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APRIL 2010

HIGH FREQUENCY ELECTRONICS

System Design Software Enhances RF Architecture Analysis & Planning

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Electrically Tunable Switched-Line Phase Shifters

Wideband LNA With Bypass Mode Resists Overload

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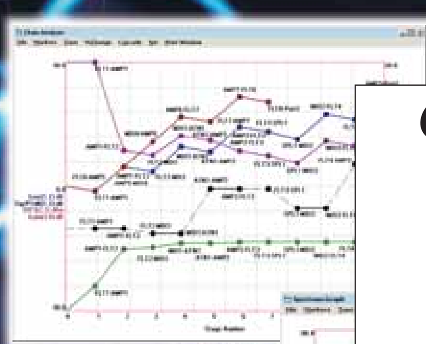

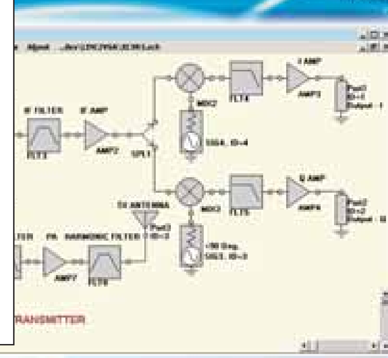

Online Edition

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Ideas for today's engineers: Analog · Digital · RF · Microwave · mm-wave · Lightwave


INTEGRATED ASSEMBLIES
3-Channel Receiver with Limiter
• RF input frequency 11 GHz
• IF frequency range 25 to 50 MHz
• 28 dB conversion gain
• 3.3 dB noise figure
• 20 dB image rejection
• High and low gain selectable
Integrated Dual-Channel Block Converter
• RF input frequency range 18 to 40 GHz
• IF output frequency range 2 to 16 GHz
• Integrated LO multipliers and filters
• Integrated RF and IF filters
Low Noise Block Downconverter
• RF input range 18 to 22 GHz
• Internal LO 17 GHz
• IF output 1 to 5 GHz
• Noise figure 2.9 dB
• 60 dB image rejection
Sub-Harmonic Upconverter and Power Amplifier Module
• RF output range 36 to 37 GHz
• LO input frequency 17.5 GHz
• Output 1 dB compression point +24 dBm
• Conversion gain 20 dB
• Carrier suppression 40 dB
• High reliability miniature hermetic MIC construction
Low Noise Block Converter with Fiber Optic IF Output
• RF input frequency range 24 to 40 GHz
• IF output frequency range 2 to 18 GHz
• Instantaneous bandwidth 16 GHz
• Noise figure 4 dB typical
• Conversion gain 50 dB including fiber optic receiver
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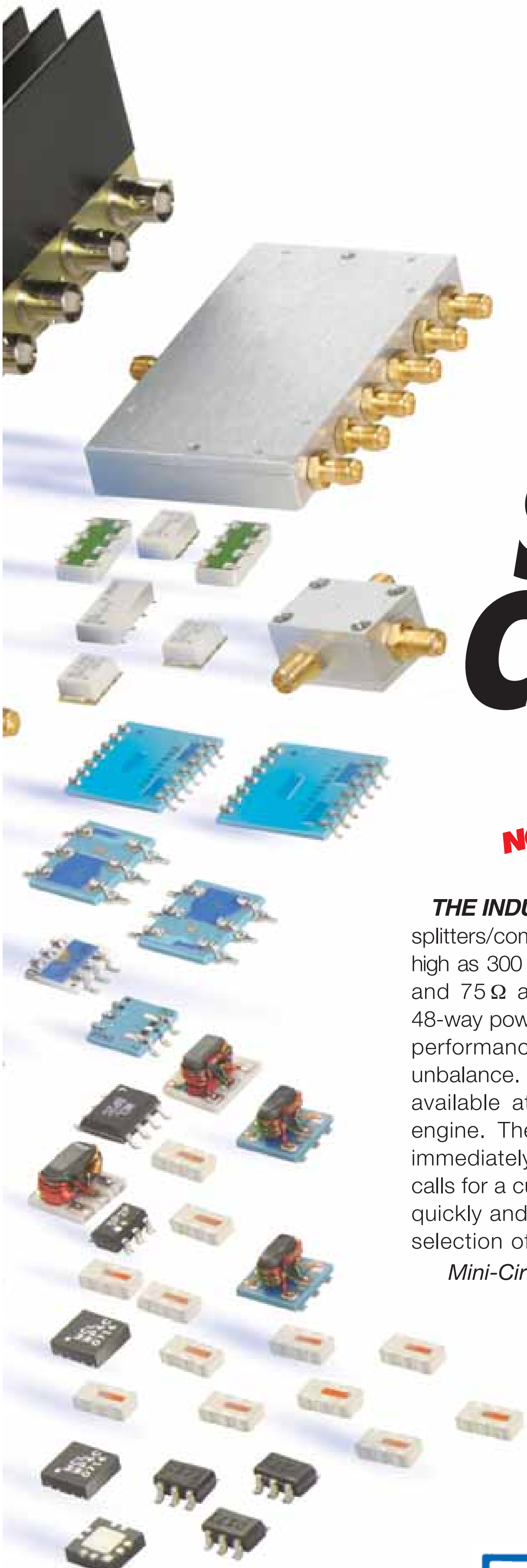
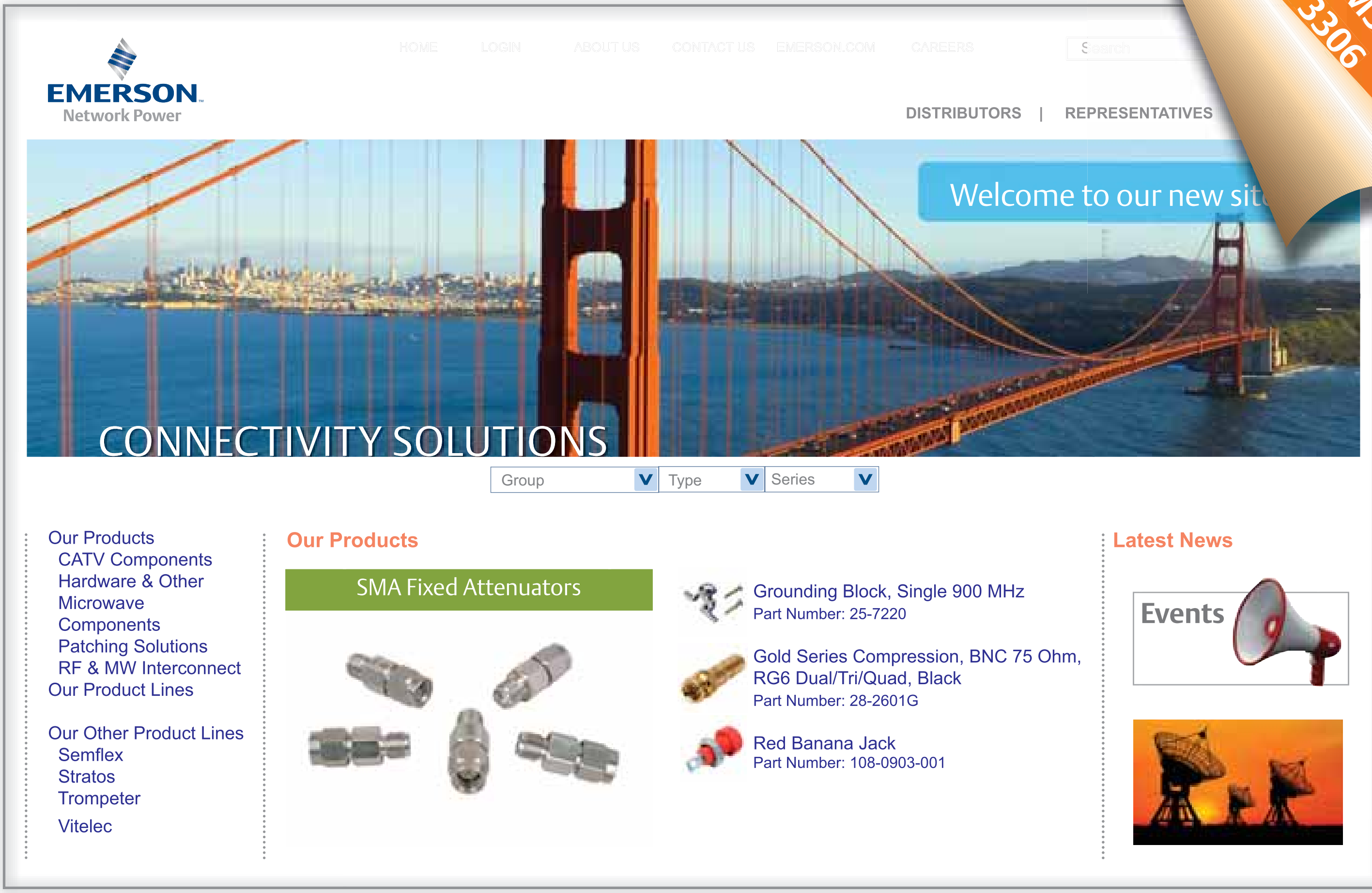


MTTS-IMS
Booth 3306



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Vol. 9 No. 4

HIGH FREQUENCY ELECTRONICS

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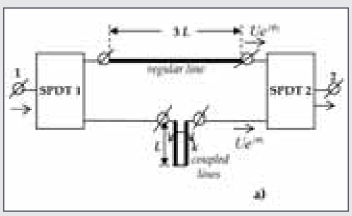

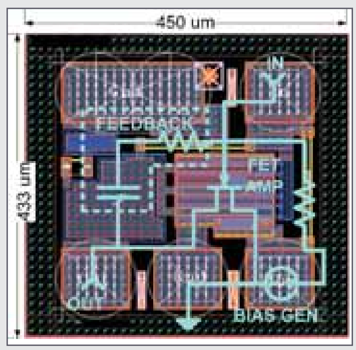

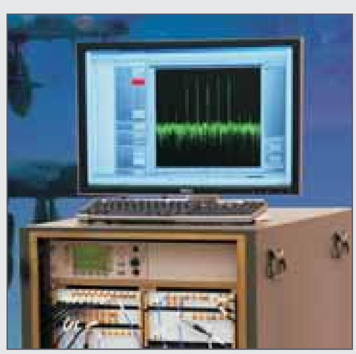

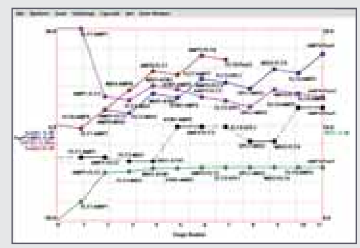

Regular Columns

On the cover—This issue's cover features the new Visual System Architect system design software from Applied Computational Sciences (ACS). You can read a description on page 46. (Artwork courtesy ACS)

HIGH FREQUENCY
ELECTRONICS

Vol. 9 No. 4, April 2010

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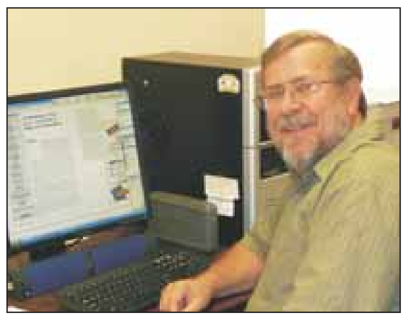
A Reminder of the FCC's Dual Role in Telecommunications

Gary Breed
Editorial Director



The timing couldn't be better, from a publishing point of view... Within a few days' time, we were assembling news for a regulatory update in our Technology Report, a significant court decision was announced regarding FCC regulation of the Internet, and the FCC released a major policy statement on the expansion of broadband technologies. With all this information, it seemed like a good time for me to write about the FCC's interesting role.

Beginning with the Communications Act of 1934, and continuing with subsequent additions and revisions to that law, the Federal Communications Commission was established with the dual role of regulating telecommunications technology and helping promote the development of new technologies.

This dual role was evident in the April 8 announcement of objectives for the development of universal broadband service. That announcement contained promotional activities, such as encouraging the public to become accustomed to using broadband services in an everyday manner, just like any other public medium, such as radio/TV broadcast, newspaper, mail, and traditional telephone. Of course, developments are already underway, but the FCC wants to make sure that it happens as fast as possible, and for all citizens.

