***, where the desired output is IF = LO – RF (in blue). The higher order IMPS are plotted in grey.

The Spurs Chart results are interpreted as follows: The range of RF frequencies defined by the LO-RF line crossing the IF band are the selected RF sub-band (encircled box in Figure 2) and is dependant of the IF and LO values chosen. There is no single solution for the IF and LO bands unless the additional constraint of having the maximum possible RF filter band is imposed.

The chart also shows that many other lines cross the IF band; these IMPs are spurs originated from the LO mixing with non-wanted input RF frequencies outside the RF filter band. It is the task of the RF input filter to eliminate these frequencies, or reduce them enough to make them appear, at the mixer output, at a much lower level than the wanted IF.

Other lines cross IF at the selected RF sub-band; they are IMPs of the wanted input and the LO that, through a different conversion other than LO-RF, produce the same IF output. In order to prevent their signal distortion effect they must fall in the rejection band of the IF filter or be properly rejected by the mixer. A practical IF filter will have its rejection and pass bands separated by a "guard" distance that, together with the rejection requirements, will impose the type and order of the filter.

The maximum pass band for the RF filter will be determined by its guard value selected (not shown in the chart) and the IMPs allowed in the IF band. In this example, the low order IMPs having m≤2 and n≤4 will be rejected be-



▲ *Fig. 2 Spurs chart representation of the LO sweep at the first conversion in a broadband super heterodyne receiver.*

fore entering the mixer, in order not to appear at the IF band.

Each time the LO is modified, the plotted lines shift from their position and new RF frequencies and spurs may appear at the IF band. It is then difficult to work with this type of chart when the initial IF and LO frequencies are unknown and the LO is going to be swept. One can get lost easily, dealing with all the lines moving as IF and LO change. It is also difficult to follow the evolution of a particular spur and see its dependency with the values of the frequency plan during a trial-and-error optimization.

An extension of the traditional Spurs Chart has been proposed[3] to calculate the band segments of incidence of the spurs within a range of LO frequencies, thus solving the problem of LO static. The spur lines are observed within a 3D-like figure bounded by two apertures or boxes (each one associated with LO_{min} and LO_{max}, similar to the encircled boxes in Figure 2) and their connecting lines.

This article presents a new approach called the Distances Chart, which also solves the drawbacks associated with the LO static and makes more comfortable the study of the conversion spurs in applications where a broad RF band is to be swept with a wide IF.

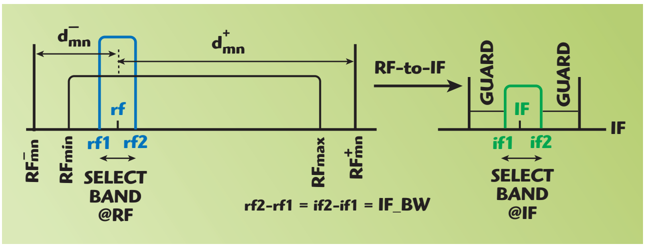
THE NEW METHOD DESCRIPTION

The distance from the RF input frequency to the RFmn spur is defined as

$$d_{mn}=RF_{mn}-RF \quad (1)$$

The intermodulation products at the mixer output are calculated as |mRF + nLO| or just mRF + nLO if (m, n) are allowed to take positive and negative values; the IMPs falling at negative frequencies are also considered. By definition, the RF_{mn} interferences verify the following condition:

$$mRF_{mn}+nLO=IF\pm[Guard+\tfrac{1}{2}\,IF\_BW] \quad (2)$$



▲ *Fig. 3 The Distances Chart approach.*

where IF is the center of the output band. Extracting d_{mn} from the above expressions gives

$$d_{mm}=1/m(IF\pm[Guard+\tfrac{1}{2}\,IF\_BW])-n/m\;LO-RF \quad (3)$$

The distance from the n^{th}LO harmonic to the limit of the IF band is

$$d_{0m}=nLD-(IF\pm[Guard+\tfrac{1}{2}\,IF\_BW]) \quad (4)$$

Finally, if IF = LO - RF is selected, one obtains

$$d_{mm}=\{(1-n)IF\pm[Guard+\tfrac{1}{2}\,IF\_BW]-(n+m)RF\}/m \quad (5)$$

Thus, d_{mn} (y-axis) can be plotted against RF (x-axis), having IF, Guard and IF_BW as the design parameters, and no dependency with the LO sweep (it is already implicit in the result).

The design approach for the frequency plan is to find the widest RF filters—in order to minimize their number—having good rejections to the RF_{mn} frequencies. The minimum d^-_{mn} and d^+_{nm} distances from every in-band frequency to the closest RF_{mn} interferers must be determined. The constraints for d_{nm} are shown in ***Figure 3***:

$$d^-_{mn}\geq rf-RF_{min}$$
$$d^+_{mn}\geq RF_{max}-rf \quad (6)$$

with rf being the center frequency of a selected sub-band, IF_BW wide, passing through the RF filter pass band.

At the lower end of the RF filter band is rf1 = RF_{min} and the constraints are

$$d^-_{mn}\geq\tfrac{1}{2}\,IF\_B$$
$$d^+_{mn}\geq RF_{max}-(RF_{min}+\tfrac{1}{2}\,IF\_BW) \quad (7)$$

At the top end of the RF filter band

is rf2 = RF_{max} and the constraints become

$$d^-_{mn} \geq RF_{max} - (RF_{min} + \tfrac{1}{2}\, IF\_BW)$$
$$d^+_{mn} \geq \tfrac{1}{2}\, IF\_BW \qquad (8)$$

"Guard" is set by trial and error and its value affects directly the design of the RF and IF filters; the higher the Guard value, the softer the RF/IF filter specifications, but the RF sweep band is reduced. The spur-free area at the Distances Chart is shown in ***Figure 4***.

The IF values are optimized for spur rejection by combining the rejection capabilities of the mixer to high order intermodulation products or spurs, and the IF filter rejection to the low order intermodulation products (poorly rejected by the mixer), provided they appear at a safe distance away from the IF band. IF = LO-RF is the preferred conversion mode because it allows for lower IF values (simplifying the next conversion stages) and better rejection of the LO harmonics in transmitters, as none of them can fall inside the broad RF output band.

Depending on the LO sweep selected, 1 to 3 different IF values are required in the first conversion stage of a receiver (or the last stage in the Transmitter case) to make a detour of the otherwise unavoidable spurs. If IF is high enough, only one single value can satisfy the condition of rejecting the lower order IMPs from the mixer, but this also implies high values for the LO, which will be in detriment to its price and phase noise performance.

CASE STUDY: DEVELOPMENT OF AN OPTIMUM FREQUENCY PLAN FOR A 0.22 TO 6 GHZ RF BAND TO A 100 MHZ WIDE IF WITH 70 DB SFDR

For the purpose of this example, a mixer with the spur table shown in Figure 1 will be considered. It will be assumed, without losing generality, that the rejection values are valid for all the RF, LO and IF frequencies involved. In a real case, an accurate nonlinear model for the mixer would be needed or different spur tables shall be obtained through a device characterization process, but such a study is beyond the scope of this article. The Distances Chart is intended for qualitative results only, and can be of great help in the very first phases of a converter design, during the definition of its topology and the specification of requirements for its main components.

The frequency plan, implemented with the lowest IF value and LO sweep, uses three different IFs for the same conversion stage and is presented in ***Figure 5***. The whole 1.33 to 6.07 GHz RF band can be covered with only three wide pass band RF filters while guaranteeing the rejection to harmful interferers (those falling at or close to IF). The problem of filtering out the lower RF interferers will be discussed at the end.

Figures 6 to ***8*** show the Distances Charts results for the 1.33 to 6.07 GHz RF portion of the frequency plan that keeps the low order IMPs (those with $m \leq 2$ and $n \leq 4$) at a minimum "Guard" distance away from the 100 MHz wide IF band.

Figure 6 is the conversion of the 4.30 to 6.07 GHz RF band to a 100 MHz wide IF centered at 4.03 GHz using a single RF filter and keeping the most harmful IMPs at a $\Delta f \geq$ 215 MHz from the IF band; Figure 7 is the conversion of the 2.49 to 4.40

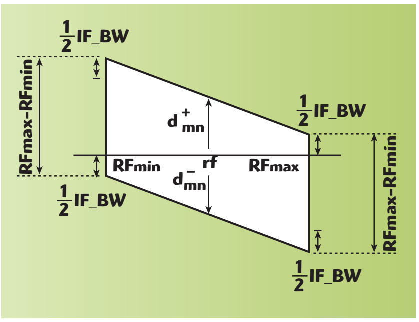


Fig. 4 Spur-free area at the Distances Chart.

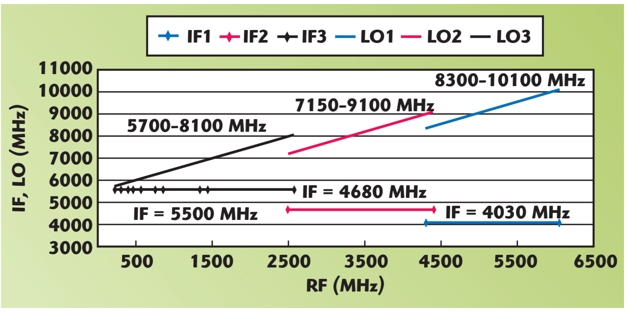


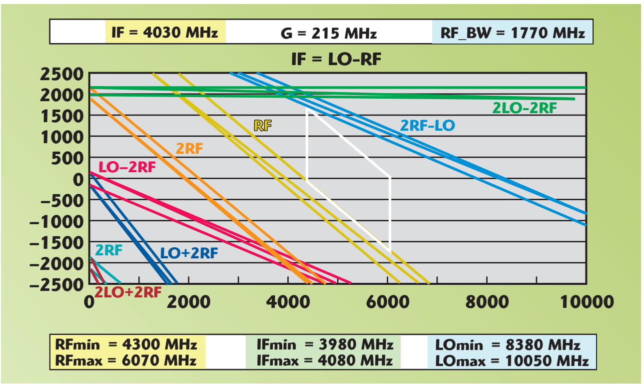
Fig. 5 Frequency plan for wideband conversion in a mixer stage using minimum LO and IF values. The IF band is 100 MHz wide.

GHz RF band to a 100 MHz wide IF centered at 4.68 GHz using a single RF filter and keeping the most harmful IMPs at a Δf ≥ 215 MHz from the IF band; Figure 8 is the conversion of the 1.33 to 2.59 GHz RF band to a 100 MHz wide IF centered at 5.50 GHz using a single RF filter and keeping the most harmful IMPs at a Δf ≥ 60 MHz from the IF band.

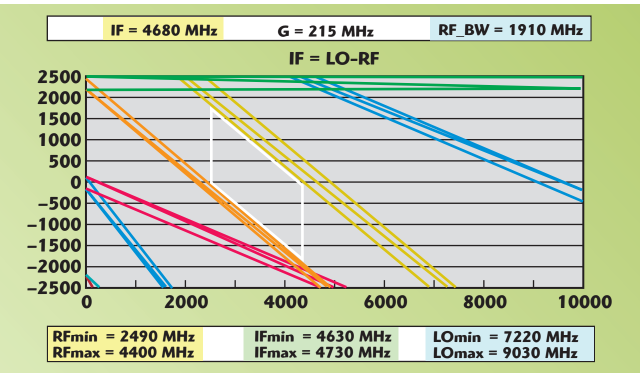
In the lower RF frequency band (below 1.3 GHz) the LO-2RF product (identified in Figure 6) can be very harmful if an interferer appears at half the wanted signal frequency ($LO-2RF_{-21}$ = $LO-RF_{-11}$ = IF). This is not dependant on the frequency plan selected.

The interferer proximity to the wanted signal (only ½ RF_{-11} separation) will prevent the use of a broadband RF filter if the mixer rejection to the 2 × 1 product is lower than the spur-free dynamic range required in the application (see the grey colored box in the table of Figure 1). Four mid-to-narrow pass band RF filters would be required here to cover the 0.22 to 1.44 GHz range (see ***Figure 9***). The use of a mixer with higher rejection to the 2 × 1 product will reduce the RF filter constraints.

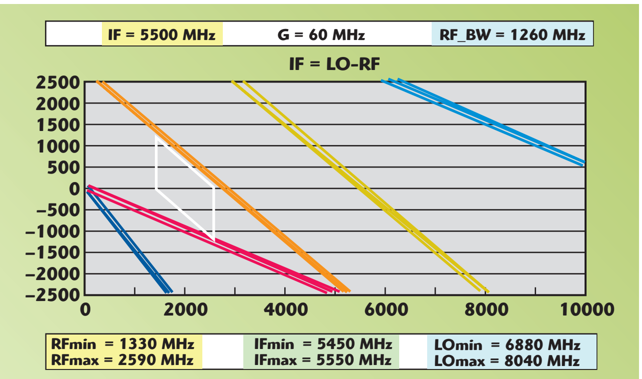
Even when no interference is present at the RF port, there is always the LO-2RF product falling at an RF distance from the IF in Rx operation. This limits the rejection capabilities of the IF filter, or puts a hard constraint on its design; both aspects degrade



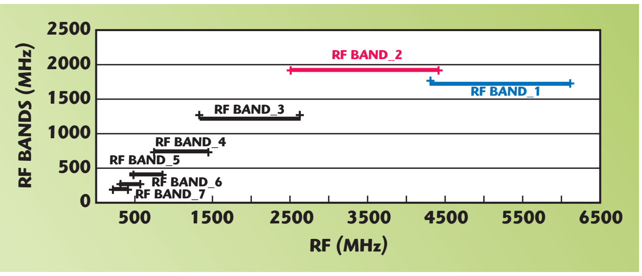
▲ *Fig. 6 Conversion of the 4.38 to 6.07 GHz band to a 100 MHz wide IF centered at 4.03 GHz.*



▲ *Fig. 7 Conversion of the 2.49 to 4.40 GHz RF band to a 100 MHz wide IF centered at 4.68 GHz.*



▲ *Fig. 8 Conversion of the 1.33 to 2.59 GHz RF band to a 100 MHz wide IF centered at 5.5 GHz.*



▲ *Fig. 9 RF sub-bands for the wideband converter.*

the overall performance and increase costs. Narrow band RF filters would also be required for Tx operation in order to guarantee a high spur-free dynamic range at the RF side, also increasing complexity and cost.

The spurs table of a given mixer can be modified if input and LO levels different than the ones used during table extraction are allowed. The dependency of the spur table rejections with the input and LO signals power levels can be approximated in double-balanced mixers[1] by

$$\Delta dBc=(m-1)\,(dbIN-dBLO) \qquad (9)$$

where m is the order of the input signal and dBIN, dBLO represent the variation of input and LO levels from the reference values used during Spur Table generation. This can be used to increase the mixer rejection to problematic spurs and reach the required SFDR, but the cost is a reduction in the output dynamic range. Example: A mixer presenting a 64 dB rejection to the 2 × 1 spur measured at –10 dBm RF will benefit from a 74 dB rejection, if fed with a –20 dBm input (for the same LO power).

Mixing products with m ≥ 3rd order for the RF and n ≥ 5th order for the LO have not been considered in the Distances Chart implemented for this study. This is a necessary limitation if broadband RF filtering is wanted, and its direct consequence is that the mixer rejections to these spurs must be equal or higher than the dynamic range specified for the converter, in case they could fall too close to or even inside the IF band.

Commercially available MMIC mixers show rejections higher than 70 to 80 dBc to these higher order IMPs, but many of those mixers do not show high enough rejections to the $3LO\text{-}3RF_{33}$ (= IF) product. If one of those mixers was used, the frequency plan shall be set to avoid RF_{33} = LO - 1/3IF. Then RF_{33} > RFmax would become a new constraint, and an additional requirement for the frequency plan shall be

$$LO_{min}-{}^{1}/_{3}\,IF>RF_{max} \qquad (10)$$

CONCLUSION

The Distances Chart is a new method to find mixer spurs, allowing for an easy optimization of the IF and RF filter bands as well as the LO sweep band in applications where a broad frequency band with wide IF is to be covered, as in the case of broadband double conversion transceivers for multiband, multistandard and SDR applications. This method is easier and more straightforward to use than the traditional spurs chart approach during the study phase of such converters. ■

ACKNOWLEDGMENT

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DIRECTION MATTERS: INCLUDING SUBSTRATE ANISOTROPY IN PLANAR CIRCUIT DESIGN FLOW

Jim Rautio,

Founder of Sonnet Software.

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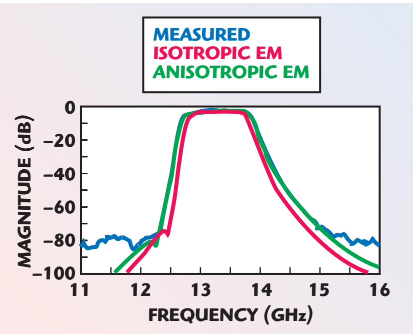
In the late 1970s, when one of the authors (Rautio) first got started in microwaves, one of his first tasks was to design filters on alumina for Landsat IV. The design was carefully performed using the commonly assumed substrate dielectric constant of 9.8. Even so, several design iterations were required. "Get used to it," he was told. "Multiple design iterations are a fact of microwave design life." Or so it was thought.