On the regulatory side, the broadband policy announcement contained goals for technical developments, including a statement that spectrum usage will be examined, re-regulated, and re-allocated as necessary to support a rapidly growing broadband distribution system. The FCC even proposed that broadband (Internet) become the backbone of a national public safety communications network, including advanced 911 emergency services. Of course, privacy and security of these communications are also included on the list of goals.

The FCC also has certain powers in regulating the business side of telecommunications. This seems to be the part that makes the news most often in media oriented to the general public, as was the case with a recent court decision regarding the FCC's authority over a company's (Comcast in this case) right to block Internet content that is competitive to it's own businesses. This decision, which was in Comcast's favor, has been analyzed everywhere from "the end of the FCC's *'Net neutrality* policy" to "a technicality that has limited implications."

My opinion is in favor of 'Net neutrality, which is a policy that can be compared to the rules regarding political advertising on FCC-regulated broadcasting. Those rules require the acceptance of political advertising from all sides (or from none at all), without selective favoritism. This policy has been thoroughly tested in the courts. I see the Comcast case as either a limited "adjustment" to FCC regulation of the Internet, or perhaps being overturned (or further clarified in its legal scope) on appeal.

There is no question that the law requires regulation of companies using the physical and electromagnetic media under FCC jurisdiction. However, the boundaries of the FCC's authority over content and business practices are constantly being challenged and redefined. Technical regulations are challenged from time-to-time as well, but at least those arguments are usually conducted on scientific terms, with much less influence by political or economic philosophy.

Broadband Everywhere

The vision of one big network connecting us all is ambitious, but has been dreamed about for many years. It started with the telephone, expanded with radio and TV broadcasting, and got much closer with the parallel development of cell phones and the Internet.

Now that advanced wireless systems and the Internet are merging in our daily lives through our communication devices, one more science fiction fantasy is approaching reality. If you are reading this, your industry is deeply involved in this exciting process!

The involvement of the FCC in the development of such "universal broadband access" is essential, just as it has been with telephone, CATV, broadcast, and all other wired and wireless telecommunications. With it's dual role of regulation and encouragement, the FCC is perfectly suited for managing the process, but in cooperation with other governmental authorities when jurisdictions overlap, in cooperation with the industries that are involved in the implementation, and with input and comment from the public—as required by the laws that created, and continue to shape, the FCC's role.

Conferences

April 10-15, 2010
2010 NAB Show
Las Vegas, NV
Information: Conference Web site
http://www.nabshow.com

April 12-13, 2010
11th WAMICON 2010—IEEE Wireless and Microwave Technology Conference
Melbourne, FL
Information: Conference Web site
http://www.wamicon.org

April 12-14, 2010
Sarnoff 2010—33rd IEEE Sarnoff Symposium
Princeton, NJ
Information: Conference Web site
http://ewh.ieee.org/conf/sarnoff/2010/

April 12-16, 2010
European Conference on Antennas and Propagation
Barcelona, Spain
Information: Conference Web site
http://www.eucap2010.org

April 12-16, 2010
2010 Asia-Pacific Symposium on Electromagnetic Compatibility (APEMC 2010)
Beijing, China
Information: Conference Web site
http://www.apemc2010.org

April 14-15, 2010
IEEE RFID 2010—International Conference on RFID
Orlando, FL
Information: Conference Web site
http://ewh.ieee.org/mu/rfid2010/

April 18-21, 2010
WCNC 2010—IEEE Wireless Communications & Networking Conference
Sydney, Australia
Information: Conference Web site
http://www.ieee-wcnc.org/2010/

May 8-11, 2010
2010 Int'l Conference on Microwave and Millimeterwave Technology (ICMMT 2010)
Chengdu, China
Information: Conference Web site
http://www.mws-cie.org/icmmt2010/

May 23-28, 2010
Microwave Week 2010: IEEE MTT-S International Microwave Symposium (IMS); Radio Frequency Integrated Circuits Symposium (RFIC 2010); The 75th ARFTG Conference
Anaheim, California
Information: Conference Web site
http://www.ims2010.org

June 14-18, 2010
4th Microwave & Radar Week
Vilnius, Lithuania
Information: Conference Web site
http://www.MIKON-2010.lt

July 5-9, 2010
ANTEM/AMEREM—14th Int'l Symposium on Antenna Technology and Applied Electromagnetics, held jointly with the American Electromagnetics Conf.
Ottawa, ON, Canada
Information: Conference Web site
http:// antem.ee.umanitoba.ca/antem_amerem2010/

July 11-17, 2010
2010 IEEE AP-S/URSI—Int'l Symposium on Antennas and Propagation and CNC-USNC/URSI Radio Science Meeting
Toronto, ON, Canada
Information: Conference Web site
http://www.apsursi2010.org

August 28-September 3, 2010
2010 IEEE Int'l Conference on Wireless Information Technology and Systems (ICWITS 2010)
Honolulu, HI
Information: Conference Web site
http://hcac.hawaii.edu/conferences/tcwct2010/

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Applied RF Techniques I
May 17-21, 2010, Boston, MA
Applied RF Techniques II
May 17-21, 2010, Boston, MA
RF and Microwave Filter Design with EM Simulation
May 17-20, 2010, Boston, MA
Radio System Design - Theory and Practice
May 17-21, 2010, Boston, MA
DSP Made Simple for Engineers
May 19-21, 2010, Boston, MA
Antennas & Propagation for Wireless Communications
May 19-21, 2010, Boston, MA
Monolithic Microwave Integrated Circuit (MMIC) Design
May 19-21, 2010, Boston, MA
Transceiver and Systems Design for Digital Communications
May 19-21, 2010, Boston, MA

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http://www.tuv.com/us/en/international_approvals_round_table_.html

International Approvals Round Tables—The purpose of this discussion will be to provide an overview of Global Regulatory Approvals processes, review potential roadblocks, and give you an opportunity to have your questions answered by our IA Division expert—Mr. Bill Holz. Please join us for an informative couple of hours!

April 15, 2010, Minneapolis, MN
April 27, 2010, Denver, CO
May 10, 2010, Rochester, NY
May 12, 2010, Pittsburgh, PA
May 19, 2010, Los Angeles, CA
May 20, 2010, Phoenix, CA
May 25, 2010, Philadelphia, PA
June 8, 2010, Portland, OR
June 10, 2010, Seattle, WA
June 17, 2010, Raleigh, NC
June 21, 2010, Grand Rapids, MI
June 23, 2010, Cincinnati, OH

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E-Mail: ed-pub@crosslink.com
http://www.antennacourse.com

ANTENNAS: Principles, Design, and Measurements

May 3-6, 2010, Annapolis, MD

Calls for Papers

59th International Wire & Cable and Connectivity Conference

Providence, RI
Conference Dates: November 7-10, 2010
Paper Submission Deadline: April 30, 2010

Topics:

Presentations of products and systems for communications, data, electronics, power, security, industrial, automotive/aerospace and specialty segments are eligible for consideration for the symposium. New developments in finished cable, compounds, coatings, tapes, yarns, fillers, shielding and strength members are all products and topis of interest to the Symposium audience, as well as new technologies in connectors, connectivity technology and materials.

Information:

Abstracts must be submitted through the IWCS Web site: www.iwcs.org. All abstracts require the following: title, author(s) and description (up to 500 words). Acceptance of abstracts will be based on originality, content, applicability, market interest and clarity.

32nd Annual Meeting & Symposium of the Antenna Measurement Techniques Association

Atlanta, GA
Conference Dates: October 10-15, 2010
Abstract Submission Deadline: May 3, 2010

Topics:

Topics include but are not limited to: Theory applications of the measurement of antennas & radar scattering; Ultrawideband or frequency independent antenna measurement; New instrumentation for testing; Diagnostic methods for antenna acceptance testing; Phased-array antenna testing; Adaptive antenna/smart antenna application/measurement; RF material design, measurement & instrumentation; Satellite antenna measurement; Advances in indoor & outdoor test ranges; Applied computational electromagnetics; and Radome characterization.

Information:

Authors addressing advancement and innovation in these or other topics of interest to AMTA are invited to submit a 200-word abstract for review and possible presentation at the Symposium. Electronic submission is required via www.amta.org.

60th Annual IEEE Broadcast Symposium

Alexandria, VA
Conference Dates: October 20-22, 2010
Abstract Submission Deadline: May 15, 2010

Topics:

The Symposium Committee seeks technical papers on the following topics: Technical issues associated with the termination of analog television broadcasting; Repurposing of analog television broadcast transmitters; Digital radio and television systems: terrestrial, cable, satellite, Internet, wireless; Streaming, IPTV, VoIP, VoD, Mobile TV, Wireless Multimedia; Wireless Broadband Networks; and Transmission, propagation, reception, re-distribution of broadcast signals.

Information:

Prospective presenters are invited to submit extended abstracts of 500-1000 words by e-mail to bts@ieee.org. Please indicate that the abstract is submitted to the 2010 Annual IEEE Broadcast Symposium, and include the corresponding author's full name and contact information including: Affiliation, address, e-mail, and phone number. Abstracts may be submitted at any time for consideration to be included in the 2010 Symposium technical program.

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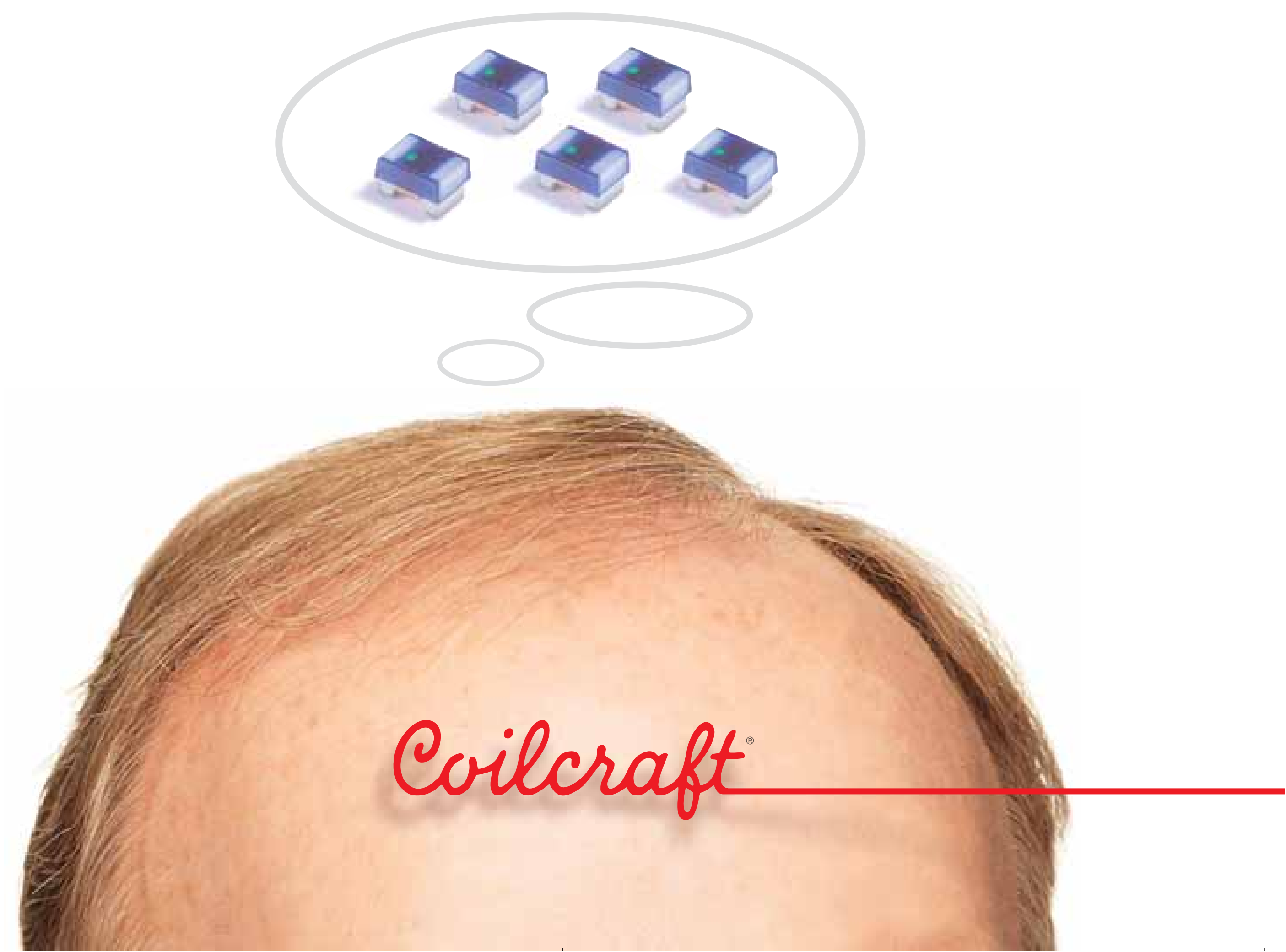


Business News

Agilent Technologies Inc. announced that its Scanning Microwave Microscopy Mode (SMM Mode) has been named one of 10 2009 Prism Award winners by judges from SPIE and the advisory board of Laurin Publishing's *Photonics Spectra* magazine. SMM Mode was officially recognized for outstanding photonics innovation in the category of "Analytical, Test, and Measurement" at a special ceremony during SPIE Photonics West. SMM Mode previously was named an R&D 100 Award winner by an independent judging panel and the editors of *R&D Magazine.* Agilent developed SMM Mode to enable high-resolution, quantitative electromagnetic materials characterization using the company's 5420 and 5600LS atomic force microscopes.

Nujira and **RF Micro Devices, Inc.** demonstrated the world's most efficient broadband power amplifier (PA) design for 4G base stations at Mobile World Congress, Barcelona, February 2010. The design integrates the new RFMD RFG1M family of high performance gallium nitride (GaN) amplifiers with Nujira's Coolteq.h envelope tracking power modulators.

Altair Semiconductor, a 4G chip company, and **Aeroflex,** a global provider of Long Term Evolution (LTE) test equipment, announced a joint LTE collaboration. Through the collaboration, Altair and Aeroflex will perform interoperability testing (IOT) to enable joint customer development and testing on a pre-tested and qualified User Equipment (UE) test setup. Following an intensive evaluation period Altair has ordered multiple 7100 LTE digital radio test sets from Aeroflex, with the first delivery in January 2010.

Mimix Broadband, Inc., commemorates its 10th year of business in 2010. The company will celebrate the occasion throughout the year, including at the 2010 IEEE MTT-S International Microwave Symposium, to be held this year in Anaheim, California.

The Wireless Communications Association International (WCAI) announced that it will once again co-locate its long running and highly successful 16th Annual International Symposium with **4G World.** The event website is http://www.4gworld.com.

Peregrine Semiconductor Corporation announced the expansion of its European design and manufacturing operations and the opening of a new facility located in Aix-en-Provence, France. Peregrine Semiconductor Europe (PSE) operations include RF integrated circuit (RFIC) design and engineering at its design center in Aix-en-Provence, France; IC wafer manufacturing from wafer foundry Sapphicon in Australia and UMC in Taiwan; assembly and packaging from Hybritech Composants Microelectroniques (HCM) France; and back-end testing at partner Rood Microtec in Germany. PSE activities will focus on developing new RFIC products of European content to better support specific European design requirements, as well as providing design services for Peregrine's next-generation UltraCMOS™ RFIC portfolio.

California Eastern Laboratories (CEL) congratulates its long-standing partner, **NEC Electronics,** on the completion of its merger with **Renesas Technology Corporation.** The new entity, Renesas Electronics Corporation, continues its 50 year partnership with CEL. The supply of CEL products that come from NEC Electronics, including RF switches, power amplifiers, low noise amplifiers, optocouplers, solid state relays, lasers, and detectors, will continue without interruption.

SemiGen, Inc., a modern outsource for die packaging, hybrid assembly, and automated PCB manufacturing and test, announced the acquisition of **Alternative Microwave Resources** (AMR) of Amherst New Hampshire. AMR is a privately held contract manufacturer specializing in hybrid assembly, engineering, and testing of RF and microwave modules up to 20 GHz. The company also troubleshoots and repairs various units such as amplifiers, VCOs, limiters, and other military subsystems and modules that need repair down to the component level.

KOR Electronics announced that it has received a prime contract from the government for $44.4 million dollars to supply advanced Digital RF Memory (DRFM) jammers for the U.S. Navy and Air Force. The contract is a firm-fixed-price, indefinite-delivery/indefinite-quantity time-and-material award from the United States Navy.

Giga-tronics announces that it has joined the new modular test standard consortium, **AXIe** (AdvancedTCA® Extensions for Instrumentation and Test). AXIe is an open standard based on AdvancedTCA (ATCA) that creates a robust ecosystem of components, products and systems for general purpose instrumentation and semiconductor test. AXIe leverages existing standards from ATCA, PXI™, VXI™, LXI™ and IVI®. The AXIe standard provides the maximum scalability to address a range of platforms including general purpose rack-and-stack, modular systems, ATE systems, bench top, and module plug-ins.

Rogers Corporation and its Advanced Circuit Materials (ACM) Division earned a distinguished DesignCon Paper Award at last month's DesignCon 2010 Conference and Exhibition in Santa Clara, CA. The paper, "Effect of Conductor Profile on the Insertion Loss, Phase Constant, and Dispersion in Thin High-Frequency Transmission Lines," was co-authored by Allen F. Horn III, John Reynolds, and Patricia LaFrance of Rogers Corporation and James Rautio, President of Syracuse, NY-based Sonnet Software. It offers insights and solutions on issues that have long plagued designers of thin printed-circuit boards (PCBs)—issues specifically related to the effects of conductor surface roughness on PCB performance.

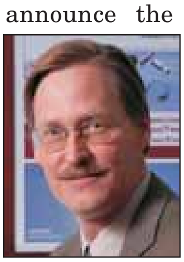
Maxtek Components Corporation, a **Tektronix** company, now offers component test and COTS (commercial off-the-shelf) screening for military, space and commercial aerospace applications through the Component Test organization of **Sypris Test & Measurement.** Sypris Test & Measurement, acquired by Tektronix in October 2009, is a provider of calibration services, testing and component sourcing services, and specialty products.

Spectrum Advanced Specialty Products announces the addition of MIL-PRF-49470 approval for Switch Mode Power Supply capacitors to its extensive military QPL offerings. These capacitors, available in industry-standard or custom case sizes, are all made in Spectrum's established MIL-STD-70 ceramic facility located in State College, PA.

Agilent Technologies Inc. announced its support of the USA Science & Engineering Festival, the country's first national science festival. The event will take place in Washington, D.C., in October 2010. The festival, expected to be a multi-cultural and multi-disciplinary celebration of science in the United States, will offer science and engineering organizations throughout the country the opportunity to present hands-on science activities to inspire the next generation of scientists and engineers. Festival organizers already have engaged more than 350 participants from the nation's leading science and engineering organizations.

People in the News

Sabritec, a Smiths Interconnect business, is pleased to announce the appointment of **Scott Pianalto** as



President. Scott brings over 20 years experience in the connector industry and most recently served as the Director of Marketing and Operations for a major connector manufacturer within the military aerospace market. In this new role, Scott will focus on implementing an accelerated growth strategy for Sabritec to strengthen and expand its position in the market place. Scott holds a BS in Chemistry from the University of California and an MBA from Pepperdine University.

RFMW, Ltd. announces the promotion of **Russ Dahl** to the newly created position Director of North American Sales. He will report to Steve Takaki, VP Sales and Marketing. Russ has been with RFMW since April 2006 and in that time has earned the respect of customers, suppliers, and the RFMW team. Russ has over 20 years of diversified experience in technology and management roles within RF Sales, Marketing, and Specialty Distribution. Through his efforts and his relationships Russ most recently has managed a large and diverse geography for RFMW. With deliberate and planned effort Russ has tripled the business in the his territory by penetrating new accounts and positioning RFMW as the go to source for it's entire linecard of RF/Microwave components.

ISOLA Group, SARL, announced **David Luttrull** has joined the company as Director of Development—Emerging Technologies. David will work closely with Isola's OEM Marketing and R&D teams to develop new products and technologies for high-speed digital and halogen-free applications. Prior to joining Isola, David was President and Chief Scientist for MG Lab Services in Phoenix, AZ. David previously worked for Park Electrochemical Corp. at its Tempe, AZ facility as R&D Director and Product Director. David holds a B.A. in Chemistry from Point Loma College in San Diego, CA, an M.S. in Organic Chemistry from Bowling Green State University in Bowling Green, OH, and a Ph.D. in Physical-Organic Chemistry from Arizona State University in Tempe, AZ.

Sales Appointments

AWR Corporation announced that it has expanded its global presence by establishing a direct sales, support, and marketing office in Korea. To better serve the region's growing customer base, Mr. Kyung Hwa Kim has been appointed AWR Korea's country manager.

Modelithics, Inc. announces its new agreement with **CogniTech Sales, LLC,** for sales and service representation for the Southeastern United States. Larry Dunleavy, Modelithics' CEO, and the Advanced Products Sales Director, Alen Fejzuli, have signed a comprehensive agreement designed to fully support Modelithics in the Florida, Alabama and Georgia markets for RF and microwave simulation models as well as characterization services.

Nitronex announced the addition of a key sales director and strategic partnerships with three premier sales representative firms. These recent sales additions are part of Nitronex's overall strategy to expand sales and customer support in North America. Nitronex has recruited **Diane DuVall** as Director of North American Sales. Recently, Ms. DuVall set up sales, marketing and operations across the U.S. and Canada at Navman Wireless. Ms. Duvall has also held senior sales director positions at Jazz Semiconductor, Skyworks Solutions and Conexant Systems. Nitronex has also partnered with **TAI Corporation, Tri-Tech Electronics** and **Thom Luke Sales,** three major sales representative organizations in North America, to assist Ms. DuVall in accelerating the sales and customer support activities.

MITEQ Inc. announced the appointment of **Spartech-South** as the company's exclusive sales representative in Florida, Georgia, Alabama, Mississippi, North and South Carolina, and Tennessee. Spartech-South will represent MITEQ's Component division of products, which includes amplifiers, mixers, frequency multipliers, passive power components, switches, attenuators, limiters, phase shifters, IF signal processing components, oscillators, synthesizers, integrated multifunction assemblies and fiber optic products. Spartech-South can be contacted at (321) 727-8045 or e-mail jim@spartech-south.com.

Electrically Tunable Switched-Line Diode Phase Shifters Part 1: Design Procedure

By Leo G. Maloratsky
Aerospace Electronics Co.

This article examines the design and performance of diode phase shifters, key building blocks for phased array, smart antenna, and measurement technologies

In building a strategy for effective integrated-circuit design, it is important to understand the characteristics of different printed phase shifters. Optimization of the printed phase shifter design process 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. In this article we consider design strategy of switched-line PIN-diode phase shifters.

RF and microwave phase shifters have many applications in various equipment such as phase discriminators, beam forming networks, power dividers, and phase array antennas [1, 2, 3]. A phased array antenna has a large number of radiating elements that emit phased signals to form a radio beam. The radio signal can be electronically steered by the active manipulation of relative phasing of individual antenna elements. Phase shifters are fundamental parts of phased array antennas. They allow an array to scan a beam or reconfigure a shaped beam. Phased antenna arrays consist of a number of individual elements, each one requiring a phase shifter that applies the necessary phase shift to steer the antenna beam [4]. In some amplitude monopulse systems [5, 6], a phase shifter provides different directional and omnidirectional antenna modes.

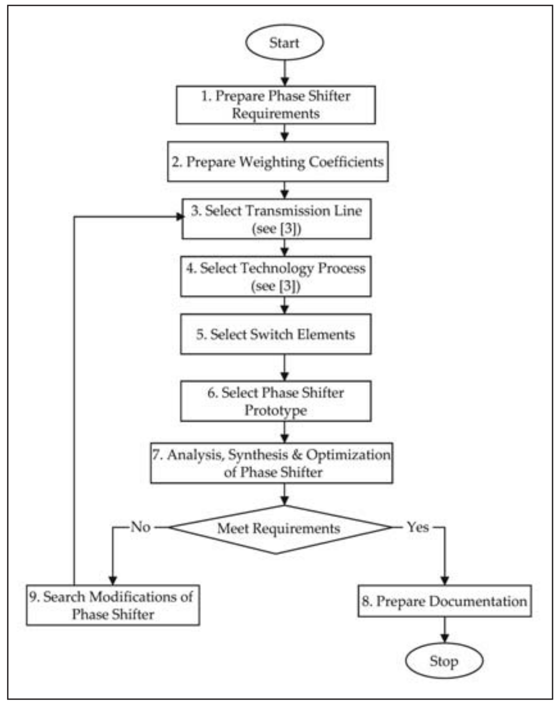


Figure 1 · Flow chart for the design of printed phase shifters.