Fast forward to 2007. EM analysis is a mainstream design tool. Dielectric Laboratories (Casenovia, NY) is having good success with rapid fire design of filters using commercial, 3D planar EM analysis. Success on first fabrication is now normal, except for certain cases. The troublesome cases use a nearly exactly zero temperature coefficient ceramic, and that ceramic is anisotropic. ***Figure 1*** illustrates the problem. For this filter, pretending that the substrate dielectric constant is isotropic means a re-design is required. With anisotropy included, the filter is ready for production.[1]



▲ *Fig. 1 Measured vs. calculated performance of a filter.*

Anisotropy means that the dielectric constant depends on the direction of the electric field. The obvious work-around for not being able to analyze anisotropy using EM is to assume a constant dielectric constant in all directions (isotropy) and to use an average dielectric constant. A percentage of a transmission line's electric field is parallel to the substrate surface and the rest is perpendicular to the substrate surface. Therefore, a weighted average of the horizontal and vertical dielectric constants is used, and the average is weighted according to the percentage of horizontal and vertical electric fields.

This works well as long as only single transmission lines are used, all with the same width. If the width is changed, the percentage of horizontal and vertical electric field has to be changed as well. A different weighted average is needed. If the difference is not so large, maybe just one isotropic dielectric constant can be used and one can still get the designs to work.

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ASSUMING ISOTROPY FAILS FOR FILTERS

The big problem comes with filters. The resonant frequencies of the resonators in filters are determined mostly by the vertical dielectric constant. In order to get the right center frequency for the filter, one can simply use the vertical dielectric constant and pretend that the substrate is isotropic. However, there is more to a filter than the center frequency; the bandwidth must also be nailed down. The bandwidth depends on the coupling between resonators, which depends on the horizontal dielectric constant. However, the horizontal dielectric constant is different.

Thus, if an anisotropic substrate is actually assumed to be isotropic, the center frequency or the bandwidth can be right but both cannot be right at the same time. This was the situation faced by Dielectric Laboratories, resulting in the "Isotropic" and the "Measured" data shown in the figure. This amount of error absolutely requires a second design iteration, "stretching" the filter to an artificially wider target bandwidth, hoping that the actual realized bandwidth would end up close to requirements.

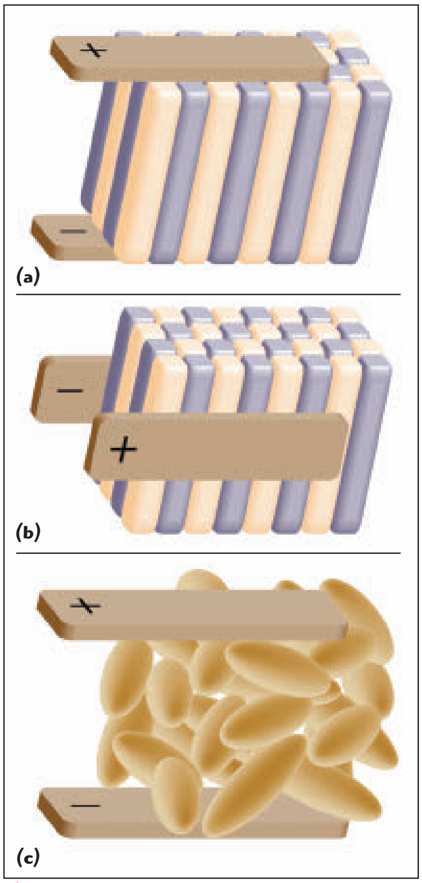
To address this problem, Sonnet modified its software to include anisotropy. Specifically, the capability to analyze "uniaxial" anisotropy was added. In other words, there is one horizontal dielectric constant for all horizontal field directions and a different dielectric constant for the vertical field direction. Dielectric Laboratories plugged the measured values for the substrate's anisotropy into the simulation using the modified software, which resulted in the "Anisotropic" curve.

ANISOTROPIC CERAMIC? RIDICULOUS!

It seems really strange. How can a ceramic possibly be anisotropic? Some kind of material is ground (sapphire is used to make alumina), and then all the randomly oriented grains are melted together. Even if the original material is anisotropic (as is the case with sapphire), the resulting ceramic should be almost perfectly isotropic. Not quite. The above reasoning works only when the grains of the ceramic are spherical. In general the grains are not spherical and the "random" orientation of the grains in the ceramic has preferences. This makes most ceramics anisotropic. For example, in the only published measurement of anisotropy in alumina that was found,[2] the dielectric constant was determined to be 8.607 vertically and 10.159 horizontally (manufacturing variability was not investigated). The usually assumed 9.6 to 9.9 represents a nice average of the two measured values, but the difference between the average dielectric constant and the true anisotropic dielectric constant easily explains the multiple design iterations on those Landsat IV filters.

To see why a ceramic can be anisotropic, look at ***Figure 2***, which illustrates a hypothetical substrate. The dark cylinders have high dielectric constant and the light areas are low, and half of the total volume is devoted to each type. For the top example (2a), the total capacitance from top to bottom is dominated by the high dielectric constant. This is just like connecting two capacitors in parallel. The total capacitance is dominated by the larger capacitor.

Next, look at the middle example (2b). Here each material still takes up the same percentage of the substrate volume. The total capacitance between the terminals is now dominated by the low dielectric constant. This is similar to connecting two capacitors in series. The smaller capacitor controls the total capacitance. The actual situation is similar to example (2c). When the ceramic grains are not spherical, then the higher dielectric constant dominates for electric field parallel to the length of the grains and the lower dielectric constant dominates for electric field parallel to the shorter grain



▲ *Fig. 2 Dielectric constant substrate components with non-spherical grains.*

TABLE I

EXTRACTED UNIAXIAL DIELECTRIC CONSTANTS FOR RESONATORS R1 AND R2

#	MHz	R1 ε_h	R1 ε_v	R2 ε_h	R2 ε_v
1	290	3.937	4.117	3.878	4.106
2	590	3.934	4.094	3.889	4.077
3	880	3.926	4.081	3.876	4.075
4	1170	3.935	4.074	3.906	4.078
5	1470	3.979	4.083	3.923	4.075
6	1760	3.990	4.076	3.936	4.072
7	2060	4.001	4.070	3.926	4.063

dimension. Thus, any ceramic that has non-spherical grains will have grains tending to be preferentially oriented and is necessarily anisotropic even if the grains themselves might be perfectly isotropic.

Not only are most ceramics anisotropic, composite substrates are anisotropic too. Composite substrates are formed of at least two different materials; for example, PTFE and glass fiber. The reason for two materials is so the substrate temperature coefficient matches that of the copper foil cladding. The two materials are selected for strength and durability. Each of the materials has a different temperature coefficient and they are mixed and formed so that the net temperature coefficient matches that of copper. The substrate dielectric constant then also becomes a weighted average of the two materials, which is also necessarily anisotropic for the same reason that ceramics are anisotropic, as described above.

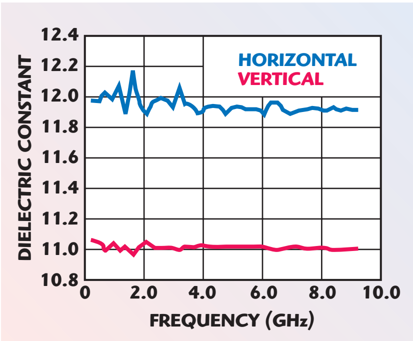
How about semiconductors? Some common microwave RFIC semiconductors are anisotropic. Yet they are designed as if they were isotropic. With so much time and money at stake (cost of failure is very high), why is this done? Because the numbers for the semiconductor anisotropy are not known. At least now they can be measured. Once measured, the anisotropy failure risk can then be removed from the planar EM design cycle.

JUST TELL ME THE ANSWER!

So now the fact that most substrate materials are anisotropic is known, the EM analyses including the effect of anisotropy can be done. What is missing? Measurements of anisotropy. There are many ways to measure anisotropic dielectric constants and most of them require substantial effort. A technique has been developed[2–5] that requires initial setup effort and sample preparation. Once this is done, measurements may be taken and reduced to anisotropic dielectric constants repeatedly and quickly.

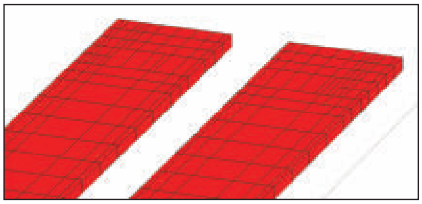
Let us start with results. ***Table 1***[3] shows results for two samples (R1 and R2) of FR4 (the popular PCB material used for computer boards, a glass fiber weave loaded epoxy) up to 2 GHz. ***Figure 3*** shows results for one sample of Rogers RO3010® laminate, a ceramic loaded PTFE substrate up to 10 GHz. It was expected that the horizontal dielectric constant would be higher than the vertical dielectric constant. For FR4, that is not the case. Also note that the FR4 measurement shows considerable dispersion, with the horizontal starting low and the vertical starting high. At higher frequencies, they are almost equal.

This suggests that the reason the horizontal dielectric constant is low is because of how the dielectric constant is measured. The procedure starts by fabricating a microstrip (or stripline) resonator and measuring the resonant frequencies. Then, several EM analyses of the same resonator are performed assuming a reasonable value for the dielectric constant. For FR4, a reasonable guess is 4.0. Next, the EM analysis resonant frequencies are compared to the measured ones. For example, if the EM analysis says a dielectric constant of 4.0 should give a resonant frequency of 1.00 GHz, but a resonant frequency of 1.01 GHz is measured, the dielectric constant of the measured substrate is approximately 2 percent lower, or 3.92. (Resonant frequencies vary inversely with the square root of the dielectric constant, which is why a delta in frequency of 1 percent requires a change in dielectric constant of 2 percent.)



▲ *Fig. 3 Measured vertical and horizontal anisotropic dielectric constants for Rogers RO3010 material.*[4]

The above approach works great for isotropic substrates, but anisotropic materials are considered here. It turns out that exactly the same approach just described can be



▲ *Fig. 4 The end of an RA resonator.*

used, except that a coupled line "RA" resonator is now built and measured, one end of which is shown in ***Figure 4***. The fine meshing required for accurate EM analysis is also shown. The entire resonator (which extends down and to the left) is nearly 25 wavelengths long. The vertical dimension is magnified 8 times. The lines are 0.050 inch wide with a 0.025 inch gap. The RA resonator has two resonances for each half wavelength of length: An even and an odd mode. The even mode (current flows in the same direction on both lines) resonance is strongly dependent on the vertical dielectric constant; the odd mode (current flows in opposite directions) also depends on the horizontal dielectric constant. Two EM analysis cases are now run using selected anisotropic dielectric constants. By comparing the EM analyzed even and odd mode resonant frequencies to the measured even and odd mode resonances, the anisotropic dielectric constants that underlie the measured resonator can be reverse-engineered. This is how the data of Table 1 and Figure 3 has been obtained. Details and complete theory are described in the literature.[2–5]

The key point is that the odd mode depends strongly on the horizontal dielectric constant. The horizontal electric field of the odd mode is at the top surface of the substrate in the gap between the two lines. If this region of the FR4 substrate is mostly epoxy, then the lower dielectric constant of epoxy dominates the odd mode resonances. This could have caused the horizontal dielectric constant to be lower than the vertical. If true, then this lower value of horizontal dielectric constant should be used for EM analyses of coupled lines on this substrate. If the bulk value of the horizontal dielectric constant was measured, it would be higher and would give bad EM analysis results for coupled lines, because the coupled line odd mode does not see the bulk horizontal dielectric constant; it sees only the horizontal dielectric constant right at the surface of the substrate.

Note also that the dielectric constants of the two samples (R1 and R2) are slightly different. This suggests that this might also be due to the fiber glass weave. For example, if the gap between the lines were close to a strand of the glass weave, then the horizontal constant will be higher. Since these measurements are quickly performed once the resonators are fabricated, statistical studies can be easily realized providing variability information, useful for yield analysis.

MEASURING ROGERS RO3010 LAMINATE

To further verify the measurement technique, resonators on Rogers RO3010 material were fabricated and measured by Rogers. The measured substrate dielectric constants were extracted by Sonnet. This substrate material is a ceramic loaded PTFE. On the scale of the resonator, the mate-

rial is perfectly homogenous. Because the microscopic ceramic grains are not spherical, it is also anisotropic. Bulk measurements of this material verify that the horizontal dielectric constant is indeed higher. As can be seen in Figure 3, the measurements can be confirmed. The measured dielectric constants are approximately 11.0 vertical and 11.9 horizontal. One might wonder why these measured values are both somewhat higher than the quoted value of 10.3 for this substrate. The reason is that substrate manufacturers use industry standard techniques for measuring dielectric constants.[6] It turns out that those methods were not developed by microwave engineers. They were developed by quality control engineers for batch-to-batch consistency, well prior to the advent of accurate EM analysis. Consistent measurement was critical and was achieved. Accurate measurement was not. Those results were never intended to be used for high accuracy EM analysis. The high accuracy results obtained for dielectric constant are intended for exactly that use and are consistent with the modern-day experience of microwave designers using these materials.

GETTING LOTS OF DATA

One might wonder how the dielectric constants are measured at so many frequencies. Generally, resonator techniques obtain the dielectric constant at one frequency. For multiple frequencies, multiple resonators must be fabricated. Not so for this technique. One very long resonator is simply built and multiple higher order resonances are used to measure the dielectric constant at multiple frequencies. For the FR4 case, the resonator is 10 inches long and eight even/odd mode resonance pairs are measured for vertical/horizontal dielectric constant determinations at eight frequencies. At 2 GHz, the resonator is four wavelengths long.

The Rogers RO3010 laminate RA resonators are 9.5 inches long and nearly 50 even/odd mode resonance pairs are measured, which determine vertical/horizontal dielectric constant pairs at nearly 50 frequencies up to 10 GHz. The resonator is nearly 25 wavelengths long. Recall that EM analysis is used to determine how even/odd mode resonant frequencies map into the underlying vertical/horizontal dielectric constants. Extreme accuracy for the EM analysis is absolutely critical for success in this effort. For example, extremely fine meshing is required. A major portion of this effort has been to quantify and bound all possible error sources in this measurement. In fact, substantially more effort has been expended in error analysis than in the actual measurement itself. As a result of this detailed error analysis it can be said with confidence that the values obtained for both dielectric constants are accurate to nearly a full four digits, with the horizontal dielectric constant showing slightly more error than the vertical. Details are shown in the literature.[2–5]

WHAT COULD GO WRONG?

The most likely failure mode in duplicating this work will be failure of the EM analysis to provide sufficiently accurate resonant frequencies. Accuracy to a few ten's of kHz is required, even for the resonances at 10 GHz.

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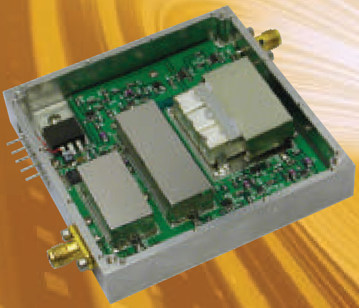

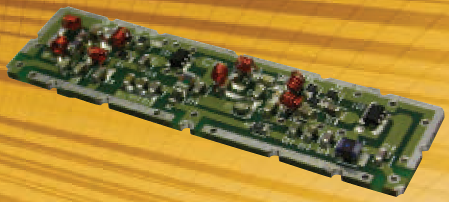

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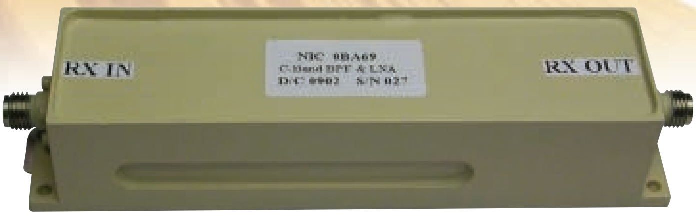

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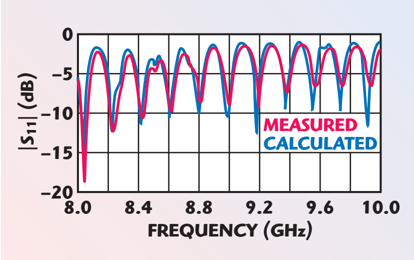
Not only is very fine meshing (for both subsection length and subsection width) required, but also the EM analysis must have extremely accurate evaluation of the "Green's function".

In short, the Green's function is the coupling between subsections as calculated by the EM analysis. For example, given 1.0 Ampere on one subsection, the EM analysis might calculate that 3.372528412 V is induced on another subsection. This calculation is repeated for every possible pair of subsections in the entire circuit. The results fill a big N×N matrix, where N is the number of subsections. Since this calculation can be time consuming, some EM analyses take a short-cut and calculate this number out to only three significant digits. While such an EM analysis might provide a fast result, it is unlikely to be usable for this application.

The Sonnet EM analysis, which is used here, calculates the Green's function to full numerical precision at all times. This is possible because the technique used performs the full precision Green's function calculation almost instantly as it is needed. There is no pre-calculation or pre-storage of the Green's function required. ***Figure 5*** shows the measured response of the nearly 25 wavelength-long resonator compared to analysis for the top two GHz (8 to 10 GHz) of the resonator, where the maximum difference between measurement and analysis occurs. With results like this, filters and amplifiers can now be designed with confidence.



▲ *Fig. 5 Measured and calculated response for the 25 wavelength-long RA resonator.*

Substrate anisotropy can now be accurately measured and included in the planar circuit design flow. This eliminates one of the few remaining major design failure risks and uncertainties, even for tight design requirements. Pretending that substrates are isotropic is history. ■

RO3010® is a registered trademark of Rogers Corp.
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POWER AMPLIFIER MODULE FOR POLAR MODULATION

The architecture of a polar-modulated power amplifier module is described. The module works at any degree of an amplifier's linearity and with higher efficiency than in commonly accepted architectures.