Figure 1 illustrates the design flow of printed phase shifters. Definition of system level specifications is the first step in the design flow of printed phase shifters. This involves both system level requirements which are applied directly to phase shifters, as well as derived requirements which depend on system requirements. Phase shifter specifications include electrical, cost, size and other requirements. The major parameters which define RF and microwave print phase shifter are frequency range, bandwidth (*BW*), total phase variance ($\Delta\varphi$), insertion loss (*IL*), switching speed, power handling (*P*), accuracy and resolution, input/output matching

(VSWR) or return loss (*RL*), harmonics level. For all requirements, a designer has to choose consecutive integer values of weighting coefficients k_i corresponding to each parameter (step 2 of design flow in Fig. 1), starting with $k = 1$ for the most important parameter [7 - 9]. 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 phase shifter prototype (step 6 of design flow Fig. 1) depends on all requirements, selected transmission line (step 3), technology process (step 4), and must take into account the corresponding weighting coefficients. The final choice of a phase shifter network and control element will depend on the required bandwidth, insertion loss, switching speed, total phase variance, power handling, accuracy and resolution, input/output matching, harmonics level.

The design strategy of printed transmission lines was described in [7]. The type of optimal transmission line depends on many different factors including the technology process. According to the phase shifter design flow (Fig. 1), a phase shifter prototype is selected (step 6) after the selection of the transmission line (step 3), technology process (step 4), and switch elements (step 5). The switching elements in digital phase shifters are PIN diodes and Field Effect Transistors (FET). The high-speed PIN diodes change resistance values from approximately 10,000 ohm to less than 1 ohm. Switching is achieved by changing the bias point of a PIN-diode from forward to reverse direction and vice versa. These PIN diodes are commonly utilized in high-speed, current controlled phase shifters. In MMIC design the switching elements are often realized with FETs. GaAs phase shifters are typically very small, on the order of a few square millimeters, which makes them good candidates for thin-film semiconductor manufacturing processes. GaAs, on the other hand, is one of the most expensive semiconductors.

Analog phase shifters are devices whose phase shift changes continuously with the control input and therefore offer almost unlimited resolution with monotonic performance. The most commonly used semiconductor control elements in analog phase shifters are varactor diodes. Varactor diodes operating in a reverse-biased condition provide a junction capacitance that varies with applied voltage and can be used as an electrically variable capacitor in a tuned circuit. Varactor analog phase shifters can achieve a large amount of phase shift and high speed and require fewer diodes than digital phase shifters, but at the cost of decreased accuracy, relatively narrow bandwidth, and low input power levels (less than 1 W). Schottky diodes are also used as variable elements in analog phase shifters, but they suffer from limited power handling capability and matching difficulty in broadband networks.

Sometimes the phase shifter prototype does not satisfy some requirements because of the selected transmission line. In this case the transmission line should be reselected to satisfy the phase shifter requirements. For minimum cost, most phase shifters use microstrip line, however, a lower loss stripline or a suspended stripline design is more desirable. The final selection of a phase shifter prototype can be made by analysis of the circle diagram [7-9]. The optimum prototype is determined by minimizing the area between real and goal performance. Synthesis of print the phase shifter is based on both system requirements and derived requirements. Synthesis results are physical dimensions of a phase shifter and lumped element values if necessary. Analysis of a print phase shifter entails definition of electrical performance based on the known physical dimensions.

There are many different ways to implement the RF phase shifter. Some of the most notable methods are based on switched-line, loaded line, and reflection theories. The switched line method is the most straightforward approach of the three because it uses the simple time delay difference between two direct paths to provide desired phase shift.

The PIN-diode switched-line phase shifter can be classified according to following types of characteristics:

- transmission line (regular, irregular, and coupled);
- number of bits;
- structure (reflection or non-reflection);
- with reciprocal and non-reciprocal devices;
- number of switched inputs/outputs (SPST, SPDT, SP3T, etc.);
- PIN diode connection with transmission line (series, shunt, series-shunt);
- bandwidth (narrow or broadband);
- configuration of elements (distributed, lumped-elements, or combination of lumped and distributed);
- maximum power (low or high).

The switched-line phase shifter includes phase elements, switch elements (PIN diodes), and control network. The selection of switch elements (step 5, Fig. 1) depends on the phase shifter requirements. Shunt diode switches are commonly used for systems with high isolation and where handling of higher power is necessary. The isolation of the off-path with shunt PIN diode is approximately 6 dB larger than in the configuration with series switches. Series diode switches are commonly used in broadband circuits. The series-shunt configuration provides greater isolation than both the series and the shunt versions, but requires a bias current from both positive and negative sources that would significantly increase the DC power dissipation.

The switched-line phase shifter is dependent only on

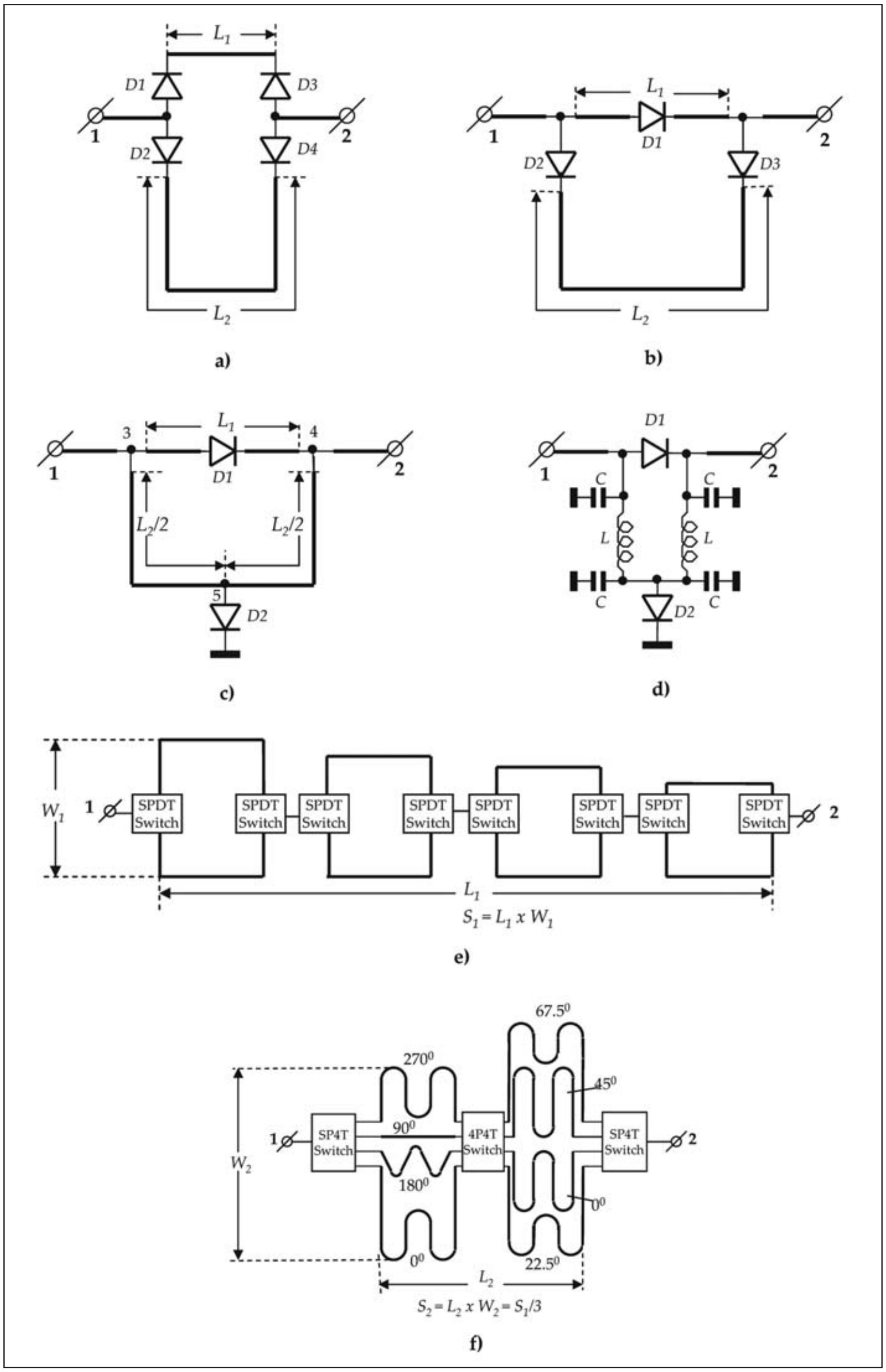


Figure 2 · Switched-line phase shifter circuit configuration options.

the lengths of line used. Also, the switched-line phase shifter is simple in both principle and design. One of the two lines is labeled as a "reference" line, and the other as a "delay" line. An important advantage of this circuit is that the phase shift will be approximately a linear function of frequency. This enables the circuit to operate at a broader frequency range. Also, the phase shift created by the switched-line phase shifters is dependent on transmission line lengths only, and they are therefore very stable over time and temperature. The PIN diodes of this phase shifter may suffer from parameter drift, but this usually provides degradation in the insertion loss of the circuit and not the phase shift. For the switched-line phase shifter, both the peak power capability and the insertion losses are independent of the phase shift.

The conventional switched-line phase shifter is comprised of two line segments of different length selectively connected to the transmission line. The different path lengths between the two line segments determines the amount of phase shift to be introduced. The transmission line is switched over from one line segment of the phase shifter to the other when the phase shift is removed. Figure 2a illustrates the schematic of the conventional switched-line phase shifter with RF input 1, RF output 2, four PIN diodes *D1, D2, D3,* and *D4,* and two transmission lines L_1 and L_2. Only one arm should be ON at a time. When the PIN diodes *D1* and *D3* are ON while PIN diodes *D2* and *D4* are OFF, the reference delay line L_1 is in the circuit. When the PIN diodes *D2* and *D4* are ON while PIN diodes *D1* and *D3* are OFF, the delay line L_2 is in the circuit. By switching the signal between two lines L_1 and L_2 of different lengths, it is possible to realize a specific phase shift:

$$\Delta\varphi = 2\pi \times \frac{\Delta L}{\lambda}$$

where ΔL is the difference between the physical lengths of the delay line (*L2*) and the reference line (*L1*); λ is the guide wavelength.

Switched-line phase shifters are often used for two largest phase shifts (180 and 90 degrees). When path L_2 is a half guide wavelength longer than path L_1, switching from path L_1 to path L_2 introduces an increased phase delay of 180 degrees. For the required 180° phase shift the difference in physical length should be $\Delta L = \lambda/2$. By switching the signal

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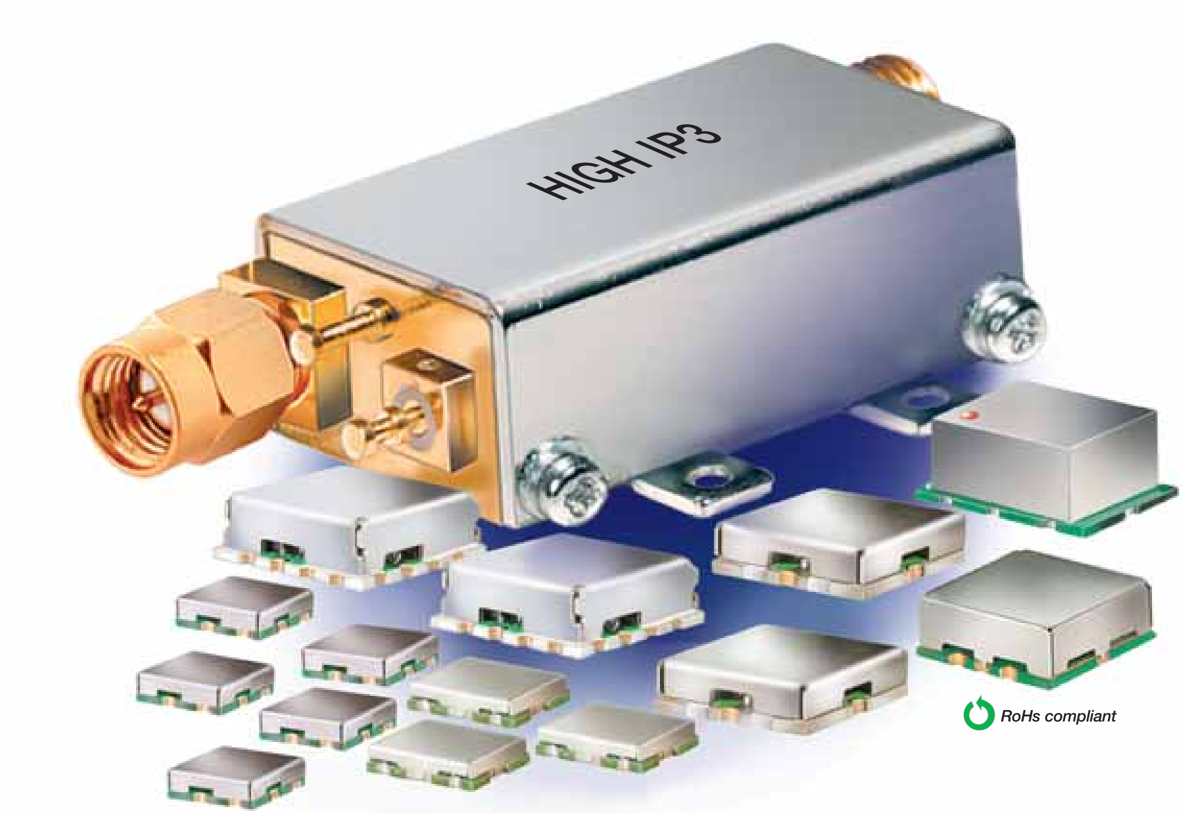

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Voltage Variable Attenuators (VVAs) deliver as high as 40 dB attenuation control over the 10 MHz through 7.0 GHz range. Offered in both 50 and 75 Ω models these surface-mount and coaxial low-cost VVAs require no external components and maintain a good impedance match over the entire frequency and attenuation range, typically 20 dB return loss at input and output ports. These high performance units offer insertion loss as low as 1.5 dB, typical IP3 performance as high as +56 dBm, and minimal phase variation low as 7°.

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IF/RF MICROWAVE COMPONENTS

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between two pre-determined lengths of transmission line it is therefore possible to realize a specific phase shift at a given frequency. However, the phase shift value tends to deviate linearly from the intended value as the frequency of the signal deviates in either direction from the center (nominal) frequency. In order to reduce the size of the switched-line phase shifter, the reference line should be shorter. The lengths L1 and L2 must be carefully selected to avoid phase errors, high return loss, and high insertion loss.

The practical design of the existing switched-line 180-deg phase shifters faces several problems. One is associated with the half guide wavelength arm ("delay line" L_2). Resonances can occur in the off line when the line length is a multiple of 0.5 λ. This line will appear resonant due to its length, and the phases will interfere in a way to reflect much of the incoming power back to the input port. The resonant frequency will be slightly shifted due to the series junction capacitances of the reversed biased diodes.

	Two-diode PS (Fig.2,c)	Three-diode PS (Fig.2,b)	Four-diode PS (Fig.2,a)
Advantages	Two PIN diodes only. Lowest Insertion Loss 0.7 dB at 180^0 state. No notch in the frequency response.	Lowest Insertion Loss 0.5 dB at 0^0 state.	
Disadvantages	Greater Insertion Loss 1.0 dB at 0^0 state.	Less power dissipation due to three series diodes. Notch in the frequency response.	Greater insertion loss 0.8 dB at 180^0 state. Less power dissipation due to four series diodes. Notch in the frequency response.
Return Loss (min), dB			
- 0^0 state	14.9	17.5	
- 180^0 state	15.8	15.3	13.0
Insertion Loss*) (max), dB			
- 0^0 state	1.0	0.5	0.7
- 180^0 state	0.7	0.7	0.8

Table 1 · Performance of 0°/180° switched-line phase shifters.

Another disadvantage of this phase shifter is a large number of the PIN diodes: the typical switched-line phase shifter (Fig. 2a) consists of two SPST switches with four diodes *D1, D2, D3,* and *D4*. Insertion loss of the switched-line phase shifter is equal to the loss of the single-pole, double-throw switches plus the line losses. Typically, the isolation of the two switches must exceed 20 dB in the required frequency band.

Figure 2b illustrates the schematic of three-diode switched-line phase shifter. Instead of two PIN diodes for switching the reference line L1 (Fig. 2a) in this circuit, one series PIN diode *D1* is used. Figure 2c is an example of the 180-deg switched-line phase shifter with two PIN diodes. In this circuit, for the 180-deg phase shifting, the diodes *D1* and *D2* are in the OFF position, and RF signal passes through line L_2 with the one-half guide wavelength length providing a 180-deg phase shift. The segments of lines between junction 5 and junctions 3, 4 have the length equal to one quarter guide wavelength plus length of short bypass line L_1. For the 0-deg phase shifting, diodes *D1* and *D2* are controlled to be in the ON position. Therefore, during the 0-deg phase shifter status, these quarter guide wavelength lines transform the short circuit of diode *D2* (the shunt PIN diode *D2* is activated by forward bias) into open circuit at junctions 3 and 4, and an RF signal passes through bypass line L_1. In this case the reference line is activated because the series diode *D1* is ON with minimum series diode resistance under the forward bias. The lengths of reference line L_1 and delay line L_2 must be carefully selected to avoid phase errors, high insertion losses and high return losses. The large errors don't occur because there are two quarter-wavelength shorted lines in the delay line L_2. Thus, both lengths (L_1 and L_2) must not be multiples of a half wavelength. Also, for the 180-deg phase shifter, the reference line length L_1 is not zero because of the finite dimensions of series PIN diode and of PADs for solder of the diode package. The disclosed phase shifter overcomes the resonant effect by using the reference line electrical length of greater than 0 degrees depending on the insertion loss limitation. In this case the delay line length should be greater than half guide wavelength in the required frequency band. The problem of switched-line phase shifter (Fig. 2c) is the difficulty of simultaneous realization of 180-deg phase shifting and the minimum insertion loss in the reference mode, because for this mode the lengths between the shunt diode connection and each of the junctions 3 and 4 should be quarter-wavelength. Therefore, the total delay line length is $L_2 = \lambda/2$, but for the 180° mode the delay line length should be greater than half-wavelength: $L_2 = \lambda/2 + L_1$. If the intended phase shift is 180 degrees, the differential path length is equal to the half wavelength of the center frequency of the signal of the transmission line. The PIN diodes suffer from parametric drift. This usually leads to the degradation in the insertion loss of the switch but not in the phase shift. The isolation per switch in the OFF line must be greater than 20 dB to avoid phase errors.

The advantage of the switched-line phase shifter is simplicity in both principle and design. The disadvantages include losses in signal path due to semiconductor devices and losses which depend on the phase shift due to unequal transmission line paths. The main disadvantage of the switched-line phase shifter network for use in broadband systems is that the bandwidth of operation is limited by the variation of differential phase shift with frequency. Also, if one of switches fails, the whole phase shifter fails. Another disadvantage of this phase shifter is the contradictory conditions for the required 180-degree phase shift and the minimum loss during 0-deg phase shift status. Table 1 illustrates performance of the 0/180-deg two-, three-, and four-diode switched-line phase shifters.

The switched-line 180-deg phase shifter is relatively large for low-frequency applications. Figure 2d illustrates lumped element 180-deg switched-line phase shifter. The quarter guide wavelength segments of the phase shifter delay line are substituted with equivalent lumped element circuits. A short segment of transmission line of characteristic impedance z and electrical length $\Theta = 2\pi l/\lambda$ (l is the physical length of transmission line, λ is the guide wavelength) is equivalent to a π-section circuit. For the quarter-wavelength segments of the phase shifter delay section, the equivalent lumped elements of the π-section are $L = z/2\pi f_0$, $C = 1/2\pi f_0 z$, where z is the characteristic impedance of the input/output line, f_0 is the center frequency of the phase shifter. The lumped element configuration of the 180-deg phase shifter can be recommended for the HF, VHF, and UHF ranges.

This article will conclude next month, examining multi-step printed-line phase shifter circuits. References will be included with Part 2.

Author Information

Leo G. Maloratsky received his MSEE degree from the Moscow Aviation Institute and his PhD from the Moscow Institute of Communications in 1962 and 1967, respectively. Since 1962, he has involved in the research, development and production of RF and microwave integrated circuits at the Electrotechnical Institute, and he was 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. Since 2008 he joined Aerospace Electronics Co. He is author of four monographs, one text-book, over 50 articles, and 20 patents. His latest book is *Passive RF and Microwave Integrated Circuits,* 2004, Elsevier. He can be reached at: lmaloratsky@cfl.rr.com

News Update: Regulatory and Standards Activities

FCC Announces Broadband Agenda

The Federal Communications Commission (www.fcc.gov) has announced an ambitious 2010 agenda for implementing key recommendations of the National Broadband Plan that involve rulemakings and other notice-and-comment proceedings. The Plan, which the FCC delivered to Congress on March 16, 2010, lays out a comprehensive strategy for connecting all corners of the nation while transforming the economy and society with the communications network of the future — robust, affordable, and high-speed Internet.

The 2010 Broadband Action Agenda announced today explains the purpose and timing of more than 60 rulemakings and other notice-and-comment proceedings the Plan recommends for FCC action. Executing these steps will accelerate deployment and adoption of robust, affordable broadband for all Americans, helping 100 million U.S. homes get affordable access to actual download speeds of at least 100 megabits over the next decade; promote innovation, investment, competition, and consumer interests throughout the broadband ecosystem; and advance the use of broadband for key national priorities, including public safety, health care, and education.

The top objective of the plan is to "promote world-leading mobile broadband infrastructure and innovation," including making an additional 500 MHz of spectrum available for mobile broadband within the next 10 years, increasing opportunities for unlicensed devices and innovative spectrum access models, and expanding incentives and mechanisms to reallocate or repurpose spectrum to higher-valued uses.

The plan also seeks to accelerate universal broadband access and adoption, and advance national purposes such as education and health care. Also on the agenda is the advance of robust and secure public safety communications networks, including creation of a nationwide interoperable public safety wireless broadband network, promoting cybersecurity, and aiding in the transition to next-generation 911 and alerting systems.

TV White Space Study Group

The IEEE 802.19 Wireless Coexistence Working Group received approval in December 2009 for a new project, IEEE P802.19.1, to develop a standard for coexistence between wireless networks operating in the TV white space.

In November 2008, the U.S. Federal Communication Commission (FCC) issued a report and order providing the rules under which unlicensed wireless devices can operate in unused TV channels, referred to as "TV white space." Regulators in other countries have also been considering TV white space regulations. These TV white space channels are those not utilized in a given geographic location for TV broadcasts, CATV headends, or other licensed devices (such as professional wireless microphones).

The IEEE 802.22 Working Group has been developing a standard for wireless regional area networks (WRANs) in the TV white space. And recently the IEEE 802.11 working group initiated a project to develop an amendment to the 802.11 wireless local area network (WLAN) standard for operation in the TV white space.

The regulations for operation in the TV white space do not restrict access to any particular type of wireless device. Since these wireless networks are unlicensed, they do not have exclusive access to the TV white space. In some locations there may be many TV white space channels while in other locations there may only be a few.

Standardized coexistence mechanisms between wireless networks operating in the unlicensed TV white space spectrum are critical to prevent interference between different wireless technologies. The P802.19.1 project provides an excellent consensus-driven forum open to all stakeholders. Information is available on the web site at http://www.ieee802.org/19/

FCC Adopts Order to Clear 700 MHz Frequencies

On January 15, 2010, the Federal Communications Commission adopted an Order and Further Notice of Proposed Rulemaking prohibiting the further distribution and sale of devices that operate in the 700 MHz frequency. This action helps complete an important component of the DTV Transition by clearing the 700 MHz band to enable the rollout of communications services for public safety and the deployment of next generation 4G wireless devices for consumers.

The order will primarily impact the use of wireless microphone systems that currently operate in the 700 MHz band. These unlicensed devices cannot continue to operate in this band because they may cause harmful interference to public safety entities and next generation consumer devices that will be utilizing the 700 MHz frequency. Thus, the Commission is making clear that no devices utilizing this frequency may be sold or distributed. In order to ensure that individuals and groups currently using unauthorized devices in this band have ample time to transition to appropriate frequencies, the FCC is providing a sunset period until June 12, 2010, one year from the DTV Transition.