This article describes the architecture of a power amplifier module for polar-modulated schemes. Polar-modulated power amplifiers use polar coordinates' representation of a signal-vector (vs. the traditional Cartesian I-Q representation used in the W-CDMA modulation scheme, for example). In this scheme, the recombination of coordinates is done at the output of the power amplifier. It is employed to make use of highly nonlinear (that is, very efficient) RF power amplifiers. However, the recombination of polar coordinates is essentially a nonlinear process. It means that the amplifier should stay nonlinear (with preferably unchanged level of nonlinearity) all the time and under all conditions.

In this article, a theory of a polar modulation is given. Based on it, the required degree of a power amplifier's nonlinearity is figured out. It is demonstrated that nonlinearity, while being a necessity, cannot become too large either. A straightforward method of keeping up the allowed nonlinearity window is shown and its shortcomings are pointed out. Finally, improvements are introduced and explained in detail. The resulting architecture allows a correct recombination of polar coordinates under any conditions of power amplifier operation.

POLAR MODULATION

The polar modulation concept is based on the fact that pure phase modulation does not create intermodulation products (sidelobes). The sidelobes are distorting a spectral mask. They are the reason for employing highly linear amplifiers. In case of phase-modulated signals, though, one can use very nonlinear (that is, very efficient) amplifiers. It will be shown that polar modulation actually requires a very nonlinear amplifier for proper operation.

Modern digital communications are characterized by their constellation diagrams, created by the positions of a signal-vector. Each modulation scheme defines a constellation diagram (QPSK, 3π/4 DQPSK, 64QAM, etc.), the transmitter produces it, and the receiver looks for signals in predetermined positions of the diagram. Traditionally, the positions of a

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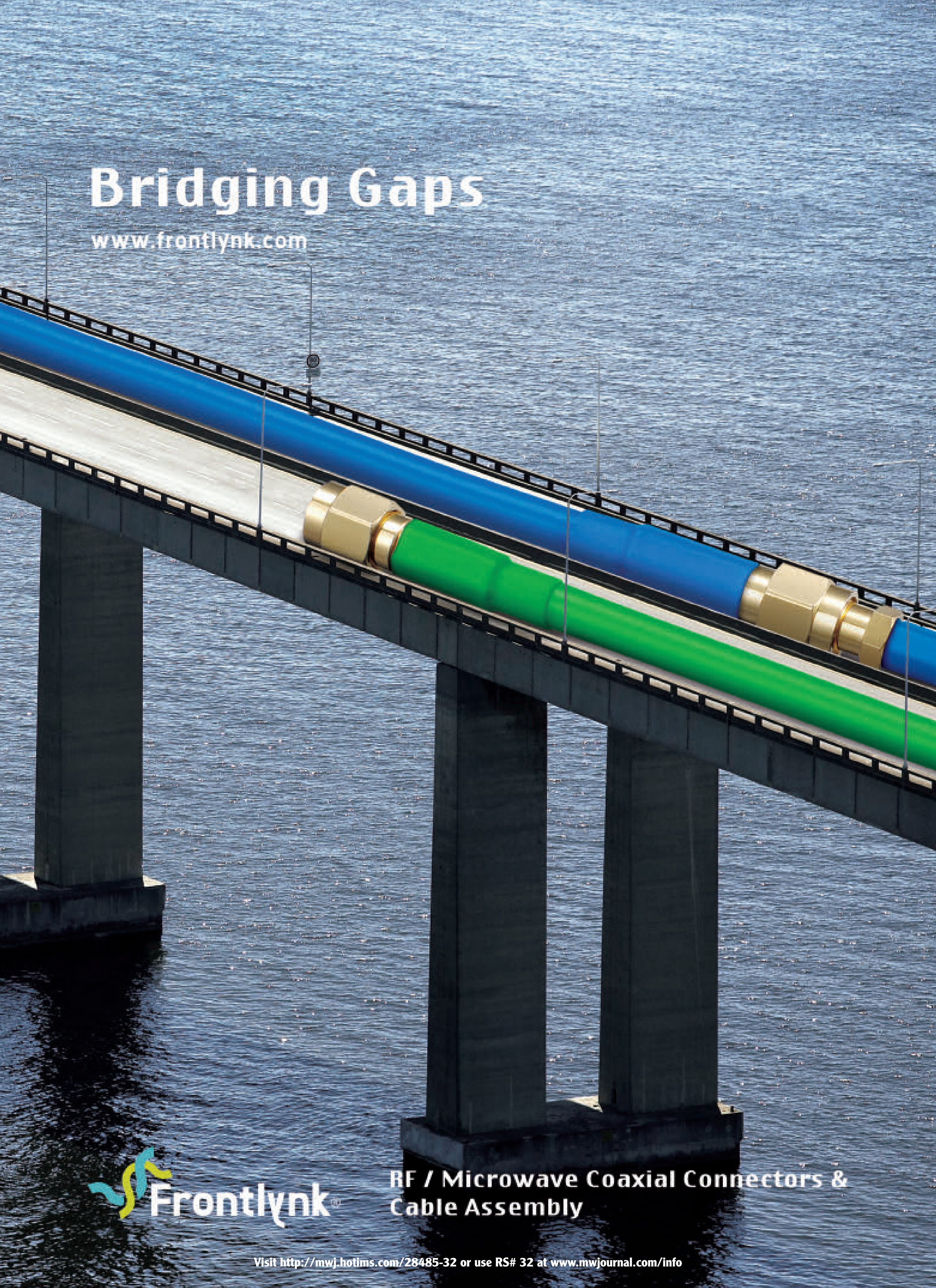
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signal-vector are described by Cartesian coordinates (Real and Imaginary, that is I-Q); however, the same positions can be exactly described by polar coordinates (amplitude and phase or magnitude and angle). The polar presentation allows at least the phase portion of a signal-vector representation to be amplified by very efficient amplifiers. The magnitude portion of a signal-vector is just a discrete DC variation, that is, requires no sophisticated amplifiers.

A concept of a polar-modulation scheme is explained in detail by F. Ditore[1] and its block diagram is given in ***Figure 1***. Usually, instead of the combination of a magnitude amplifier and a combiner, the signal from an envelope detector is applied directly to the collector of the output stage of a phase amplifier. It simplifies the block diagram, but creates its own challenges.

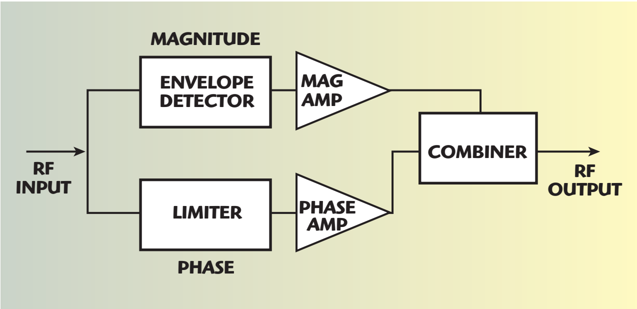

Fig. 1 Block diagram of a concept of polar modulation.

REQUIREMENTS TO POLAR-MODULATED POWER AMPLIFIERS

The separation of the RF input signal into magnitude and phase is essentially a nonlinear process. As follows from the figure, it includes two highly nonlinear components: an envelope detector and a limiter. This immediately suggests the need for a nonlinear recombination. Since, in polar modulation, the recombination is done at the power amplifier itself, it has to be nonlinear. The degree of nonlinearity is determined from the required dynamic range.

The dynamic range of the EDGE waveform (the standard where polar modulation is most commonly used) is approximately 17 dB, as follows from the Agilent ADS time domain presentation of undistorted EDGE source, shown in ***Figure 2***. This dynamic range has to be reproduced by the variation of magnitude portion of a polar-modulated signal (since the phase portion produces a constant envelope). According to the commonly accepted architecture, the signal from an envelope detector (representing the magnitude of a signal-vector) is applied directly to the collector of an output stage of the amplifier. The only way to replicate magnitude variations is to use a nonlinear amplifier, since an amplifier in a linear mode of operation is DC supply independent. The amplifier has to be nonlinear enough to reproduce 17 dB of magnitude variation.

The degree of nonlinearity, though, depends on the input RF power and the DC bias voltage. The higher the input power or/and the lower the DC bias, the more nonlinear the amplifier. To estimate the degree of a power amplifier's nonlinearity needed to produce 17 dB of dynamic range, consider the following example:

A typical set of graphs of output power vs. DC bias for a 1 W BJT transistor is shown in ***Figure 3***, where the input power is varied from -20 to +20 dBm. From the figure, it follows that, at high input power levels, 17 dB of magnitude variation is achieved with DC variation from 3 down to 0.2 V. It

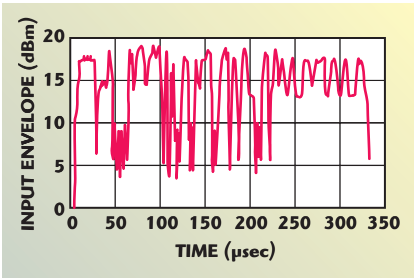

Fig. 2 Time domain presentation of an undistorted EDGE source.

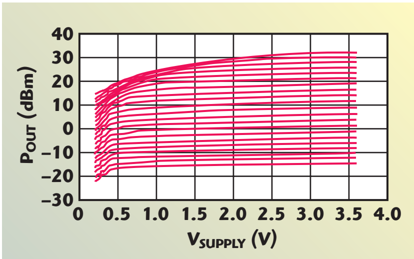

Fig. 3 Dependence of the output power on the DC voltage of a typical BJT transistor.

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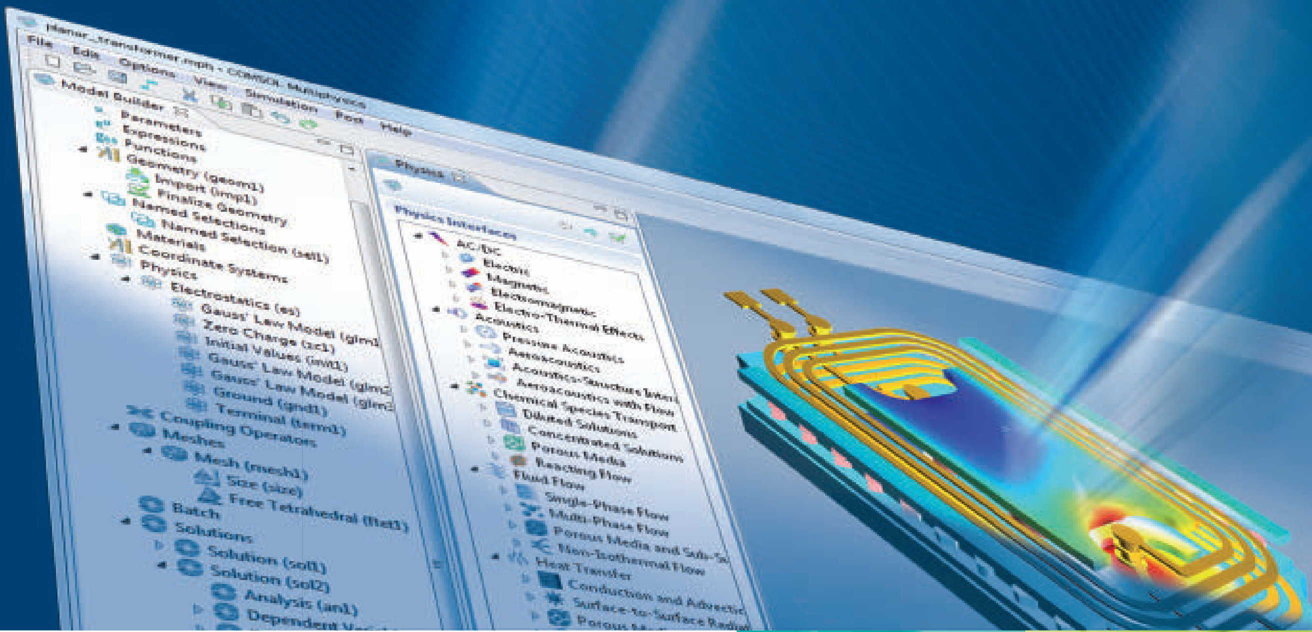

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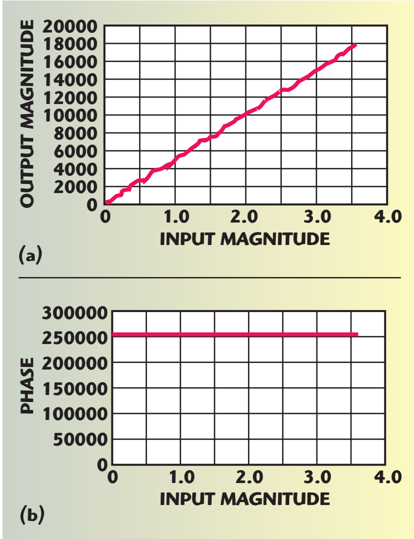
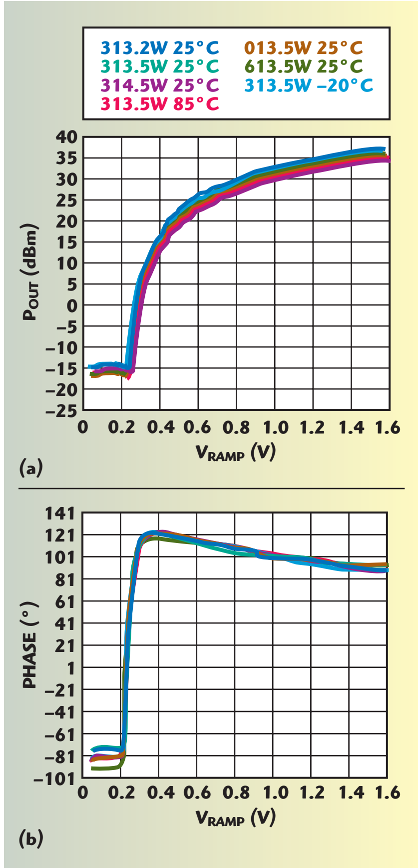
is also interesting to note that the amplifier becomes unacceptably linear when the input RF power level drops by just a few dB. However, the degree of amplifier nonlinearity has its limitations. It cannot be too large. The reason for that is in the accuracy of polar coordinates' recombination at the output of the power amplifier. The relationship between polar coordinates at its output should be the same as at the input. This relationship is expressed as AM-AM and AM-PM characteristics. They show dependence of the output magnitude and phase on the input magnitude. Ideally, there should be no phase variation and a straight line coming through the origin in magnitude variation, as demonstrated in ***Figure 4***.

Keeping up the acceptable level of recombination accuracy is challenging. The reason for the challenge is in the output parasitic capacitance of BJT transistors (Miller capacitance).[2] It is a variable capacitance, the value of which depends on the applied collector voltage. The problem with that capacitance is that it rotates the phase of the input phase signal, and the rotation depends on the capacitance value. The effect is most pronounced at low collector voltages (up to 0.3 to 0.4 V) and is observed in the nonlinear behavior of AM-AM and AM-PM characteristics, causing their misalignment. A typical set of AM-AM and AM-PM graphs is given in ***Figure 5***, where V_{ramp} is the voltage applied to the collector of the output transistor. From the figure, it follows that a somewhat linear behavior of AM-AM and AM-PM characteristics happens only when V_{ramp} is above 0.3 V. The amplifier is still nonlinear enough when collector voltages vary from 3 down to 0.3 V (see Figure 3); however, this example shows how sensitive the nonlinearity setting is in polar-modulated amplifiers.

It is important to make the amplifier nonlinear enough—to ensure the required dynamic range of coordinates' recombination, and, at the same time, to be not very linear—to keep the acceptable accuracy of the recombination. A straightforward solution of these contradicting requirements is to fix the input RF power at high level (approximately 20 dB in the example), and to make the DC supply voltage higher than a threshold level (0.3 V in the same example). The variation of RF power, requested by the base station, is done at the output of the amplifier.