The Commission is also unveiling an aggressive consumer outreach plan in order to assist consumers who have previously purchased wireless microphone systems

and other related devices that utilized the 700 MHz band. Through the Commission's website, www.fcc.gov/cgb/wirelessmicrophones, consumers can learn whether their wireless device is currently operating in the prohibited band and whether their devices may be retuned to operate on another band.

FCC Makes Declaratory Ruling on Wireless Towers

A November 2009 Declaratory Ruling by the FCC promotes the deployment of broadband and other wireless services by reducing delays in the construction and improvement of wireless networks. Wireless operators must generally obtain State and local zoning approvals before building wireless towers or attaching equipment to pre-existing structures. To encourage the expansion of wireless networks, Congress has required these entities to act "within a reasonable period of time" on such requests.

In many cases, delays in the zoning process have hindered the deployment of new wireless infrastructure. Accordingly, the FCC has defined timeframes for state and local action on wireless facilities siting requests, while also preserving the authority of states and localities to make the ultimate determination on local zoning and land use policies.

The first part of the Declaratory Ruling concludes that there should be a "reasonable time" beyond which inaction on a siting application constitutes a "failure to act." In the event a State or local government fails to act within the appropriate time period, the applicant is entitled to bring an action in court under Section 332(c)(7)(B)(v) of the Communications Act, and the court will determine whether the delay was in fact unreasonable under all the circumstances of the case. The Commission concluded that the record supports setting timeframes of 90 days for the review of collocation applications; and 150 days for the review of siting applications other than collocations. The ruling also declares that a state or local government cannot deny a wireless service facility siting application because service is available from another provider.

Multi-Gigabit Wireless Specification

Wireless Gigabit Alliance (WiGig, www.wirelessgigabitalliance.org), an organization founded in May 2009 to advance the adoption and widespread use of 60 GHz wireless technology worldwide, has announced the completion of its unified wireless specification. The WiGig specification enables high performance wireless display and audio and provides data transfer rates more than 10 time faster than today's wireless LANs, extending Wi-Fi technology while supporting backward compatibility with existing Wi-Fi devices. The WiGig version 1.0 specification includes the following key elements:

- Supports data transmission rates up to 7 Gbps – more than 10 times faster than the highest 802.11n rate
- Supplements and extends the 802.11 Medium Access Control (MAC) layer and is backward compatible with the IEEE 802.11 standard
- Physical layer enables both the low power and the high performance WiGig devices, guaranteeing interoperability and communication at gigabit rates
- Protocol adaptation layers are being developed to support specific system interfaces including data buses for PC peripherals an display interfaces for HDTVs, monitors and projectors
- Support for beamforming, enabling robust communication at distances beyond 10 meters
- Widely used advanced security and power management for WiGig devices

LXI Consortium Elects Board and Officers

The LXI Consortium recently held its annual elections for the Board of Directors, officers and committee chairs. Von Campbell of Agilent Technologies will continue to serve as the Consortium's president. He holds a bachelor's degree in electrical engineering from Purdue University and a master's in electrical engineering from Stanford University. Campbell oversees Agilent's involvement in multiple industry consortia.

The Board of Directors will consist of three appointed directors from the Strategic Members and two elected directors from the Participating Members:

- Von Campbell, Agilent Technologies
- Jochen Wolle, Rohde & Schwarz
- Bob Stasonis, Pickering Interfaces
- Rob Purser, The MathWorks
- David Ashley Poole, Aeroflex

Other officers elected by the Board include:

- Technical Committee Chair: David Owen, Pickering Interfaces
- Conformance Committee Chair: Jochen Wolle, Rohde & Schwarz
- Marketing Committee Co-Chairs: Elizabeth Persico, Agilent Technologies; and Bob Stasonis, Pickering Interfaces
- Executive Director: Bob Helsel, Bode Enterprises, LLC

Since the beginning of 2009, the LXI Consortium has grown steadily, both in terms of membership and in the number of compliant products available.

40 and 100 Gb/s Ethernet Protocols Drafted

Ethernet protocols with operating speeds of 40 Gb/s and 100 Gb/s are closer to reality. Project completion and final approval as a standard are expected in June 2010. The IEEE 802 Executive Committee approved forwarding the draft of the next higher speed Ethernet standard for the final of two stages of balloting. Once the ballot has been completed, the draft standard will be submitted for approval by the IEEE-SA Standards Board as an IEEE standard.

IEEE P802.3ba will be known by its full name of "IEEE

Standard for Information Technology— Telecommunications and Information Exchange Between Systems – Local and Metropolitan Area Networks – Specific Requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications – Amendment: Media Access Control Parameters, Physical Layers and Management Parameters for 40 Gb/s and 100 Gb/s Operation."

The project aims to extend the existing IEEE 802.3 Ethernet protocol to operating speeds of 40 Gb/s and 100 Gb/s in order to provide a significant increase in bandwidth while maintaining maximum compatibility with the installed base of IEEE 802.3 interfaces, previous investment in research and development, and principles of network operation and management.

In addition, a related standard, the International Telecommunication Union's Telecommunication Standardization Sector (ITU-T) Recommendation G.709, "Interfaces for the optical transport network (OTN)," is being revised to support transport of 40 Gb/s and 100 Gb/s Ethernet over the OTN and is on track for approval.

For more information on the IEEE P802.3ba 40Gb/s and 100Gb/s Ethernet Task Force, visit http://www.ieee802.org/3/ba/

Major EMC Committees Join Forces

The aim of EMC (electromagnetic compatibility) is to ensure the reliability and safety of all types of systems wherever they are used and exposed to electromagnetic environments. Both of the principal IEC TCs (Technical Committees) that deal with EMC – CISPR, the International Special Committee on Radio Interference, and TC 77: Electromagnetic compatibility – held joint meetings in late 2009.

CISPR deals with the protection of radio reception against the unwanted effects of interference caused or emitted by all types of electrical appliances. On one hand, it sets the limits of interference that enable different devices to function in the same electromagnetic environment. On the other, it deals with the instrumentation and the various methods used for measuring those emission levels.

TC 77 prepares International Standards and TRs (Technical Reports) that deal with the correct operation of devices or equipment subjected to electromagnetic disturbance, including network overloading. TC 77 has a horizontal function since it exists to serve the work of many other TCs.

Work in progress involving both CISPR and TC 77 includes the following:

- Several SCs (Subcommittees) in CISPR are currently working on introducing the new RMS-Average (root mean square) detector, which was developed to provide better protection for digital broadcast services.
- Work is continuing in CISPR/A to develop the use of FFT (fast Fourier transform) measurements. Potentially, this could dramatically reduce the test

time for emission measurements.

- CISPR/A is also working on reference site measurements and antenna calibration. Both are important reference documents for test equipment used in emission measurements.
- CISPR/B has set up two maintenance teams. One is studying the important area of micro-generation technologies, or Grid Connected Power Conditioners. The other is developing a new method of measuring emissions from microwave ovens based on Amplitude Probability Density.
- CISPR/D is working on developing suitable standards to cover new vehicular technologies such as hybrid and all-electric drive systems.
- CISPR/F has introduced radiated emissions testing for battery-driven products that previously might not have been the object of testing.
- CISPR/I is continuing with work on new International Standards for multimedia products.

On a general level all the CISPR SCs work together with IEC TCs and external organizations to develop standards that continue to provide adequate protection for all users of the radio spectrum, while at the same time make use of the latest measurement techniques and cover the ever-converging technologies seen in products in the marketplace.

The Member Bodies of CISPR are CIGRE (International Council on Large Electric Systems), EBU (European Broadcasting Union), ETSI (European Telecommunications Standards Institute), IARU (International Amateur Radio Union), and ITU-R (International Telecommunications Union – Radio-communications Sector).

For more information, see the International Electrotechnical Commission (IEC) web site: www.iec.ch

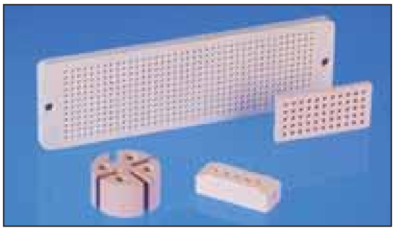
Alliance Holds Organizational Meeting

The ProTECTS (Promotion of Two-Way Emergency Communication and Tracking Systems) Alliance held its first organizational meeting, in Phoenix, Ariz., immediately following the annual Iridium Communications Inc. Partners Conference in late January. The ProTECTS Alliance is intended to serve as a bridge connecting industry, government, the international search-and-rescue (SAR) community and end users.

Since its inception in late 2009, the ProTECTS Alliance has reached a membership level of 38 companies. Membership is open to mobile satellite companies, service providers, product developers, manufacturers, system integrators, network operators, resellers, distributors, retailers, users, consultants, SAR organizations, first responders, trade associations, regulatory bodies and non-governmental organizations (NGO).

Iridium will serve as a facilitator for the ProTECTS Alliance and will provide assistance in hosting meetings and distributing information through the Iridium Web site, www.iridium.com

Substrates & Laminates



Alumina Fixtures for High Temp Brazing

Morgan Technical Ceramics' Wesgo/Duramic business (MTC-Wesgo/Duramic) offers custom made alumina fixtures used to isolate and insulate metal components during high temperature brazing processes. Design and configuration of MTC-Wesgo/Duramic Alumina Fixtures are highly flexible. Both simple and intricate features, including small diameter holes, can be machined to tight tolerances to meet customer requirements. Cleanliness is ensured through a specially designed air firing process. Also, during the brazing process, thermal expansion of the fixture is matched to that of the Alumina insulator used for ceramic-to-metal seals.

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Ceramic Laminates

As an alternative to PTFE circuit materials, Rogers RO4000 glass-reinforced hydrocarbon/ceramic laminates deliver high-frequency performance even though they can be processed with the same low-cost methods used for epoxy/glass (FR-4) materials. Now available with a dielectric constant of 6.15 (RO4360 laminates), these laminates exhibit a low Z-axis coefficient of thermal expansion (CTE) for dependable plated-through-hole (PTH) quality in multi-layer circuit and package designs. RO4000 laminates also feature a high glass transition temperature (greater than +280° C) and excellent thermal conductivity.

Rogers Corporation
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Copper-Clad Laminates

Park Electrochemical Corp. introduces Mercurywave™ 9350. Mercurywave 9350, which has a controlled dielectric constant of 3.5, is available in both copper-clad laminate and prepreg product forms. The dielectric constant of Mercurywave 9350 material has been independently tested to 43 GHz and found to be stable at 3.5. Park offers Mercurywave 9350 copper-clad laminates in a wide array of thicknesses, including thin core and industry standard thicknesses of .020 and .030 inches. Mercurywave 9350 is lead-free assembly compatible and RoHS compliant and is well suited to RF and Microwave applications such as broadband communications, WiFi/WiMax and RFID, as well as power amplifier, filter, combiner, radar and guidance devices.

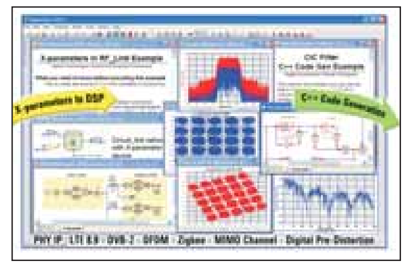
Park Electrochemical Corp.
www.parkelectro.com

EDA Tools

New Software Release

Modelithics, Inc. has released an enhanced version of their popular linear and non-linear device and system level component model library software. The Modelithics COMPLETE Library version 7.0 encompasses all passive and active models currently available from Modelithics for designers using Agilent Technologies' Advanced Design System EDA software. This upgrade also introduces 32 new Modelithics® Global Models for passive RLCs, and non-linear models for diodes, switches, amplifiers, and transistors. Additionally, Modelithics announced their new pricing strategy. The price of the Modelithics COMPLETE Library will now be available at the same cost of the CLR Library alone. All customers with current Platinum Maintenance contracts for the CLR Library will receive upgrades to the Modelithics COMPLETE Library; hence, will receive licensing for the NLD (diode), NLT (transistor) and SLC (system level components) Libraries as well.

Modelithics, Inc.
www.modelithics.com



Software Generates C++ Code

Agilent Technologies Inc. announced that its new release of SystemVue software generates C++ code and supports X-parameter models for connecting communications system-level design to baseband DSP and RF design flows. SystemVue 2010.01 also includes 4G applications for digital pre-distortion and MIMO channel modeling, as well as updates to its LTE, DVB-2, OFDM, and ZigBee reference libraries. The latest version introduces a new export capability for C++ source code generation and dynamic linked library (DLL) models. The export capability also is included in the new W1718 C++ code generator. Export of compiled models is free of charge with the W1461 SystemVue base platform. Pricing for the SystemVue environment starts at approximately $17,000.