▲ *Fig. 4 Ideal relationship between input and output variations magnitude (a) and phase (b).*



▲ *Fig. 5 Typical AM-AM (a) and AM-PM (b) performance of a polar-modulated amplifier at 900 MHz.*

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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	+45.8	8.0	+54	28	8.0	1995	1895
ZHL-5W-2G+	800-2000	45	+37	+38	8.0	+44	24	2.0	995	945
ZHL-10W-2G+	800-2000	43	+40	+41	7.0	+50	24	5.0	1295	1220
ZHL-16W-43+	1800-4000	45	+41	+42	6.0	+47	28	4.3	1595	1545
• ZHL-20W-13	20-1000	50	+41	+43	3.5	+50	24	2.8	1395	1320
ZHL-30W-252+	700-2500	50	+44	+46	5.5	+52	28	6.3	2995	2920
• ZHL-50W-52	50-500	50	+46	+48	6.0	+55	24	9.3	1395	1320
• ZHL-100W-52	50-500	50	+47	+48.5	6.5	+57	24	10.5	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+)

ZHL-16W-43X
ZHL-30W-252X

ZHL-5W-2GX

LZY-1X+
LZY-2X+
ZHL-10W-2GX
ZHL-50W-52X
ZHL-100W-52X

ZHL-20W-13X

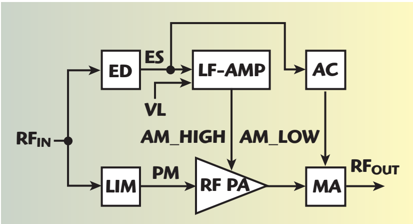
SHORTCOMINGS OF STRAIGHTFORWARD IMPLEMENTATION

The straightforward implementation of a polar modulated amplifier works in principle; its approach is documented.[3] Its block diagram is shown in ***Figure 6***. It is almost the same as the block diagram of the concept of a polar-modulation scheme (see Figure 1), only with the addition of a "smart" attenuator (MA) and a "smart" DC bias (LF-AMP). However, one should avoid placing components with RF loss at the amplifiers' output. The specific reasons for NOT placing an attenuator to the output of a polar-modulated amplifier include:

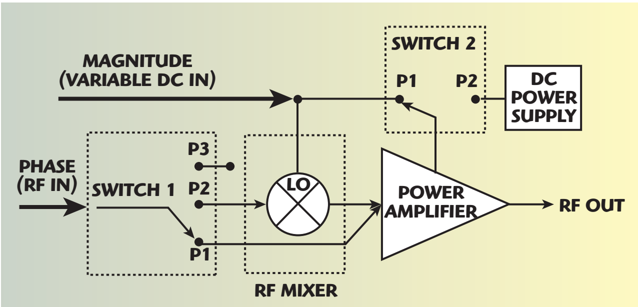
- It is an inefficient mode of operation. Every 3 dB reduction of RF power level by the output attenuator leads to halve the initial efficiency of the power amplifier. For example, if the power amplifier is biased for 60 percent efficiency at 30 dBm of output power and the base station requests 27 dBm of output power, then the module would operate with only 30 percent efficiency.
- The amplifier is becoming "unprotected" at its input. If for any reason an input RF power level is reduced, the PA would slip out of its nonlinear mode of operation (which means that it would no longer recombine magnitude and phase correctly).
- The output attenuator has to operate at high powers, so it would require PIN diode implementation. It is also expensive, since PIN diodes could not be made in the same IC die as the power amplifier itself.

POWER AMPLIFIER MODULE FOR POLAR MODULATION

The recombination of polar coordinates has to be done on a nonlinear component. It would be nice if that component was an amplifier itself, but any nonlinear enough components would do the job. Instead of adding a "smart" attenuator to the output of the amplifier, add a "smart" multiplier to its input. The job of that "smart" multiplier would be to recombine coordinates when the amplifier itself is in a linear mode (that is, when the RF power level is too low or DC bias is too high) and to be transparent when the amplifier is nonlinear enough. It leads to the block



▲ *Fig. 6 Block diagram of a polar-modulated amplifier meeting the nonlinearity requirements.*



▲ *Fig. 7 Block diagram of a polar-modulated power amplifier module.*

diagram of a polar-modulated power amplifier module shown in ***Figure 7***.

A RF signal from a limiter (phase) is applied to Switch 1. The function of this switch is to send an input signal either directly to the input of the power amplifier (when it operates in nonlinear mode) or to the RF input of a low-power multiplier (when the amplifier is linear). A DC variable signal from the envelope detector (magnitude) is applied to the LO input of a low-power multiplier and simultaneously to Switch 2. The function of Switch 2 is to apply the magnitude signal either to the collector of the amplifier (when it operates in nonlinear mode), or to switch its collector to the battery with fixed voltage, labeled "DC power Supply" (when the amplifier is linear). Switch 1 has a neutral position "P3", which is used during the operation of Switch 2 (to ensure that the switching between the fixed battery and magnitude signal is done when no RF input is present). This architecture affords an efficient mode of an amplifier's operation (since there is a possibility to provide a nonlinear bias to the amplifier for any given level of RF input power using a look-up table, for example); it is going to work at any conditions of RF input power even if the amplifier is linear at those conditions. This solution can be implemented in the same die as an amplifier itself, which, for all practical terms, does not increase the cost of solution.

CONCLUSION

In this article, an optimum architecture of a power amplifier module for polar-modulated schemes was derived. In the process of its derivation, a theory of polar modulation was given. It was made clear that in order to properly recombine polar coordinates, the power amplifier has to be nonlinear. It was also emphasized that the degree of nonlinearity has its limits, determined by the accuracy of the polar coordinates' recombination, and that limitation is fundamental (due to Miller capacitance, intrinsic to the die). It was pointed out that the most logical method of keeping up a predetermined level of nonlinearity is not efficient and expensive. Finally, a module architecture, offering a more efficient operation and less expensive implementation, was introduced. The offered solution works for any mode of power amplifier operation, allowing integrators to concentrate on the optimum mode rather than to worry about operability of the module. ■

References

1. F. Ditore, "Polar Modulation Ups Efficiency in Mobile PA Designs," *CommsDesign*, September 4, 2003.
2. P. Reynaert and M.S.J. Steyaert, "A 1.75 GHz Polar Modulated CMOS RF Power Amplifier for GSM-EDGE," *IEEE Journal of Solid-State Circuits*, Vol. 40, No. 12, December 2005, pp. 2598-2608.
3. A. De Graauw and L. Van Den Oever, "Amplifier Architecture for Polar Modulation," *Patent Publication* # WO 2008/032264 A2.

ULTRA LONG LIFE MECHANICAL RF SWITCHES

Prior to developing its mechanical switch product line, Mini-Circuits was a significant purchaser of mechanical switches for use in ATE for internal automated production test facilities. These switches were made using a combination of springs and solenoids, and most operated for less than 1 million cycles or approximately 50 days in the company's production environment. As necessity is the mother of invention, this turnover prompted Mini-Circuits to attempt to design a mechanical switch to address the short operating life, long lead times, and high cost of using commercially available mechanical relay switches.

Based on experience, the design objective was to develop a long life mechanical switch. Mini-Circuits set the following criteria as a means to meet that objective:

TABLE I

MECHANICAL SWITCH RF PERFORMANCE

<table>
<tr><th>Model No.</th><th>Type</th><th>I.L. (dB)</th><th>Isol. (dB)</th><th>VSWR</th><th>RF(1) Power</th></tr>
<tr><td>MSPT2-18XL</td><td>SP2T Reflective</td><td>0.25</td><td rowspan="3">85</td><td rowspan="2">1.2:1</td><td rowspan="3">10 W</td></tr>
<tr><td>MSPT2TA-18XL</td><td>SP2T Absorptive</td><td>0.2</td></tr>
<tr><td>MTS-18XL-B</td><td>Transfer</td><td>0.2</td><td>1.15:1</td></tr>
<tr><td colspan="6">(1) Cold Switching. Hot switching is 100 mW maximum to achieve specified life.</td></tr>
</table>

- Replace the use of springs with magnetics
- Select combinations of materials based upon compatibility and ability to mate with limited wear
- Simplicity of design with the minimum number of components possible
- Cost effectiveness to meet internal and external market demands

RF PERFORMANCE

The development effort of the Mini-Circuits mechanical RF switch has resulted in a number of patents awarded and pending on a design that is free from springs or other tension devices, using solely magnetics for contact movement. Equally important to extended life, the switch is required to meet a minimum standard of RF performance. Mini-Circuits' mechanical RF switches are all broadband switches operating from DC to 18 GHz and meet the RF performance criteria listed in ***Table 1***.

QUALIFICATION TESTING

Over many years, Mini-Circuits designers produced many design iterations. In order to validate these designs a methodology was developed to evaluate the useful life of a mechanical relay switch, starting with defining the criteria for a "failure" of the switch.

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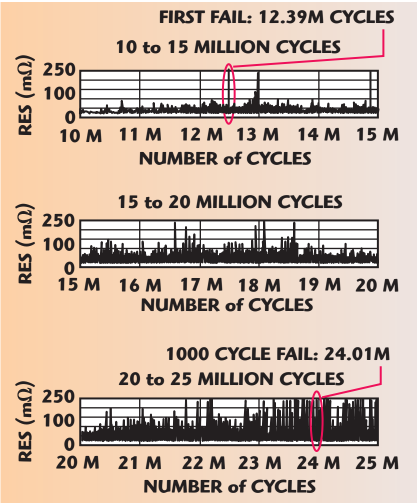
Brooklyn, NY

It was commonly believed that a mechanical switch has "failed" when it fails to switch states (was closed when expected to be open, or open when expected to be closed), i.e. catastrophic failure. Mini-Circuits learned that failure of a mechanical RF switch occurs prior to catastrophic breakdown. Through testing, it was shown that a mechanical switch will actually experience many cycles of degraded performance prior to reaching final catastrophic failure. For practical purposes, in a customers' application, the number of failed switching cycles is a more meaningful criteria for determining the "failure" of a mechanical switch. For example, many commercially available mechanical switches are specified at one-million cycle life expectancy; however, Mini-Circuits has seen that these switches often exhibit failed performance starting at 800,000 cycles. In a test environment, every failed switch cycle can mean rejecting a good DUT.



▲ *Fig. 1 Contact resistance vs. number of cycles.*

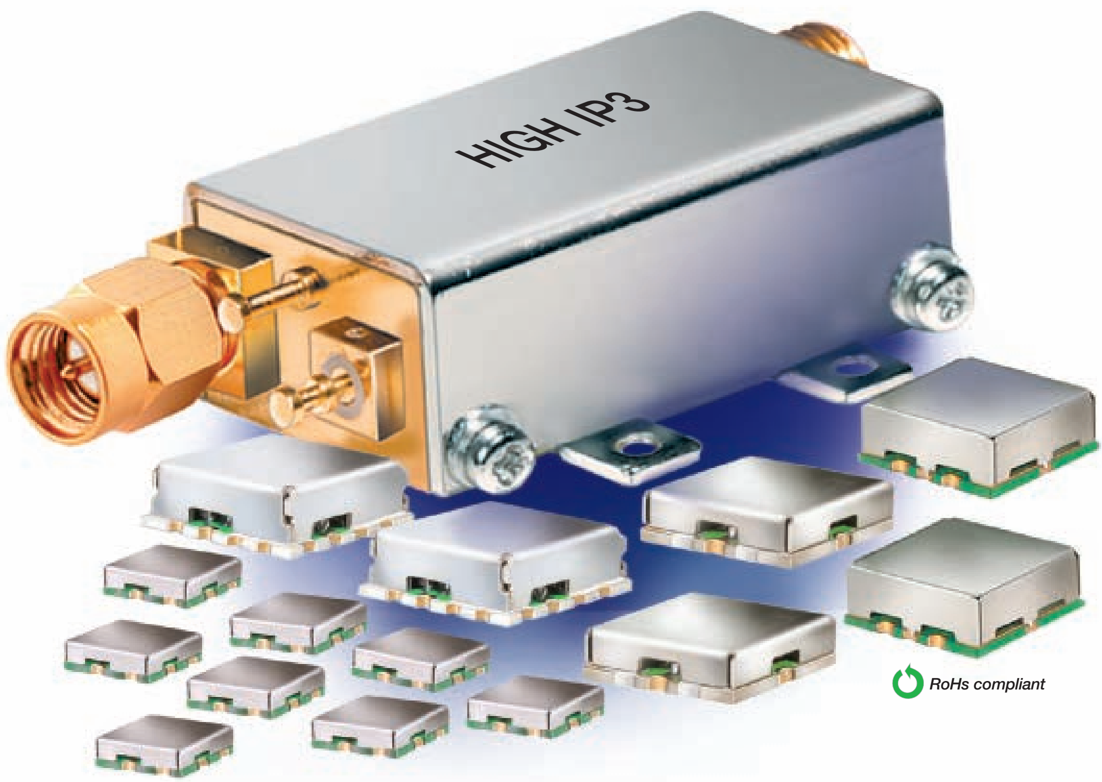
As a result, Mini-Circuits defines "Life Test Failure" as an accumulation of individual switch cycle performance failures. The pass criterion for any one performance-cycle is a closed-switch-state that measures DC resistance less than 240 milliohms, which is equivalent to an increase in RF insertion loss at low frequencies of 0.021 dB. The Mini-Circuits criterion for Mechanical Switch Life Test is that the switch must pass two sets of conditions validating both short-term and long-term failures: First 10 cumulative cycle failures occurs after 5 million total switch cycles (equals 2 DPPM) and Cumulative of 1000 cycle failures occurs after 10 million total switch cycles (see ***Figure 1***).

In addition to Life Test, another critical criterion is operation in Sleep Mode. Sleep testing validates the ability of a mechanical switch to remain in a fixed state for an extended period of time, and still switch reliably to another state when energized. This parameter is a result of applications where mechanical relay switches are used to switch-in redundant paths in the event of a failure in the main path (see ***Figure 2***).

Mini-Circuits continues to test switches in this mode of operation. Sets of switches were stored in a laboratory environment and in a fixed state over a period of four years. At specific intervals, switches were removed and tested for their ability to "switch" after the period of inactivity. All switches operated successfully the first time they were energized, including those energized after being dormant for four years.

SWITCH TUNE-UP

Even though the life of the Mini-Circuits switches is



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greater than any other switch on the market today, the switches will fail at some point. However, their unique construction makes it very practical to service the switch by cleaning the contact assembly enabling switch performance recovery for extending the switch life to well over 100 million cycles. Mini-Circuits also validated the effectiveness of the "tune-up" on the mechanical switches, subjecting switches to extended life testing with "tune-ups" after any switch reached 1000 cumulative failed switch cycles. The company has achieved total switch life cycle of greater than 300 million cycles (see ***Table 2***).

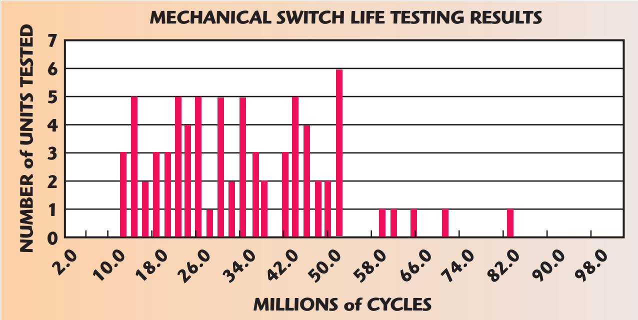
TABLE II

EXTENDED LIFE TEST RESULTS

Unit No.	No. Cycles Achieved	No. Tune-ups Req.'d
1	336 Million	23
2	336 Million	17
3	306 Million	29
4	339 Million	21
5	339 Million	20

PRODUCTION LIFE TESTING

It is a Mini-Circuits internal quality requirement that each production lot of mechanical RF switches be subjected to sample life testing prior to Lot Acceptance. On each production lot, a minimum of two switches are randomly selected and subjected to the same DC life test as outlined above. All units are required to pass the First Failure and the Cumulative Failure criteria for lot acceptance. Data is recorded on all production lots; ***Figure 2*** represents the distribution of switch cycle-count at which 1000 Cumulative Cycles occurred for each of the 75 switches.



▲ *Fig. 2 Production test results: Switch 1000 cumulative switch-cycle failures.*

CONCLUSION

Through a unique design approach, Mini-Circuits has developed and validated a new design concept for mechanical RF switches that, for all practical purposes, do not wear out and have a lifetime far exceeding switches commercially available on the market today. They have demonstrated ability to be used in excess of 300 million cycles with periodic tune-up, meeting all electrical performance as outlined in the catalog datasheet.

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V560ME09-LF	400-800	0.4-4.6	-102
V500ME01-LF	500-1000	0.8-13.5	-96
V585ME73-LF	600-1200	0-13	-100
V585ME30-LF	800-1600	1-21	-103
V585ME46-LF	1000-2000	1-20	-100
V600ME10-LF	1600-3200	0.5-20	-89
V600ME14-LF	2000-4000	0-24	-89

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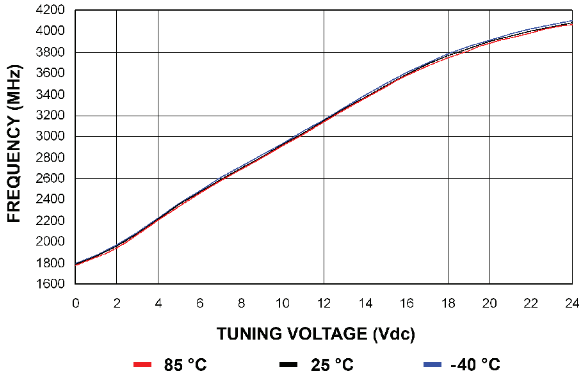

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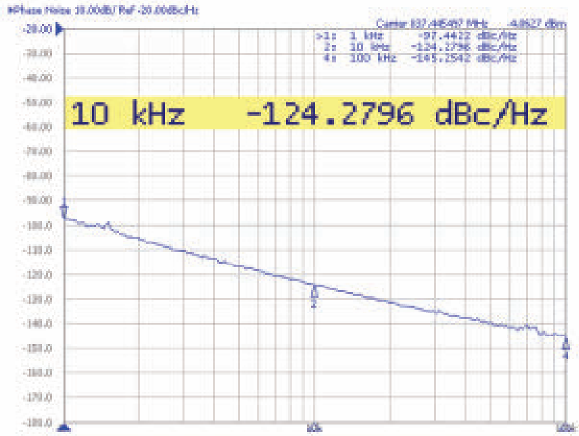
CRO0410A-LF	390-430	0.5-4.5	-117
CLV0625B-LF	540-710	0.5-11.5	-114
ZRO0833A1LF	826-841	0.3-4.7	-122
ZRO1560A1LF	1560-1560	0-5	-121
CRO1900B-LF	1898-1902	0.5-4.5	-121
CRO2065B-LF	2005-2065	0.5-4.5	-112
CRO2542A-LF	2545-2560	0.5-4.5	-115
CRO3344A-LF	3339-3349	0.5-4.5	-115

ZRO0833A1LF (826 - 841 MHz)



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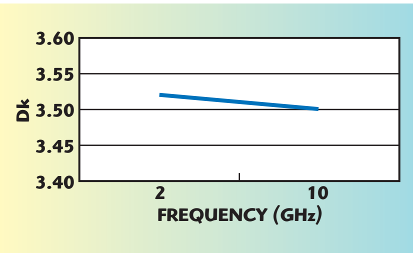
The Mercurywave 9350 laminate and prepregs have well controlled electrical properties with a Dk of 3.5 at 10 GHz by stripline. ***Figure 1*** shows Dk versus frequency from 2 to 10 GHz demonstrating stability across the entire frequency range. It has a Df of 0.004 at 10 GHz by stripline; ***Figure 2*** shows stable Df across the same 2 to 10 GHz frequency range. This electrical performance is also stable over temperature from -40° to 80°C, as shown in ***Figure 3***, and at 24 hr humidity saturation testing from 25 to 85 percent RH, as shown in ***Figure 4***.