Agilent Technologies, Inc.
www.agilent.com

White Paper on Grounding Concepts in EM Simulators

One of the most misunderstood concepts with electromagnetic (EM) and circuit simulators and their results is how "ground" is defined and used within them., This white paper, written by EM expert Dr. John Dunn, demon-

strates the importance of correctly selecting and assigning “ground” within EM simulators and how it is essential for successfully predicting the performance of board, package, and their associated interconnects. Specific examples at the board, package, and chip level are discussed as well as tips that can be used at the circuit level to aid ground studies. The white paper is available at www.awrcorp.com/axiem

AWR Corporation
www.awrcorp.com

New Modeling Standard

Agilent Technologies Inc. announced its support for IBIS-AMI (Algorithmic Modeling Interface)—a modeling standard for SerDes transceivers created to enable fast, statistically significant analysis of high-speed serial links. Agilent’s work in support of this standard is expected to yield the commercial release of a new version of Advanced Design System, ADS 2010, which will allow signal integrity designers to integrate IBIS-AMI models into their ADS projects.

Agilent EEsof
www.agilent.com/find/eesof

Component Test Products

PXI Programmable Amplifier and Attenuator

National Instruments today 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 (VSAs) to measure low-level signals. As part of the NI PXI platform, the new attenuator and amplifier are optimized for use with NI LabVIEW graphical system design environment and NI LabWindows™/CVI ANSI C software development environment as well as C, C++ and .NET programming.

National Instruments
www.ni.com/rf

Connectivity Test Appliance

Willtek Communications has announced the 1491 WiFi Connectivity Test Package, which satisfies requirements for wireless LAN device testing. Service centers will use this new product for easy Go/NoGo testing of WiFi-enabled devices, including smartphones and even routers. The new test solution from Willtek is immediately available. Willtek’s test package tells faulty from intact WiFi devices. A test protocol provides adequate documentation of the results. The associated test software guides the user through a simple connectivity test. Along with a Pass/Fail verdict, it provides additional technical information such as the MAC address and several transmit and receive parameters.

Willtek Communications
www.willtek.com

General Purpose Test Environment

For high-performance, high-speed testing of RF and microwave devices, Aeroflex introduces the SMART^E™ 5300 general-purpose test environment. The DC to 40 GHz SMART^E™ 5300 is unique in its ability to test, monitor, and control any Device Under Test (DUT) within a single test environment. SMART^E™ 5300 is designed for parametric and functional testing in the military/aerospace and high-performance commercial markets. It is currently available for delivery 24 to 28 weeks upon receipt of order. Because of the high degree of customization and scalability, prices can vary considerably.

Aeroflex, Inc.
www.aeroflex.com

Product Catalog

Keithley’s 2010 Test & Measurement Product Catalog is a complete test and measurement resource. The CD is arranged by product type and application area with sections including: digital multimeters and systems; switching and control; RF/microwave switching; power supplies optimized for telecom device test; source and measure products; low level measurements and sourcing; function/pulse/ arbitrary/pattern generators; semiconductor test; optoelectronics test; data acquisition products; and test and measurement accessories.

Keithley Instruments
www.keithley.com

LNA With a Bypass Mode Improves Overload Resistance for Mobile TV

By Chin Leong Lim
Avago Technologies

This article is a case history describing the design choices and tradeoff considerations required to meet a particular set of customer specifications

Television (TV) stations broadcast in the very high frequency (VHF; 30-300 MHz) and ultra high frequency (UHF; 300-900 MHz) bands. Opposite to the small cell philosophy popularized by modern wireless telephone service, free-to-air TV broadcast is historically driven by the need to extend the area of coverage, as doing so will garner a larger audience. So, commercial TV transmissions utilize tall aerial towers and power level in the 10-50 kW range in order to maximize their radio horizon. In comparison, the transmit power of a cellular repeater is many magnitude orders lower at ~50 W.

Mobile TV allows the commuting public to watch TV programs on hand-held or portable devices [1]. The mobile TV functionality can be incorporated into notebook personal computers, Personal Digital Assistant (PDA), In-Car-Entertainment (ICE) system [2], and cellular handsets, etc. Technically, the mobile TV poses a unique problem in that the distance between the transmitter and receiver can change considerably as the user travels to different locations. Given that only miniature aerials (i.e., low gain aerials) can be embedded in these portable products, the TV receiver must understandably be designed with very high sensitivity to permit clear reception at the coverage fringes. Unfortunately, the large RF gain will result in overloading of the mixer and IF stages when the user moves into the proximity of high power TV transmitters. Once the signal waveform is distorted by an over-driven amplifier or a mixer, it cannot be corrected by simple filtering or signal processing.

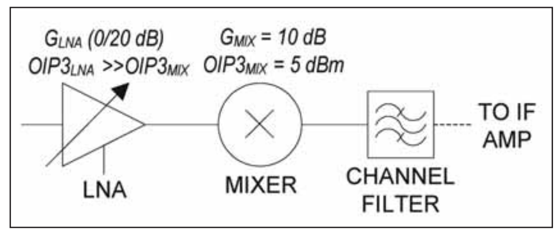


Figure 1 · Block diagram of receiver front-end with a variable-gain LNA stage. Mixer performance is reflective of consumer-grade TV receiver RFICs.

Input signal	LNA gain (dB)	Total gain (dB)	Total output IP3 (dBm)	Total input IP3 (dBm)
Weak	20	30	5	–25
Strong	0	10	5	–5

Table 1 · Gain and IP3 values for the receiver front-end in Figure 1.

Although it is technically possible to engineer higher overload tolerance in the mixer and IF stages, the required hardware will be too prohibitively expensive for this price-driven product category. Practical implementations of the mobile TV receiver almost universally rely on reducing the overall gain in the presence of strong signals as this is a far more cost effective solution to the overloading problem—hence the need for gain-controlled RF and intermediate frequency (IF) amplifier stages. The ability to vary RF gain greatly relaxes the linearity requirement in the mixer stage [3] and therefore allows low cost radio

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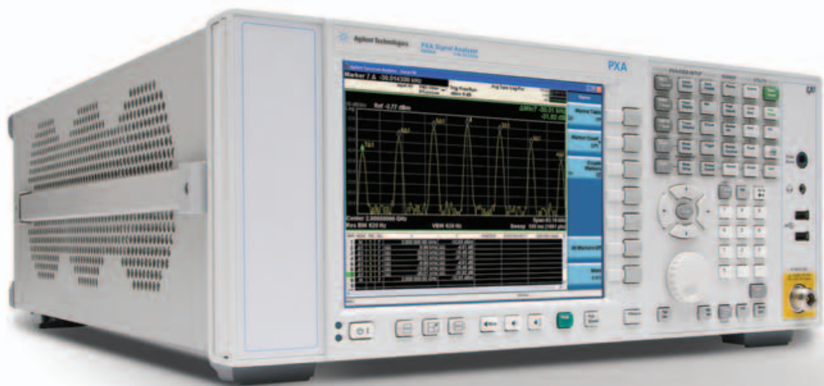

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Input shunt	Medium	Medium	Input match, selectivity*
LNA stage bypass	High	Highest	None
Reduce bias current	Low	Lowest	Linearity
*high impedance damping version only			

Table 2 · Cost-performance comparison of the various LNA gain control methods.

frequency integrated circuit (RFIC) with lesser linearity performance to be used for implementing the receiver. A cascade analysis of a receiver front-end with switchable LNA gain (Fig. 1 and Table 1) shows that the overall third order input intercept point (IIP3) can be improved by the same amount as the gain change. Hence the receiver that can alter its RF gain will have better large signal handling compared to one with a fixed gain.

The LNA gain can be varied automatically and without additional control circuit by making use of the wideband automatic gain control (AGC) function that is ubiquitous to contemporary broadcast receiver RFICs [4, 5]. Because the wideband AGC is derived from the part of the signal chain before the channel selecting filters, it is also able to respond to overload from adjacent channel transmissions.

A Survey of Common Topologies for LNA Gain Reduction

One widely adopted approach to reduce the RF gain is to shunt part of the signal to ground just before the LNA stage (Fig. 2a). This scheme owes its popularity to the minimal number of RF switching elements. However, it suffers from a major weakness in that the closed switch introduces a large impedance mismatch at the LNA input, and the consequential standing waves may affect other system parameters. To maximize the gain reduction, a variation of this technique connects the damping element to the high impedance side or "hot" end of the LNA parallel resonant network; this technique is popular in automotive sound and home TV broadcast receivers because they use variable tuning parallel resonant LC filters a.k.a. "pre-selectors." However, by shorting the tuned circuit, the pre-LNA RF selectivity is sacrificed for a larger gain control range [6].

An alternate approach bypasses the LNA stage with a pair of RF switches when the received signal is overloading the stages further down the receive signal chain; i.e., mixer or IF amplifiers. The non-amplified signal from the aerial is then directly routed to the down-converter RFIC (Fig. 2b). As long as the components in the alternate route (e.g., aerial, microstrip trace in the bypass path and the input to the down-converter RFIC) are designed with the same characteristics impedance (e.g., 75 Ω), no mismatch is introduced into the signal path. Nevertheless, using a pair of RF switches results in a higher circuit complexity than the other methods.

A third method reduces RF amplification by lowering the LNA device's quiescent current (Fig. 2c) and has seen wide adoption in LNA designs based on dual-gate MOSFET [7], cascode [8], differential pair of common emitter amplifier [3, 7] and quadrature pair [3]. These types of amplifiers are characterized by additional non-RF input terminals (e.g., G2 of the dual gate MOSFET and the base of the cascode's common base stage) that can be conveniently used for controlling the bias current. This method results in the lowest circuit complexity as no switching element is required, but suffers from progressively poorer linearity as the collector/drain current is reduced from the device normal DC operating point [9].

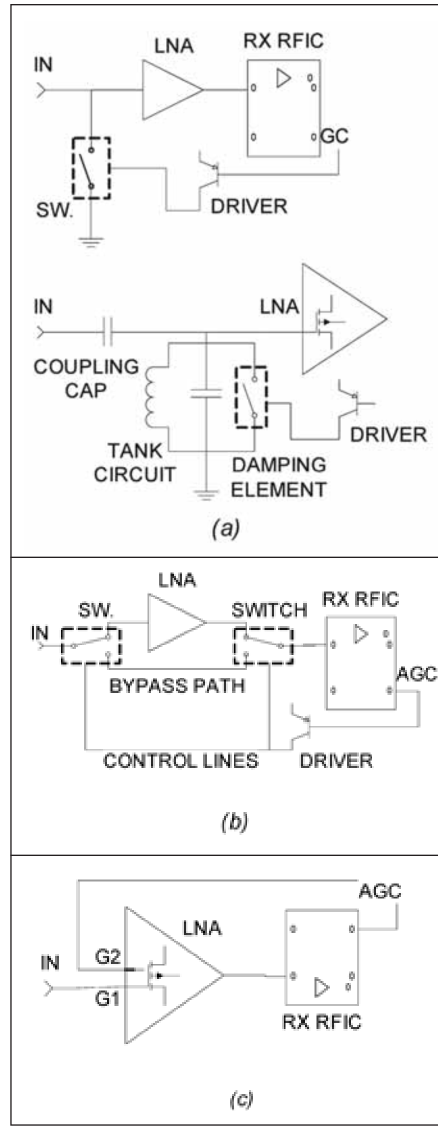

Figure 2 · Three common methods for RF gain control in consumer-grade broadcast receivers: (a) LNA input damping, (b) LNA bypass switching and (c) gate bias modulation in a dual gate MOSFET LNA. The LNA gain is automatically reduced based on feedback from the down-converter RFIC's AGC.

Parameter	Target	This work
LNA Gain (dB)	15 ~ 20	18.5 ~ 21
LNA noise figure (dB)	< 1.3	0.8 ~ 1.3
LNA IIP3 (dBm)	≥ 6	9.5 ~ 12.5
Bypass Loss (dB)	> –5	–3.8 ~ –4.5
bypass IIP3 (dBm)	≥ 20	> 20
LNA Current Id (mA)	< 200	30
Test frequency range: 47-870 MHz		

Table 3 · Comparison of customer's target requirements versus this design's measured results.