▲ *Fig. 1 Dk vs. frequency by stripline.*

The thermal and mechanical properties are also advantageous for RF and microwave applications. Mercurywave 9350 has a high Tg of greater than 200°C by Dynamic Mechanical Analysis (DMA) and low coefficient of thermal expansion (CTE) of 2.5 percent from 50° to 260°C. The CTE in the X/Y direction is 10-14 ppm/°C from -40° to 125°C. The low Z-axis CTE provides excellent plated through hole quality even under extreme temperature changes. It is compatible with lead free processing withstanding multiple 260°C reflows. Mercurywave 9350 has a high peel strength of 7 lbs/in (1.23 N/mm) using Reverse Treated Foil copper for adhesion and which also provides for a very low loss contribution by the copper. It is compatible with alternative oxide and ENIG/immersion tin plating chemistries. Mercurywave 9350 does not require any special fabrication techniques or special surface roughness requirement for solder mask adhesion. Standard hole wall preparation can be used as no sodium etchant or plasma treatment is needed. The material is capable of v-score singulation and meets/exceeds IPC 4103/11

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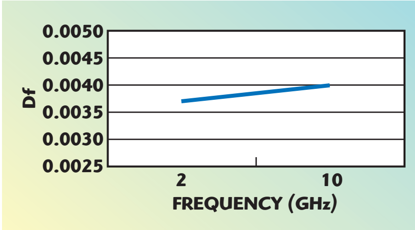


Fig. 2 Df vs. frequency by stripline.

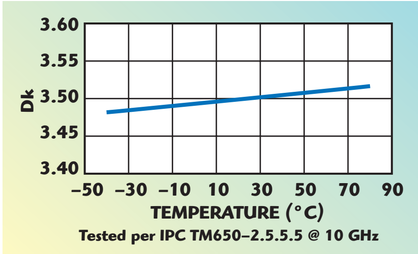


Fig. 3 Dk vs. temperature.

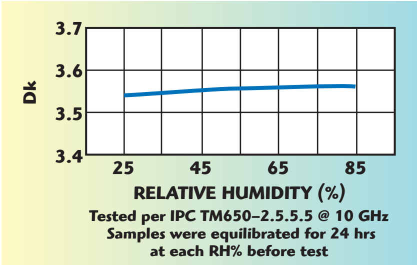


Fig. 4 Dk vs. humidity @ 25°C.

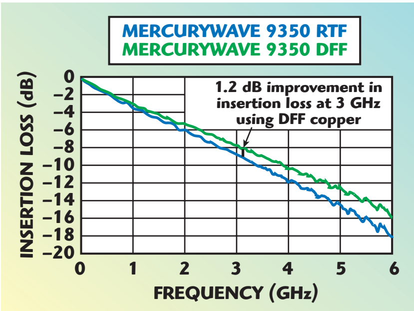


Fig. 5 130" meanderline trace comparison (insertion loss) of WiMAX antenna application operating at 3 GHz.

electrical and mechanical requirements. ***Table 1*** summarizes its thermal properties.

Mercurywave 9350 RTF has better insertion loss than competing materials. ***Figure 5*** shows the insertion loss versus frequency for a 130" meanderline trace comparison for a WiMAX antenna application operating at 3 GHz. The Mercurywave 9350 RTF shows a 1.2 dB improvement in insertion loss at 3 GHz over Mercurywave 9350 using DFF (Dual Flat Foil). It also has the capability to flow and fill

TABLE I

MERCURYWAVE 9350 THERMAL PROPERTIES

Property	Mercurywave™ 9350
Tg (DMA)	≥200°C*
Td (TGA)	360°C
T_{260}	200 min.
T_{288}	40 min.
T_{300}	18 min.
Solder Float (4" x 4" Cu Clad 288°C time to failure)	>600 sec.
Pressure Cooker (1 hr.)	
Moisture Gain	0.15%
Solder Dip (288°C)	>600 sec.

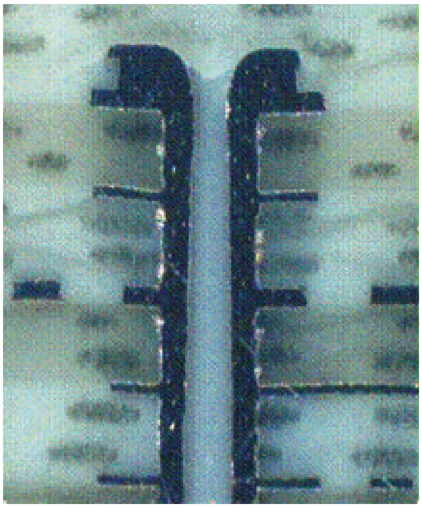


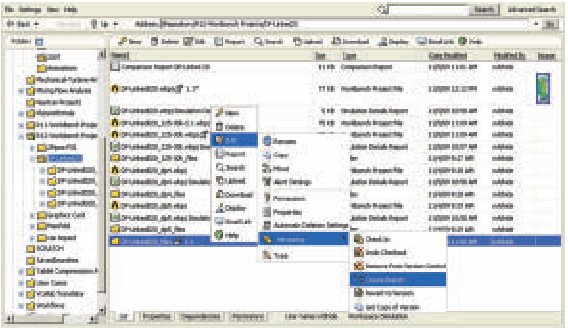
Fig. 6 Buried via cross-section.

PCBs requiring buried via designs (see ***Figure 6***).

Mercurywave 9350 is available in a range of core thicknesses of 0.003" (0.076 mm) and up. Multiple panel sizes are available and prepregs for multilayer lamination (106 and 1080 prepregs). Potential applications include various base station equipment (PAs, filters, combiners, etc.), automotive (radar, communications, road tolling), satellite communications (LNBs, LNAs, GPS), military (communications, guidance systems, radar) and broadband antennas (WiFi, WiMAX, RFID, LANs).

Park Electrochemical Corp., Melville, NY (631) 465-3600, www.parkelectro.com.

RS No. 302

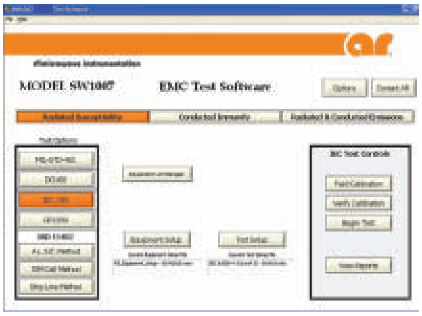


SIMULATION SOFTWARE

VENDORVIEW

ANSYS Inc. announced the release of ANSYS® Engineering Knowledge Manager™ (ANSYS® EKM™) 2.0, a product focused on simulation process and data management (SPDM). The solution set addresses some real-world challenges that engineers face, such as how to better manage, share and reuse simulation data as well as how to capture the engineering expertise that a simulation result represents. ANSYS EKM 2.0 offers a number of significant enhancements that simplify and speed up work, especially for remote teams that hand off data to each other as part of collaborative design. By managing simulation data and processes using ANSYS EKM technology, companies can more effectively leverage the full power of simulation. The ultimate result is shortened time to market and protection of valuable intellectual property.

ANSYS Inc., Southpointe, PA (724) 746-3304, www.ansys.com.
RS No. 310



SOFTWARE FOR COMPLIANT TESTING

VENDORVIEW

AR's SW1007 software is a standalone program that combines conducted immunity test software and radiated susceptibility test software into one user-friendly package suitable for corporate to professional test lab users. The software automatically performs both calibration and immunity testing in full compliance with IEC 61000-4-3, 4-6; MIL STD 461/462 RS103, CS114 and RTCA/DO160 Section 20 specifications. The new version has an updated user interface including a tab system and organizes all the features for quick, easy access and makes selecting test standards much easier. The SW1007 also has the ability to control more equipment and the report generating feature has been enhanced to offer more control and customization.

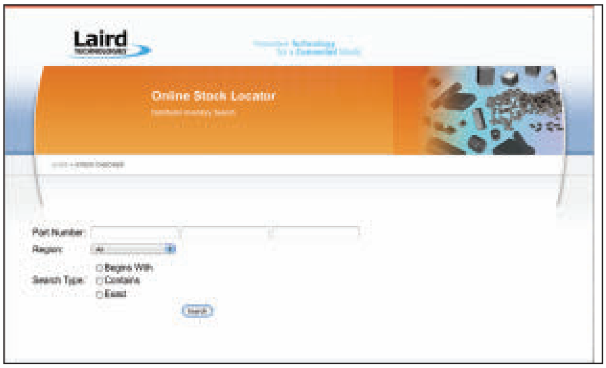
AR RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181, www.ar-worldwide.com.
RS No. 311

SERIAL/PARALLEL USB DESIGNER'S KIT

VENDORVIEW

The HMC-DK008 Serial/Parallel USB Interface Designer's kit provides a user friendly interface for programming Hittite's family of digital attenuators and variable gain amplifiers. This kit allows the designer to set desired attenuation and gain states, toggle between serial and parallel control modes, and construct custom serially clocked input signals. The HMC-DK008 Designer's Kit includes a Serial/Parallel USB Interface Board, custom USB and ribbon cable assemblies, and software CD-ROM.

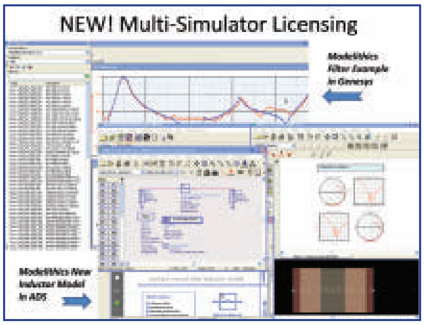
Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343,
www.hittite.com.
RS No. 312



ANTENNA STOCK LOCATOR

This recently launched online antenna stock locator system provides Laird Technologies' customers an electronic platform to directly access qualified distributors and their available inventory through the Lairdtech.com website. Laird Technologies' online users now have a single destination to search the antenna inventory of several select distributors at the same time. The system can identify all Laird Technologies IAS products, which includes Land Mobile Radio – LMR (Portable, Vehicular, Base Station), Broadband Wireless Access – BWA (WiMAX, WISP and Cellular), Wireless LAN – WLAN, and Radio Frequency Identification – RFID applications based on partial or entire part numbers, as well as by global region of availability. These indicators make it simple and easy for users to pinpoint which distributor can best fit their needs.

Laird Technologies Inc.,
St. Louis, MO (847) 839-6907, www.lairdtech.com.
RS No. 313



PASSIVE COMPONENT LIBRARY

Modelithics announced the release of its latest version (v 6.1) of the Modelithics® CLR Library™ of reliably accurate and highly scalable models for all currently supported simulators. This expanded collection of well-documented substrate and part-value scalable capacitor, resistor and inductor families from popular vendors like Johanson Technology, ATC, Murata, Coilcraft, Kemet, Panasonic, Samsung, TDK and Darfon broadens the design engineers' options for using microwave circuit simulation tools to increase design efficiency and decrease design costs. With this v 6.1 release, Modelithics announces a new multi-simulator license option for customers who possess more than one circuit simulator.

Modelithics Inc.,
Tampa, FL (888) 359-3659,
www.modelithics.com.
RS No. 314

ONLINE DESIGN TOOL

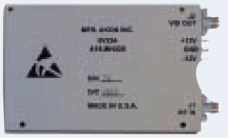
VENDORVIEW

The High Performance Foams Division of Rogers Corp. has created an online design guide that helps designers select the proper Rogers BISCO® Silicones for use in railcar floating floor designs and systems. Use of the Floating Floor Online Design Guide will assist transportation engineers and designers in quickly evaluating options for materials that meet their specific design needs. When using the Floating Floor Online Design Guide designers proceed through four quick steps (there are options for both metric and English units). With the calculations entered, the designer then receives the results as well as different options to laying out the proper BISCO material. To use the Online Design Guide go to www.rogerscorp.com/hpf/tools/floatingfloor.

Rogers Corp., Carol Stream, IL (630) 784-6200,
www.rogerscorp.com.
RS No. 315

High Speed SDLAs

VENDORVIEW



AKON's series of high speed SDLAs, log components offer SDLA performance with ERDLVA accuracy. Absolute accuracies of ±3.0 dB over frequency, temperature and power can be offered over an extended range of 0.5 to 18 GHz, while resulting in 10 ns of propagation delay, 10 ns rise time and 60 ns recovery time. Units covering 0.5 to 2.0 GHz (A15-MH226), 2.0 to 6.0 GHz (A15-MH227), 6.0 to 18.0 GHz (A15-MH228) and 2.0 to 18.0 GHz (A15-MH225) are available in packaging as small as 3.5" × 2.6" × 0.5".

AKON Inc.,
San Jose, CA (408) 432-8039,
www.akoninc.com.

RS No. 216

RMS Power Detector

ADI announced the expansion of its TruPwr™ RF power detector product family with the introduction of a new integrated device for 3G and 4G mobile terminals. The ADL5504 is a highly accurate, easy-to-use means of determining the RMS (root mean square) power of complex waveforms. It can be used for power measurements of both simple and complex waveforms and is particularly useful for measuring high crest factor (high peak-to-RMS ratio) signals, such as W-CDMA, CDMA2000, WiMAX, WLAN and LTE waveforms. It is also effective for optimizing the performance of linear power amplifiers.

Analog Devices Inc.,
Norwood, MA (781) 329-4700,
www.analog.com.

RS No. 217

Push-lock SMB Connectors

The SMB connector is a follow-on design to the SMA and features a smaller interface with a snap-on coupling. For high vibration environments, the two pound minimum disengagement force of the standard SMB design is not sufficient. Aviel has added a push-lock feature to the standard MIL-STD-348 snap-on coupling SMB design. That increases the disengagement force to a minimum of five pounds. A locking shell pushes over the mated interfaces, locking the interface while allowing full rotation of the mated pair. Pulling back the shell allows the interfaces to be disengaged. The mating pairs include a right angle plug with crimp attachment for RG-174U cable. The jack interface is designed for standard PC board and bulkhead mounting. Connectors are hermetically sealed and meet the IP68 immersion test.

Aviel Electronics,
Las Vegas, NV (877) 805-7381,
www.avielelectronics.com.

RS No. 218

RF Coaxial Cable Assemblies

This new line of low-loss RF coaxial cable assemblies features rugged stainless-steel solder-clamp construction and attenuation of 0.36 dB/ft. at 18 GHz. The LL142 Series cable offers shielding effectiveness of greater than -110 dB with an operating temperature range of -55° to +85°C (extended range of -55° to +125°C available through special order). The LL142 Series cable offers a minimum bend radius of 0.8" and is available in-stock with SMA Male to SMA Male connectors, as well as Type N and TNC connectors. Crystek's stocking distributors also support a large variety of RG174 and RG316DS cables in a variety of configurations.

Crystek Corp.,
Fort Myers, FL (239) 561-3311,
www.crystek.com.

RS No. 219

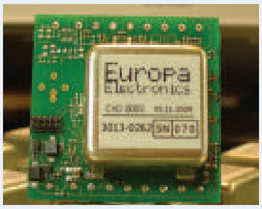
Frequency Synthesizer

The MBS-8000 is a frequency synthesizer that operates as a broadband RF signal generator from 500 to 8000 MHz. The unit is capable of 100 kHz step size, < 10 mSec switch speed, and utilizes a 10 MHz external or internal reference. The MBS-8000 operates on +5 VDC at 230 mA, and features +7 dBm output power, low phase noise (<- 95 dBc/Hz at 100 kHz, Fout=8 GHz), from -30° to +70°C. Low spurs and harmonics are additional features of the MBS. The MBS is small (3.5" × 2.5" × 0.6") and has female SMA connectors on the reference and RF I/O ports.

EM Research Inc.,
Reno, NV (775) 345-2411,
www.emresearch.com.

RS No. 220

Crystal Oscillator



The COLD Series (MCXO) is a new crystal oscillator digitally compensated by ARM that offers instant switch on with low DC power. The frequency source technology provides full performance at switch on, no warm up time is required to stabilise the signal, and power consumption is only 50 mW. The features of low power consumption, extended temperature range and instantaneous operation make it suitable for applications in industrial electronics, instrumentation, radio communications, aerospace, synchronisation and defence.

Europa Electronics,
Châlons en Champagne, France
+33 6 24 73 75 80,
sales@europa-electronics.com.

RS No. 221

Integrated Voltage-controlled Oscillator

VENDORVIEW

These eight new SMT packaged PLLs with integrated RF voltage-controlled oscillators (VCO) are ideal for cellular infrastructure, broadband, LTE/4G and test equipment applications from 660 MHz to 5.1 GHz. The HMC824LP6CE, HMC826LP6CE, HMC828LP6CE, HMC831LP6CE and HMC836LP6CE are SiGe BiCMOS PLLs with integrated VCOs that provide output frequency coverage from 780 MHz to 3.7 GHz. Across the line, SSB phase noise is as low as -120 dBc/Hz at 10 kHz offset, with output power levels of up to +12 dBm. Also released are three new SiGe BiCMOS PLLs with integrated VCO RFICs that feature tri-band outputs.

Hittite Microwave Corp.,
Chelmsford, MA (978) 250-3343,
www.hittite.com.

RS No. 222

Directional Couplers

Models 100404010 and 100404020 are directional couplers that operate in a frequency range from 0.4 to 4 GHz. Coupling (with respect to output) is 10 ± 0.5 dB, 20 ± 0.8 dB and frequency sensitivity is ±0.5 dB. These directional couplers offer directivity of > 16 dB, > 25 dB, maximum VSWR (any port) of 1.2; insertion loss of < 1.1 dB, < 0.75 dB; and maximum power rating (input) of 20 W average, 3 kW peak. Standard connectors are SMA Female and the couplers' operating temperature is -54° to +85°C. Delivery: stock to 30 days. Unit may be manufactured to meet military specifications.

Krytar,
Sunnyvale, CA (877) 734-5999,
www.krytar.com.

RS No. 223

700/850 MHz Diplexer

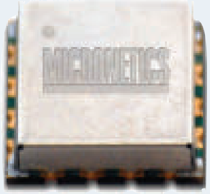
Microlab announced a new 700/850 MHz diplexer, designed to separate and combine the new 700 MHz LTE band and 850 MHz cellular bands. Tuned cavities provide in excess of 50 dB isolation between bands, sufficient for most indoor diplexer applications, such as sharing a common antenna or distributed antenna system. Its modest size also makes the unit very suitable in Neutral Host Combiner Boxes. The low band extends from 698 to 793 MHz, incorporating all the new proposed 700 MHz bands and the 850 MHz band, 824 to 894 MHz, which includes the most common CDMA/cellular bands and the GSM-850 band. Both inputs are rated up to 100 W input power.

Microlab/FXR,
Parsippany, NJ (973) 386-9696,
www.microlab.fxr.com.

RS No. 252

New Waves

Voltage-controlled Oscillator



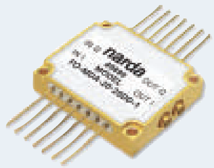
The MW500-1841 1/2" SMT voltage-controlled oscillator (VCO) operates in a frequency range of 2150 to 2370 MHz from 0.2 to 4.8 V tuning while using a 5 V supply. Phase noise at 10 kHz is -98 dBc/Hz. Output power is +8 dBm ±1.5 dBm across the band over temperature while using less than 40 mA of current.

Micronetics Inc.,
Hudson, NH (603) 546-4167,
www.micronetics.com.

RS No. 224

Modulator Driver

VENDORVIEW



Model FO-MDA-20-25DD-1 is a dual-channel DQPSK modulator driver for 40 and 100 Gb/s optical transponder applications that has been tested at data rates as high as 113 Gb/s, demonstrating excellent performance even at the highest data rates. The FO-MDA-20-25DD-1 is designed to interface with a Sierra Monolithics SMI 4025 DQPSK multiplexer/clock multiplier unit on the input and an Avanex Mach-Zehnder lithium-niobate MZ DQPSK modulator at its output. However, other models are available with a different pitch of its output connectors so the unit can also be specified for other modulators, including those from Fujitsu. It integrates a separate channel for I and Q signals within its 36 × 28 × 8 mm package and uses GPPO connectors.

Narda,
Hauppauge, NY (631) 231-1700,
www.nardamicrowave.com/east.

RS No. 225

Two-way Power Divider

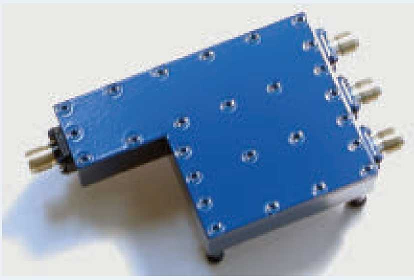
PS2-52-450/8S covers the frequency range of 5 to 40 GHz with 2.2 dB insertion loss, 13 dB isolation and 1.90:1 maximum VSWR. Amplitude and phase balance are 0.8 dB and ±10 degrees, respectively. Power rating is 1 W and 2.92 female connectors are utilized.

Pulsar Microwave,
Clifton, NJ (973) 779-6262,
www.pulsarmicrowave.com.

RS No. 226

VHF LC Triplexer

VENDORVIEW



Reactel part number 3TP-86/198-11 is a VHF LC triplexer. This unit exhibits low loss and high isolation as it splits the VHF band into 30 to 88, 100 to 172 and 225 to 400 MHz channels. This unit has a high power option and can be outfitted with most any RF connector. Please contact the factory for this or any other filter requirement that you have.

Reactel Inc.,
Gaithersburg, MD (301) 519-3660,
www.reactel.com.

RS No. 228

Coaxial to Waveguide Adapters

RLC Electronics now offers coaxial to waveguide adapters in a variety of configurations for specific applications. Option A includes broadband adapters whose excellent electrical specs are maintained over the entire adapter bandwidth. Option B offers enhanced performance over a specific band of the adapters' bandwidth. Computer design and the latest in RF techniques coupled with precision assembly ensure optimal electrical performance in the recommended frequency ranges.

RLC Electronics Inc.,
Mount Kisco, NY (914) 241-1334,
www.rlcelectronics.com.

RS No. 229

Coaxial Rotary Joints

Sage Laboratories Inc. offers a standard line of coaxial rotary joints suitable for use in commercial, military and medical equipment applications. All of the standard products are available from stock. Also, an extensive library of custom and modified designs exists at Sage from years of solving customer needs. Sage will search its library or develop a custom solution that meets your needs. The company's catalog product family features units covering DC to 40 GHz. A variety of connector types, orientation and mounting configurations are available.

Sage Laboratories,
Hudson, NH
(603) 459-1600,
www.sagelabs.com.

RS No. 230

Ultra-high Temperature Crystal Oscillator

The PX-420 crystal oscillator is a new solution for the timing of ultra high-temperature electronics. Able to withstand continuous operating temperatures of up to 250ºC, the product is ideal for harsh environment applications, including oil and gas downhole operations. With the PX-420, Vectron successfully combines its advanced quartz resonator design for outstanding frequency stability with silicon on insulator (SOI) technology to meet the high-reliability requirements demanded by these harsh environment applications. Design engineers now have a solution for applications requiring continuous, high-reliability operation at temperatures ranging from -55° to 250°C. The unique compliant quartz resonator mounting scheme also provides high shock and vibration resistance.

Vectron International,
Hudson, NH
(888) 328-7661,
www.vectron.com.

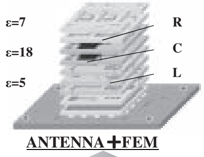
RS No. 231

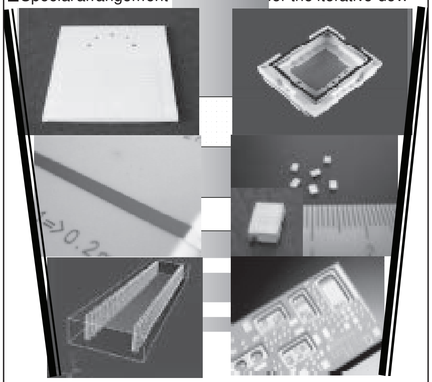
Voltage-controlled Oscillator

The model ZRO2407A1LF is an RoHS compliant voltage-controlled oscillator (VCO) in S-band. The ZRO2407A1LF operates at 2400 to 2415 MHz with a tuning voltage range of 0.5 to 4.5 VDC. This VCO features a typical phase noise of -115 dBc/Hz at 10 kHz offset and a typical tuning sensitivity of 14 MHz/V. The ZRO2407A1LF is designed to deliver a typical output power of 3 dBm at 5 VDC supply while drawing 21 mA (typical) over the temperature range of -40° to 85°C. This VCO features typical second harmonic suppression of -18 dBc and comes in Z-Comm's standard MINI-16-SM package measuring 0.5" × 0.5" × 0.22".

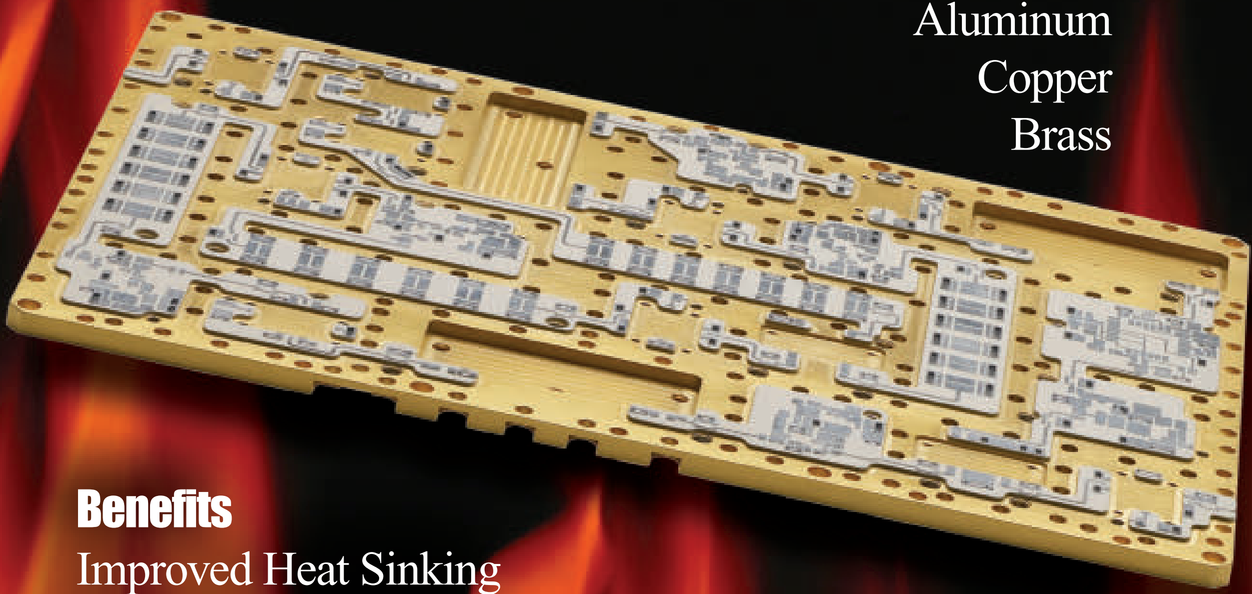
Z-Communications Inc.,
San Diego, CA
(858) 621-2700,
www.zcomm.com.

RS No. 232





Beat the Heat!



Backing Materials
Aluminum
Copper
Brass

Benefits
Improved Heat Sinking
Dimensional Stability
Easier Component Mounting
Improved RF Grounding
Less Assembly Process Time and Better Yields

Metal-Backed Microwave Boards from MCN

When thermal efficiency is critical, choosing a metal-backed board design can provide improved thermal disbursement capabilities for high power applications. The thick metal ground plane can provide a rigid, flat base for component attachment increasing the reliability and durability of your product. At MCN, our 25 plus years of microwave experience has led to the development of proprietary processes to meet your design requirements for high precision performance. An in-house technical support team at MCN will work with you from material selection, design for manufacturing through the assembly process to provide the best solution and value for your board level requirements.

Other Capabilities:
- PTFE Hybrid & Metal Core Multilayers
- Precision Laser Cutting
- Conductive Epoxy Attachment

MCN
Modular Components National

105 E. Jarrettsville Road • PO Box 453 Forest Hill, MD 21050
Tel: 410/879-6553 • Fax: 410/638-7356
www.modularcomp.com

Amplifiers

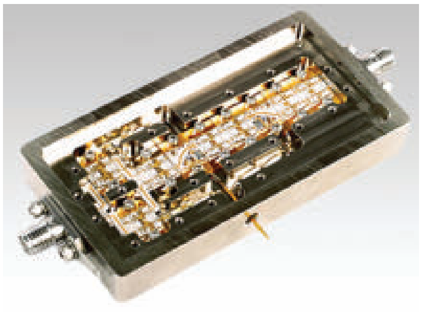
GaN Amplifier

The model SSPA 0.8-2.5-40 is a high power, Gallium Nitride (GaN) amplifier that operates from 800 to 2500 MHz minimum and is packaged in a compact, high performance package. This amplifier is designed for operation in harsh environments. Typical output power is 40 W across the band at P3dB. Small-signal gain is 53 to 54 dB across the band typically. Power added efficiency in saturation is typically 30 to 40 percent across the band. Input and output VSWR is 2.0:1 maximum. This unit is equipped with DC switching circuitry that enables and disables the RF devices inside the amplifier in 3500 ns typical for turn on and 1600 ns typical for turn off time.

Aethercomm Inc.,
Carlsbad, CA (760) 208-6002,
www.aethercomm.com.

RS No. 233

3 W Amplifier



AML announced the immediate availability of a high power broadband amplifier model AML618P4202. This amplifier operates over 6 to 18 GHz with industry-leading DC to RF efficiency. Output P1dB is +35 dBm (3 W) minimum. Gain is 42 dB minimum with flatness within ±2.5 dB maximum. DC current at +12 VDC is under 2.5A. Dimensions are 2.85"L × 1.5"W × 0.5"H.

AML Communications Inc.,
Camarillo, CA
(805) 388-1345,
www.amlj.com.

RS No. 234

Solid-state Amplifiers

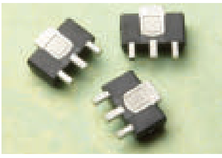
VENDORVIEW

AR RF/Microwave Instrumentation has introduced a family of new solid-state amplifiers that are more compact, more efficient and more powerful than previous models. The new "S" Series covers 0.8 to 4.2 GHz and powers up to 800 W. These models employ a new design that delivers more than twice the power of older models. With these improvements, AR has maintained the superior rugged design for mismatch tolerance and excellent linearity.

AR RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181,
www.ar-worldwide.com.

RS No. 253

DC to 80 GHz TWA



The AMMC-5025 is claimed to be the first ultra-broadband traveling wave amplifier (TWA) for high-speed digital communications applications that operate in the 30 kHz to 80 GHz frequency band. Aimed at microwave radio systems and satellite VSAT applications, the amplifier measures 1.6 mm by 1.0 mm and provides 8 dB of small-signal gain and gain flatness of ±0.7 dB, along with better than 10 dB input and output return loss. Suitable for instrumentation and MMIC applications, the AMMC-5025 is ideal for use in test and measurement equipment, radar warning receivers, wideband communications and surveillance systems, and point-to-point radios.

Avago Technologies,
Wetzlar, Germany +49 6441 92460,
info@promotionteam.de, www.avagotech.com.

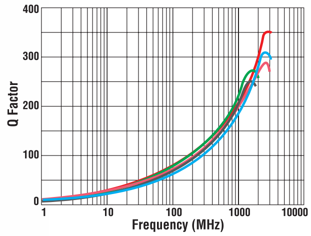
RS No. 235

More Q. Less Cu

29
Copper
63.546

These tiny new air core inductors have the highest Q and current handling in the smallest footprint.

Coilcraft's new SQ air core inductors have unmatched Q factors: most are above 200 in the 1-2 GHz range! That's 3 times higher than comparably sized 0805 chip coils.

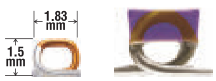


Q factors are 3X higher than standard chip inductors

And with their extremely low DCR, they can handle 4 to 8 times more current: up to 4.4 Arms.

SQ air core inductors are perfect for your LC filter and RF impedance matching applications. They come in 15 values ranging from 6 to 27.3 nH, all with 5% tolerance.

These coils are significantly smaller than existing air core inductors. We reduced the footprint by using close-wound construction and keeping the leads close to the body. The square shape cuts the height to as low as 1.5 mm and creates flat top and bottom surfaces for easy automated handling and stable mounting.



The square shape and narrow footprint reduce board space by 60-75% over conventional air core inductors.

See how the ultra-high Q and current handling of Coilcraft's new SQ air core inductors can maximize the performance of your next design. For complete specifications and free evaluation samples, visit **www.coilcraft.com/sq**

Coilcraft®

www.coilcraft.com 800/322-2645

Visit http://mwj.hotims.com/28485-20 or use RS# 20 at www.mwjournal.com/info

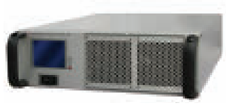
Solid-state Power Amplifier

The model BHE25869-50 is a solid-state Class "AB" linear amplifier that operates over the full 2500 to 6000 MHz frequency band and delivers a minimum of 50 W. The amplifier uses the latest Gallium Nitride (GaN) technology and is packaged in a standard rack mountable enclosure measuring 19" × 22" × 5.25".

Comtech PST,
Melville, NY (631) 777-8900,
www.comtechpst.com.

RS No. 254

50 W Rugged Amplifier System



The BBS26A8CHM ruggedized amplifier system is Empower's latest in microwave solid-state amplifiers. This compact and lightweight system features high power output and excellent efficiency. The amplifier utilizes high power GaN devices. It fits in standard 19-inch equipment racks, weighs less than 70 lbs and is available with or without touch-screen LCD control, Ethernet connectivity and a full range of other options including 400 Hz aircraft power.

Empower RF Systems Inc.,
Inglewood, CA (310) 412-8100,
www.empowerrf.com.

RS No. 236

Power Amplifier

The MSD-1698904 is a power amplifier that operates in a frequency range from 400 to 500 GHz. The power amplifier offers gain of 40 dB; gain flatness of ±1.0 dB; power out 1 dBm compression point of 46 minimum, 47 dBm typical; current of 6A typical; I/O VSWR of 2.0:1; I/O RF connectors are SMA-F; DC voltage of 28 V; OL: OL-003648; and environment includes MIL, GBNT. This model has an operating temperature of -55° to +85°C. Available with TTL.

Microwave Solutions Inc.,
National City, CA (619) 474-7500,
www.microwavesolutions.com.

RS No. 237

Low Noise Amplifier

VENDORVIEW

The TAMP-1521GLN+ (RoHS compliant) is a 50 ohm low noise amplifier that operates in a frequency range from 1380 to 1520 MHz. This model utilizes advanced E-PHEMT technology in a two-stage low noise amplifier design built into a shielded case (size: 0.591" × 0.394" × 0.118").

The drop-in module offers ultra low noise figure and high gain with good input and output return loss over the entire frequency range and without the need of external matching components. Features include: ultra low noise figure of 0.75 dB typical; high IP3 of 27 dBm typical; high gain of 35 dB typical; and integrated bias matching and stability circuits. Price: $14.95 (Qty. 5-49).

Mini-Circuits,
Brooklyn, NY
(718) 934-4500,
www.minicircuits.com.

RS No. 238

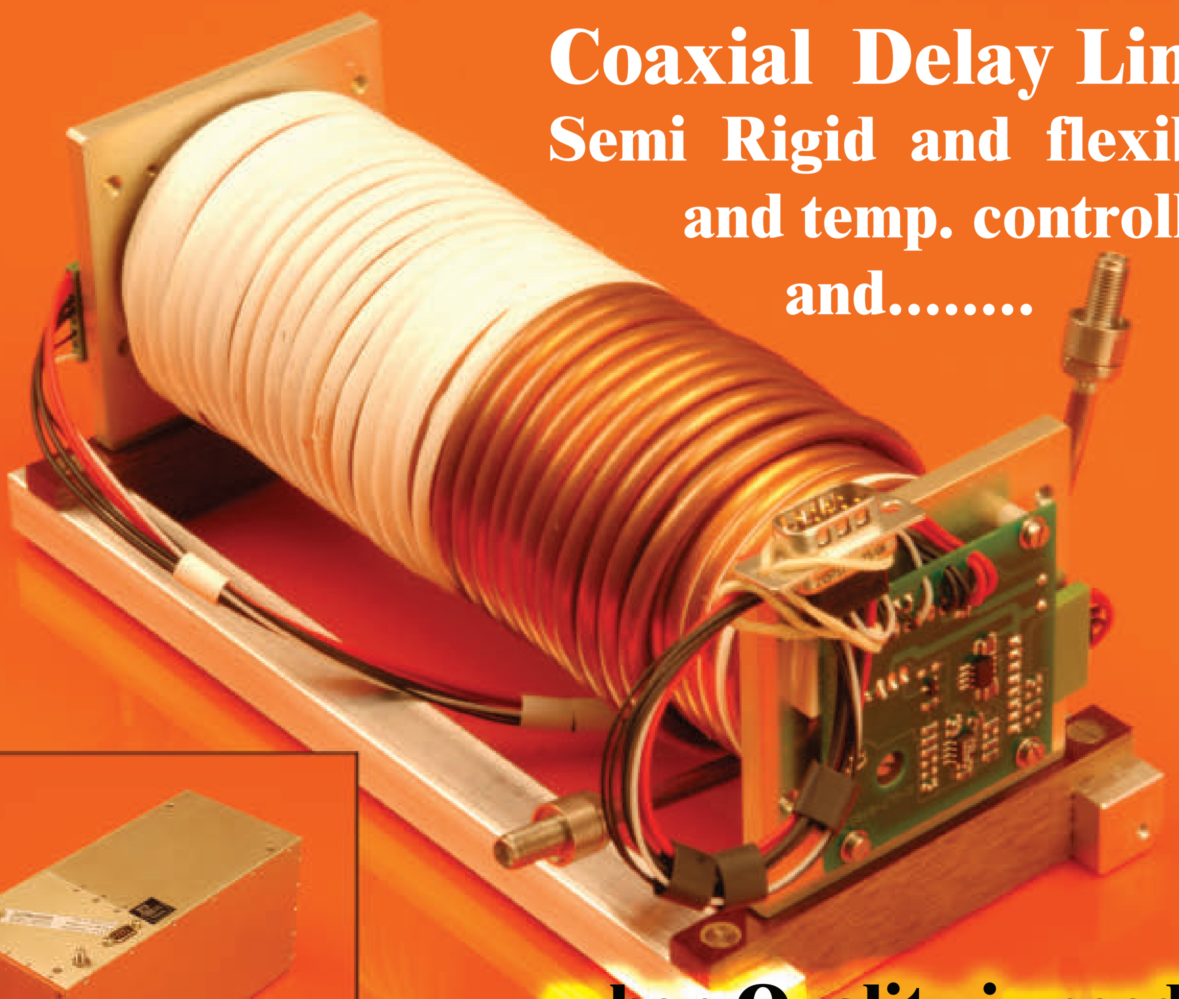
Broadband High Power Amplifier

VENDORVIEW

MITEQ introduces a new addition to its family of broadband high power amplifiers. Model AMF-8B-18002650-70-37P-PS is a self-cooled 3 RU rack-mount high power amplifier, covering 18 to 26.5 GHz and delivering minimum of 5 W of power. The SMA connectorized box is 3.47" high, 16.99" wide excluding brackets, and 12.12" deep including fans. This model can be horizontally or vertically mounted. Housing is EMI shielded, CE certified and can operate in ambient temperature up to 50°C. This power amplifier includes over temperature protection in addition to full internal regulation. A 20 dB output coupled port is optional.

MITEQ Inc.,
Hauppauge, NY
(631) 436-7400,
www.miteq.com.

RS No. 239



NEW PRODUCTS

GaN CATV Amplifier Module

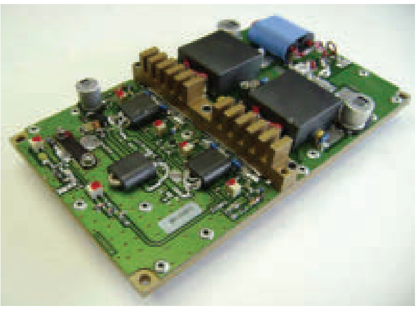
VENDORVIEW

RFMD recently released 'green' gallium nitride (GaN)-based CATV amplifier modules. The D10040200PL1 and D10040230PL1 are designed for use as power doubler amplifiers in current and next generation CATV infrastructure applications. The D10040200PL1 and D10040230PL1 are hybrid power doubler amplifier modules designed to provide the final amplifier stage for CATV trunk amplifiers, line extenders and optical nodes. The parts employ GaAs PHEMT and GaN HEMT die and operate from 45 to 1000 MHz. They provide high output capability, excellent linearity and superior return loss performance with low noise and optimal reliability. With low current and extremely low distortion, the D10040200PL1 and D10040230PL1 are unconditionally stable under all terminations.

RFMD,
Greensboro, NC (336) 664-1233,
www.rfmd.com.

RS No. 240

Broadband Pallet Amplifier



The LD600-10.80 (RES-INGENIUM) is a high performance two-stage Class AB pallet amplifier. It was designed for Industrial, Scientific and Medical (ISM) applications operating with pulsed signals (600 W, 10 percent duty), and for military applications up to 200 W CW. This rugged amplifier, featuring the Freescale™ MRF6V2300NR1 power transistor, achieves 40 dB gain and features gain-flatness of ±1 dB across the HF-VHF band (10 to 80 MHz). It operates from -10° to +60°C. Connectorized versions are available upon request.

Richardson Electronics, LaFox, IL (630) 208-2200, www.rell.com.

RS No. 255

COFDM Power Amplifier

Stealth Microwave introduced the SM7177-43, designed primarily for the European D-ENG market. The unit operates from 7.1 to 7.7 GHz with a P1dB of +43 dBm. Gain is 55 dB with a flatness of ±0.5 dB across the band. Standard features include forward and reflected power detection, TTL On/Off, gain control and an RF sample port. In module form, the unit measures 7.5" × 3.97" × 0.79"; an integral heatsink and fan are also available. This amplifier can also be packaged in lab unit and 19" rack configurations.

Stealth Microwave Inc.,
Ewing, NJ (888) 772-7791,
www.stealthmicrowave.com.

RS No. 241

Ka-band TWT

The TWT TH 4092 is a Ka-band travelling wave tube for SATCOM uplinks that has been designed for large earth-station uplinks and airborne applications. It features a four-stage collector design for an efficiency > 50 percent, has been developed for high linearity and can be either cathode or BFE switched. Operating in Ka-band, the unit offers a typical gain of 46 dB minimum from 27 to 31 GHz and delivers output power up to 500 W peak and 350 W CW. The TWT TH 4092 also features conduction cooling.

Thales Components & Systems,
Paris, France +33 (0) 13070 3500,
www.thalesgroup.com/components-subsystems.

RS No. 242

RFoG Amplifier

TriQuint Semiconductor announced a breakthrough new RFoG amplifier for optical receivers as part of the company's new TriAccess™ line. The new amplifier performs with less than half the equivalent input noise (EIN) of current solutions.

TriQuint Semiconductor Inc.,
Hillsboro, OR (503) 615-9000,
www.triquint.com.

RS No. 243

Material

Soft Seal Foam Material

VENDORVIEW

For use in today's ever smaller and thinner yet far more functional hand-held devices, the High Performance Foams Division of Rogers Corp. has introduced a new addition to the PORON® materials family – PORON® ThinStik™ Soft Seal. PORON ThinStik Soft Seal material is an innovative impact sealing PORON® Urethane gasketing foam with a built-in adhesive layer for enhanced sealing, cushioning and impact resistance. Highly compressible PORON ThinStik Soft Seal is the ideal product for ultra-thin gap filling, combining the most compressible PORON foam with the most compressible PORON construction. ThinStik Soft Seal is ideal for LCD gasketing and sealing needs in gaps as thin as 0.10 mm.

Rogers Corp.,
Woodstock, CT (860) 928-3622,
www.rogerscorp.com.

RS No. 245

Software

Simulation Software

VENDORVIEW

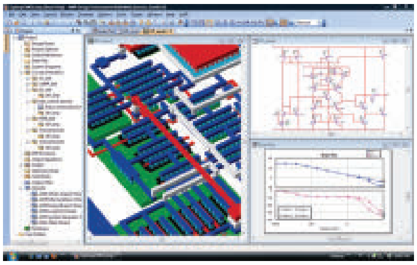
ANSYS Inc. announced the 12.1 release of HFSS™ software, the industry-leading technology for 3-D full-wave electromagnetic field simulation. The product introduces a new integral equation (IE) electromagnetic solver option, which is based on 3-D full-wave method of moments (MoM), that can be implemented in the HFSS desktop. This technology is effective for large-scale radiating and scattering simulation studies. HFSS software helps engineers design, simulate and validate the behavior of complex high-performance RF, microwave and millimeter-wave devices in next-generation wireless devices, defense communication systems and consumer electronics. Users of this latest version of HFSS software can achieve a dramatic reduction in development time and costs while at the same time realizing increased reliability and design optimization.

ANSYS Inc.,
Canonsburg, PA
(724) 746-3304,
www.ansys.com.

RS No. 256

RFIC Design Software

VENDORVIEW



AWR announced Version 2009 of its Analog Office high-frequency analog and RFIC design software. This latest release includes AWR's patent-pending multi-rate harmonic balance (MRHB™) technology, which dramatically increases the speed and reduces the computer memory required to perform steady-state analysis of complex multi-tone designs such as those found in receivers and transmitters with multiple stages of upconversion and downconversion. Analog Office Version 2009 also offers AWR's AXIEM™ 3D planar EM technology, which now supports 64-bit operating systems, multi-core PCs and shape pre-processing algorithms that decrease solution time for complex geometries.

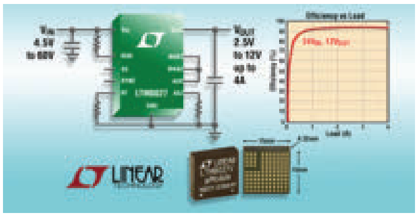
AWR,
El Segundo, CA
(310) 726-3000,
www.awrcorp.com.

RS No. 246

Subsystems

DC/DC µModule Regulator

The LTM8027 is a 4A system-in-a-package DC/DC µModule® regulator capable of operating from a 60 V supply without any input protection. The LTM8027 includes the inductor,



power switches, switching regulator and all support components in a small 2.6g, 15 × 15 × 4.32 mm land grid array (LGA) plastic package. The device can regulate an output voltage ranging from 2.5 to 24 V from an input supply of 4.5 to 60 V (65 V absolute maximum). The LTM8027's rugged voltage rating makes it a suitable voltage regulator for 12 and 24 V automotive and heavy equipment such as industrial robotics, 48 V telecom, as well as avionics and industrial control systems.

Linear Technology Corp.,
Milpitas, CA
(408) 432-1900,
www.linear.com.

RS No. 244

QFN Packaged Receiver

VENDORVIEW

This 27 to 34 GHz QFN packaged receiver offers a noise figure of 2.5 dB and 13 dB conversion gain. The receiver, identified as XR1019-QH, integrates a low noise amplifier (LNA), image reject mixer and LO buffer amplifier within a fully molded 4×4 mm QFN package, making the device easy to install and handle in volume applications. The XR1019-QH is ideal for wireless communications applications such as point-to-point (PTP) microwave radio, LMDS, SATCOM and VSAT.

Mimix Broadband Inc.,
Houston, TX
(281) 988-4600,
www.mimixbroadband.com.

RS No. 247

Signal Processing Assembly

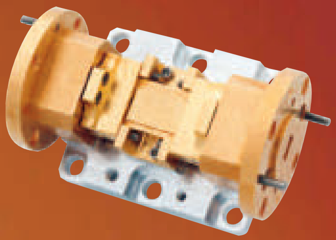
The model RFOC-811-QRC is a new 8 to 11 GHz RF signal processing assembly. The assembly includes three independent subsystems. A total of 29 RF components are integrated in the assembly. Eight voltage-controlled 60 dB PIN diode attenuators and eight fast PIN diode switches (Switch ON/OFF: 50 ns maximum) are used to process the RF signals along different paths of interest. The isolation between the three independent subsystems in the assembly is typically 70 dB. The size of the device is: 8.5"L × 3.9"W × 1.85"H.

Planar Monolithics Industries Inc.,
Frederick, MD
(301) 631-1579,
www.pmi-rf.com.

RS No. 248

MILLIMETER WAVE COMPONENTS

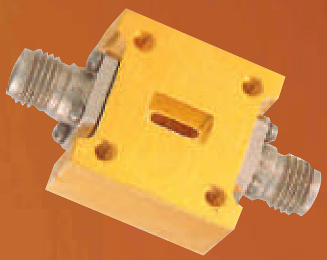
AMPLIFIERS • MIXERS • MULTIPLIERS



AMPLIFIERS

Model Number	Frequency (GHz)	Gain (dB, Min.)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	In/Out VSWR (Max.)	Output Power at 1dB Comp. (dBm, Typ.)
JSW4-18002600-20-5A	18-26	34	1.5	2.0	2.0:1/2.0:1	5
JSW4-26004000-28-5A	26-40	25	2.5	2.8	2.2:1/2.0:1	5
JSW4-18004000-35-5A	18-40	21	2.5	3.5	2.5:1/2.5:1	5
JSW4-33005000-45-5A	33-50	21	2.5	4.5	2.5:1/2.5:1	5
JSW5-40006000-55-0A	40-60	18	2.5	5.5	2.75:1/2.75:1	0

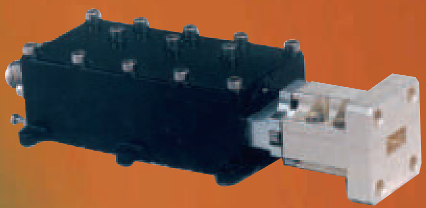
Higher output power options available.



MIXER/CONVERTER PRODUCTS

Model Number	Frequency (GHz)			Conversion Gain/Loss (dB, Typ.)	Noise Figure (dB, Typ.)	Image Rejection (dB, Typ.)	LO-RF Isolation (dB, Typ.)
	RF	LO	IF				
LNB-1826-30	18-26	Internal	2-10	42	2.5	25	45
LNB-2640-40	26-40	Internal	2-16	42	3.5	25	45
IR1826N17*	18-26	18-26	DC-0.5	11	9.5	25	25
IR2640N17*	26-40	26-40	DC-0.5	11	9.5	25	25
SBW3337LG2	33-37	33-37	DC-4	-7.5	8	N/A	25
TB0440LW1	4-40	4-42	.5-20	-10	10.5	N/A	20
DB0440LW1	4-40	4-40	DC-2	-9	9.5	N/A	25
SBE0440LW1	4-40	2-20	DC-1.5	-10	10.5	N/A	20

* For IF frequency options, please contact MITEQ.



MULTIPLIERS

Model Number	Frequency (GHz)		Input Level (dBm, Min.)	Output Power (dBm, Min.)	Fundamental Feed Through Level (dBc, Min.)	DC current @+15VDC (mA, Nom.)
	Input	Output				
MAX2M260400	13-20	26-40	10	10	18	160
MAX2M200380	10-19	20-38	10	10	18	200
MAX2M300500	15-25	30-50	10	10	18	160
MAX4M400480	10-12	40-48	10	10	18	250
MAX3M300300	10	30	10	10	60	160
MAX2M360500	18-25	36-50	10	10	18	160
MAX2M200400	10-20	20-40	10	10	18	160
TD0040LA2	2-20	4-40	10	-3	30	N/A

Higher output power options available.

MITEQ also offers custom designs to meet your specific requirements. For additional information or technical support, please contact our Sales Department at (631) 439-9220 or e-mail components@miteq.com

ISO 9001 ANAB

3 YEAR WARRANTY

MITEQ

100 Davids Drive • Hauppauge, NY 11788
TEL.: (631) 436-7400 • FAX: (631) 436-7430
www.miteq.com

Frequency Distribution Unit

The model 8451A is a Time and Frequency Distribution Unit that specializes in precise reference frequency signal distribution applications ranging from 1 to 20 MHz, ±1 dB and 1 to 30 MHz, ±2 dB. This unit provides an extremely low contributed phase noise floor of -170 dBc as well as high output to output and input to input isolation of > 100 dB at 10 MHz while maintaining low harmonic distortion and spurious measurements. Additional advanced features of model 8451A are single or redundant inputs, with automatic or manual switchover, 12 separately buffered outputs, as well as single or redundant power supplies.

TRAK Microwave,
Tampa, FL
(813) 901-7200,
www.trak.com.

RS No. 249

Test Equipment

LTE Test Capability
VENDORVIEW

Agilent announced an LTE test solution that combines the Agilent 89600 VSA LTE FDD and LTE TDD analysis software with the highest-performance member of the Agilent X-Series, the Agilent N9030A PXA signal analyzer. The PXA provides industry-leading RF performance that supports both LTE FDD and LTE TDD. It delivers up to 140 MHz analysis bandwidth and up to 75 dB of spurious-free dynamic range with typical flatness of ±0.4 dB, making it an ideal solution for 3G, 4G and beyond. LTE Advanced, one of the standards candidates for true 4G mobile broadband systems, will extend LTE to even wider bandwidth, up to 100 MHz, making the PXA an ideal investment for customers transitioning from 3G to 4G.

Agilent Technologies Inc.,
Santa Clara, CA
(800) 829-4444,
www.agilent.com.

RS No. 250

Multi-port Calibration Box

This rapid automatic multi-port calibration box (RapACal) allows an easy and rapid one or multi-port (n-port, n = 1, 2, 3, …) calibration of vector network analyzers (VNA) up to 18 GHz. The calibration is quite simple. The number of ports is unlimited. Only for the calibration:

RapACal will be controlled over VNA-internal PC interface (LAN and USB) with a graphical user interface from a windows operating system (NT, XP, Vista). Price: €5900.

Heuermann HF-Technik GmbH,
Stolberg, Germany
+49 2402/9749764,
www.hhft.de.

RS No. 251

RF Signal Conditioning Modules

National Instruments expanded its automated test product line with two new RF signal conditioning modules that enhance the measurement accuracy and flexibility of PXI-based RF and microwave test systems. In applications such as RF signal path degradation modeling, field strength metering and receiver testing, engineers can combine the new NI PXI-5695 8 GHz programmable RF attenuator with a vector signal generator (VSG) to improve RF signal quality at low power levels. Engineers can integrate the NI PXI-5691 8 GHz programmable RF preamplifier, which also functions as a power amplifier, with VSGs to increase maximum power and with vector signal analyzers (VSA) to measure low-level signals.

National Instruments,
Austin, TX
(800) 258-7022,
www.ni.com.

RS No. 257

China MW 2010
April 13-15 2010
Beijing China

ChinaMW 2010-China`s Premier Microwave and RF Event

2010 China International Exhibition & Forums on Microwave and RF

'Professional, Authoritative, Innovation and Fruitful`, Being the Premier Microwave and RF Exhibition in China, 2010 China International Exhibition and Forums on Microwave and RF (ChinaMW 2010) will be held on April 13-15, in Beijing International Convention Center, Beijing, China. ChinaMW 2010 will be pleased to see World Top Microwave and RF Corporation & suppliers (from US, Canada, Switzerland, France, Germany, Italy, Japan, Singapore, Irland, U.K., Korea, and etc.,) to participate, A great platform and bridge for global cooperation in Microwave and RF fields in China, and Good commercial results & technical cooperation will be definitely expecting and making……

ChinaMW 2010 Orgaznier-China Electrotechnical Society (CES) is the largest national society in China, with 44 national technical institutions, 25 provincial societies, over 50,000 personal members and more than 1500 corporation members from every industry. CES will fully utilize its resources, by using its accumulated customers database and long-term cooperation relationship with industries, to invite good qualified and great quality of Chinese key customers, end-users, purchasing manager and technical professionals to join in the event, that is one of the distinguished highlights of ChinaMW 2010, and great cooperation opportunities for the exhibitors will be beyond your expectation.

ChinaMW 2010 will play an important role in greatly influencing the purchasing decisions of Chinese customers, promoting the Microwave and RF development in China, increasing the Microwave and RF products & technologies imports to China and make.

Together with ChinaMW 2010 Exhibition, CES will host China Microwave and RF High-Tech & Marketing Development Forums; 2010 China Telecommunication Industry, Aerospace & Aviation Industry, and Microwave & RF Technology & Market Development Forums; 2010 Microwave and RF Whole Solutions Seminars, exhibitors & customers meets.

Action now, good prospects, Taking valuable opportunity, Share important microwave and RF market in China!

For details, please contact:

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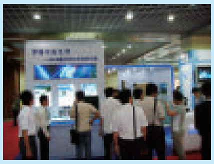
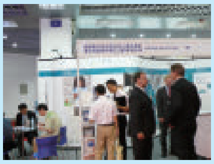
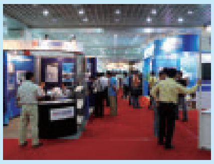
Http://ChinaMW.ces.org.cn; http://www.ces.org.cn








Http://ChinaMW.ces.org.cn

Component Reliability for Electronic Systems

Titu-Marius I. Băjenescu and Marius I. Bâzu

The main reason for the premature breakdown of today's electronic products is the failure of the components used to build these products. To help ensure longer-lasting, more technically sound products and systems, a solid understanding of effective ways to minimize the degradation is essential.

The aim of *Component Reliability for Electronic Systems* is to contribute to the understanding and development of electronic component reliability addressed to people involved in designing, manufacturing and/or testing electronic equipment. From reliability engineers to electrical engineers, anyone involved in the facets of electronics and telecommunications from design to testing would benefit from this book.

The book begins with an introduction offering the link between the reliability of the electronic systems and the electronic components. The first part is dedicated to general issues of reliability engineering, including reliability assembly, assessment, packaging, failure analysis, test and testability.

The second part is focused on specific issues of the reliability of electronic components. Unlike the existing reliability books that are dedicated to one category of components, this book offers in a single source current information about the reliability of all types of electronic components that could be used in electronic systems such as passives, diodes, Si power transistors, optoelectronic components, thyristors, MMICs, microprocessors, hybrids, microsystems/sensors and even nanostructures.

A detailed alphabetical index and a specific bibliography at the end of each chapter complete the picture of the information covered. It is also a practical book bringing together the latest research and industry experience that can be used by students and professors as well as experts and managers in industry. It is a good reference piece and contains comprehensive information on reliability for most types of electronic components.

To order this book, contact:

Artech House
685 Canton St., Norwood, MA 02062
(781) 769-9750 ext. 4030;
or
16 Sussex St., London SW1V 4RW, UK
+44 (0) 20 7596-8750

700 pages; $129, £79
ISBN: 978-1-59693-436-8

2010 INTERNATIONAL MICROWAVE SYMPOSIUM

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THE GOLDEN STATE OF MICROWAVES

Have you seen what WWW.IMS2010.ORG has to offer lately?

If you haven't been to the **IMS2010 website** please take a moment to log on and view updates for the upcoming IMS2010 symposium. The IMS2010 website is a great place to start if you are not familiar with the symposium or local area. Here you can gather **general information** and also learn about **travel** and **lodging** near the Anaheim convention center. We also recommend that you view the **technical** program schedule along with learning more about who is **exhibiting** and how your company can become an **exhibitor.**

Don't forget to mark your **calendars** for two fun-filled hours of networking with **"Microwave & RF" female** colleagues during IMS2010. There is a **Women in Microwave Engineering** (WIM) reception happy hour to be held Tuesday evening at the **Uva Bar** located in Downtown Disney. Check the IMS program for more details.

For those **family** and **guest** of attendees, please be sure to visit the IMS2010 **hospitality suite** which will be located at the Sheraton Hotel. Only a short distance from the Anaheim convention center, we have created a **comfortable setting** where you can meet with friends, grab a snack, **check email** and learn what the local area has to offer. There will also be special activities for the **children**.

We look forward to your attendance and **participation** in the coming year at **IMS2010!**

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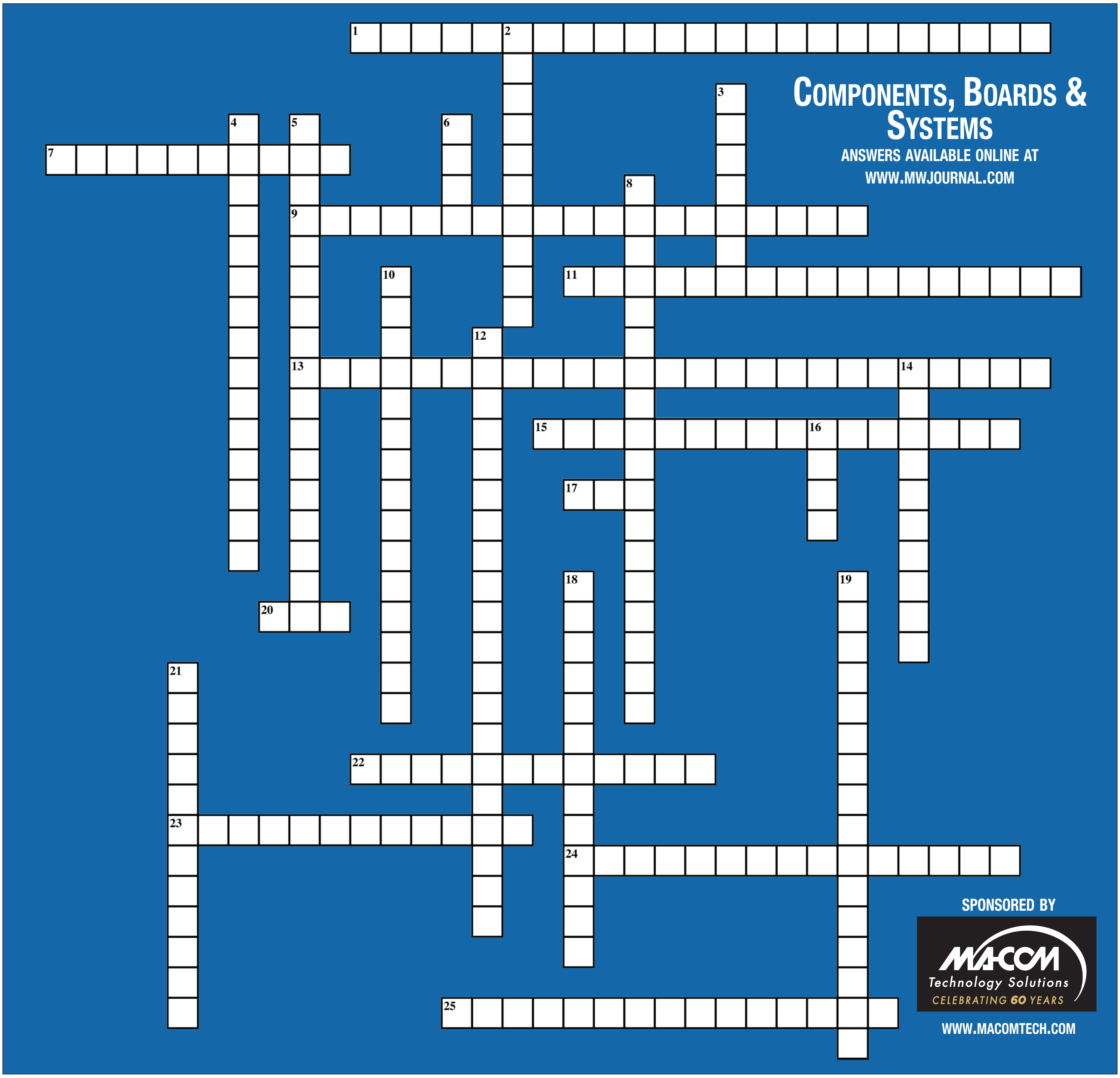


Across

1 Amplifier that uses polar coordinates representation of a signal-vector instead of traditional Cartesian I-Q representation (3 words)

7 Uses finite element math to approximate how a circuit will behave (2 words)

9 When the dielectric constant of a material varies depending on the direction of the electric field (2 words)

11 The capacitance seen looking into the input of a device, Cm (2 words)

13 Multi-tone distortion product that results when two or more signals are present at the input of a nonlinear device (2 words)

15 The directional (angular) dependence of radiation from the antenna (2 words)

17 System on Chip

20 One of the most popular glass reinforced epoxy laminates used for making PCBs

22 A measure of how much better a material is as a path for magnetic flux as compared to free space

23 The power range over which a component or system functions properly (2 words)

24 A list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, components, parts and the quantities of each needed to manufacture an end item (3 words)

25 Type of function used to solve inhomogeneous differential equations subject to boundary conditions (2 words)

Down

2 An unbalanced transmission line structure that consists of a ground plane on the back side of a PCB, the dielectric material of the PCB and a narrow strip on the top side of the circuit board

3 A receiver protector that allows low power signals to propagate from the antenna of a receiver to the next sensitive stage, but rejects high power signals that may be incident on the antenna

4 Shunt capacitor that carries RF energy from a specific point in the circuit to ground (2 words)

5 A measure of loss-rate of power in a substrate material (2 words)

6 Voltage Standing Wave Ratio

8 A measure of the extent to which a material concentrates electrostatic lines of flux, Dk (2 words)

10 An electronic circuit whose output is proportional to its input, but capable of delivering more power into a load (2 words)

12 A representation of a signal modulated by a digital modulation scheme such as QAM or PSK (2 words)

14 At a given point in a transmission system, the difference between the incident and reflected power (2 words)

16 The amount of power at which the amplitude of the output of a device is reduced by 1 dB from the expected small-signal gain

18 UWB (3 words)

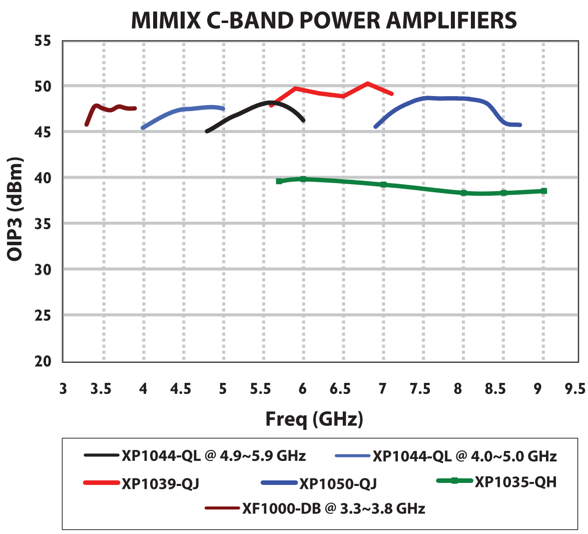
19 A circuit that takes a high-frequency signal as input and provides an output that is the "envelope" of the original signal (2 words)

21 A circuit that splits the power of an input signal into two or more locations without producing impedance mismatch (2 words)

MIMIX POWER AMPLIFIERS & FETs... DRIVING LINEARITY

In today's world, the challenge is moving an ever-increasing amount of information through the same narrow bandwidths. Here at Mimix Broadband, our power amplifiers and FETs drive linearity and minimize distortion, maximizing innovation.

Like our XP1050-QJ Power Amplifier. This PA delivers 15 dB of gain, 34.5 dBm of P1dB and 48 dBm of OIP3 in a standard QFN package, making it an ideal choice for point-to-point radios operating in the ETSI 7 GHz radio band, with modern high-order modulation schemes. The XP1050-QJ is the light at the end of the tunnel!



MIMIX BROADBAND IS DRIVING LINEARITY

	Device	Frequency (GHz)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	Current (mA)	Voltage (V)	Package (mm)
Power Amplifiers	XP1044-QL	3.5-6.0	19.5**	34.0	46.0	850	8.0	7x7
	XP1039-QJ	5.6-7.1	16.6	35.5	49.0	1400	8.0	6x6
	XP1050-QJ	7.0-9.0	15.0	34.5	48.0	1400	8.0	6x6
	XP1035-QH	5.9-9.5	26.0	29.0	39.0	500	6.0	4x4
FETs*	XF1000-DB	DC-6.0	10.0***	34.0	47.0	550	8.0	3x6
	XF1001-SC	DC-6.0	10.0**	30.0	45.0	350	8.0	SOT-89

*FETs Coming Soon | **@ 6.0 GHz | ***@ 4.9 GHz

Explore our wide range of high linearity products and download complete datasheets at www.mimixbroadband.com.

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