Application Background

The customer, a maker of consumer TVs, requested a reference design that must satisfy the RF specifications listed in Table 3. The intended application is LNA of a dual mode (analog/digital) mobile TV receiver in the 47-870 MHz range. In addition to the performance requirements, low component count and cost of implementation are also crucial to customer acceptance

Initially, existing MMICs from Avago Technologies' product portfolio, which consist of field effect transistors as both amplifying and switching elements (e.g., MGA-72563 or MGA-785T6), appeared to be the best candidates. A highly integrated monolithic solution such as one of these will result in the lowest cost, footprint and current consumption. After checking the devices' product specifications, we realized that these MMICs cannot fulfill the wide bandwidth and linearity requirements. Finally, we settled on a solution that combines a wideband, high linearity MMIC LNA (MGA-68563) with an external RF switch consisting of PIN diodes.

Component Selection and Circuit Design

This MGA-68563 MMIC is a single stage GaAs pHEMT amplifier with gate width of 800 microns (Fig. 3). The device gate is connected to an internal current mirror to compensate for process variations and to minimize the effects of threshold voltage variations. It utilizes lossy negative feedback for circuit stability and to flatten the frequency response to a 3 dB deviation from 0.1 to 1 GHz [10]. The MMIC is verified to be unconditionally stable as it has larger than unity Rollett stability factor values ($k \geq 1$) in the 0.1 to 4.0 GHz range.

As this MMIC was originally designed for single-frequency applications, its product specification recommended a simple input matching network consisting of one series inductor. Due to the previously described heavy internal feedback, no output matching is required as the output return loss is already good (ORL ≥ 10 dB) below 1 GHz. However, it is difficult to match the input over the 4-octave frequency range (47-870 MHz) using conventional LC networks. An RF transformer can match the input over the required bandwidth, but it was ruled out on cost and height reasons. So, instead of matching the device conventionally, the FET drain current (Ids) is varied above the 10 mA nominal value to optimize the input return loss (IRL). Although the required IRL (≥ 10 dB) is already met using a 20 mA Ids current, a final value of 30 mA was chosen because it allows more margin for the IRL to be degraded by the subsequent addition of the PIN diode switching circuit. The MMIC pin 4 controls the current flow through internal bias generator

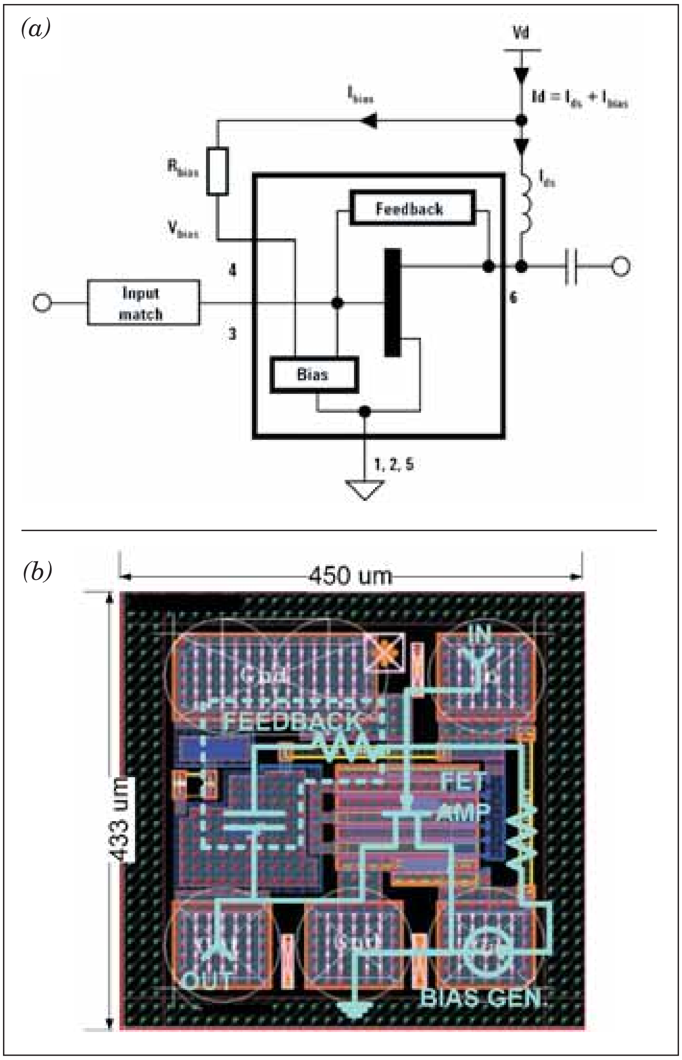

Figure 3 · MGA-68563 MMIC LNA (a) The simplified equivalent circuit where the MMIC on-chip components are shown enclosed by the thick-lined box while outside the box are the external components needed for input matching, bias control and drain supply decoupling. (b) The die layout with the functional components superimposed over it.

via an external resistor R1 (Figs. 3a, 5b) and therefore, redimensioning R1 conveniently changes Ids while the supply voltage Vd is fixed at 3.0 V. An incidental benefit that can be expected from the 300% increase in Ids is higher linearity.

The first design iteration required four PIN diodes to implement the switch by-passable LNA (Fig. 5a). This configuration is a fairly standard way to implement a double pole double throw (DPDT) switch using PIN diodes and is common in tower mounted LNAs, which must be bypassed during transmit. The circuit operates by turning on the upper pair of PIN diodes while the lower pair is zero

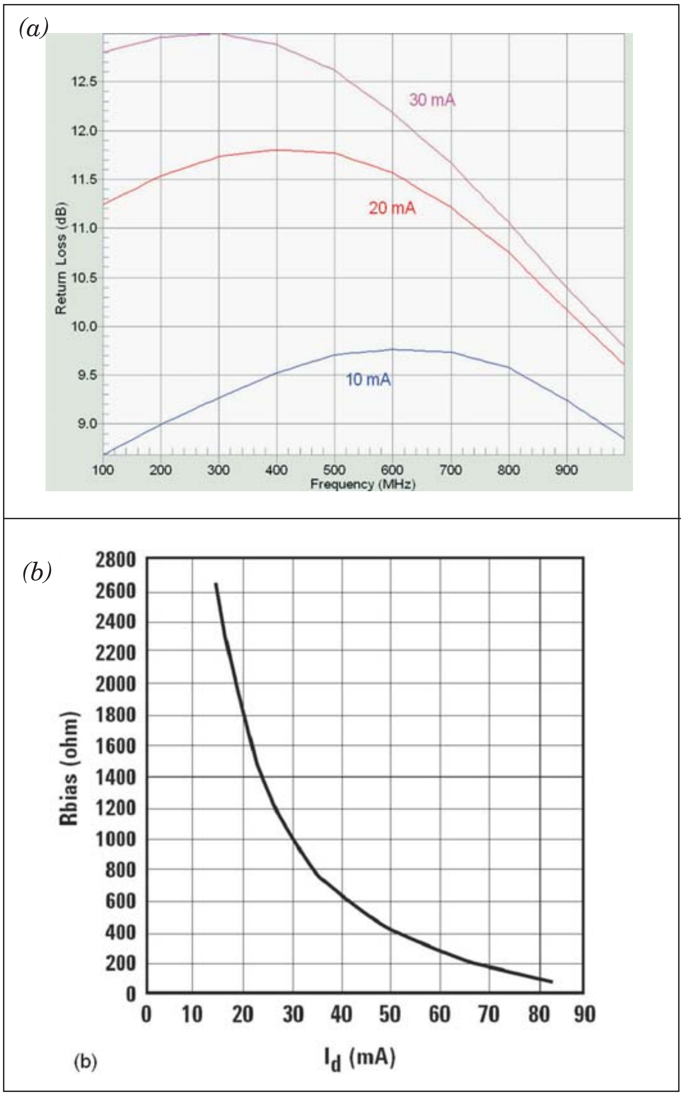

Figure 4 · (a) IRL vs. frequency as function of the FET drain current, Ids. IRL improves with higher Ids and so increasing Ids can obviate the need for input matching, and (b) The relationship between R1 (Rbias) and Ids.

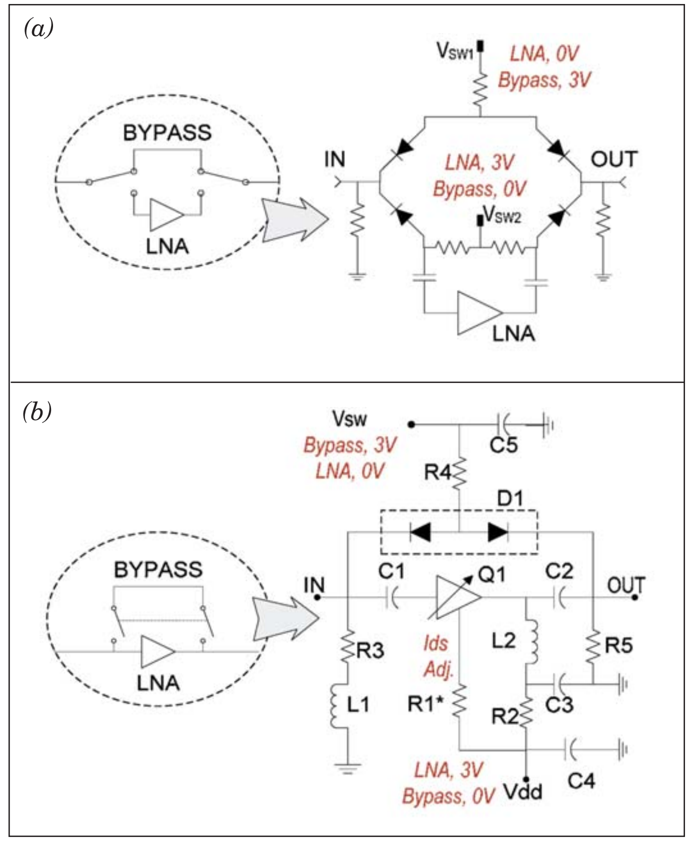

Figure 5 · Evolution of the switching circuit (a) initial four PIN diode design and (b) eventual design with reduced number of PIN diodes.

biased and vice-versa. During normal operation, only the lower PIN diode pair is turned on and so the RF signal is amplified by the LNA. When it is necessary to reduce RF gain, only the upper PIN diode pair is turned on in order to route the signal around the LNA (i.e., bypass mode). The resistors are required for regulating the PIN diodes' forward current and for isolating the RF signals from the logic control ports (VSW1 and VSW2). Despite meeting the customer's performance expectations, the component count raised a customer objection.

Following the customer feedback, a different switch circuit arrangement was devised to halve the previous design's number of PIN diodes. In the revised design as shown in Figure 5b, only the bypass path is connected or disconnected from the input and output ports by PIN diodes in a greatly simplified double pole single throw (DPST) arrangement.

Due to the absence of switching elements in LNA path, the LNA supply (Vdd) has to be switched off during the bypass mode in order to make use of the intrinsic isolation of the unbiased FET. A trade-off of this design is that the RL of the bypass path is poorer due to being shunted by the finite gate and drain impedances of the unbiased FET.

During normal LNA operation, the PIN diodes supply is turned off (V_{SW} = 0V) while the LNA supply is restored to 3V. However, the zero-biased PIN diodes have some parasitic capacitances that allow the higher frequencies to pass through. So, the LNA's gain and RL are compromised by the incomplete disconnection of the bypass path from the input and output ports.

L1 and L2 are ferrite beads inductors, and their function in the PIN diodes' and the MMIC's biasing networks is to present high impedances over the entire frequency range (Fig. 5b). Without L1's choking action, part of the input signal will be shunted to ground via R3's parallel-connected parasitic capacitance [11]. Measurement of a

Comp.	Value / part number
C1	1 nF
C2	47 pF
C3	1 nF
C4	1 µF
C5	1 nF
D1	Hsmp-3893/E
L1	Murata BLM18RK102SN
L2	Murata BLM18RK102SN
Q1	MGA-68563
R1	270 R
R2	4.7 R
R3	270 R
R4	270 R
R5	270 R

Table 4 · Value / part number of components associated with the circuit diagram in Figure 5b.

prototype without L1 provides experimental verification that the aforementioned signal loss is detrimental to LNA noise figure (Fig. 8). C3-C5 decouple RF signals from the DC supply lines and are dimensioned to be low reactance ($X_C \leq 5\ \Omega$) at the lowest operating frequency. C1 and C2 provide DC blocking at the MMIC input and output. A small value is deliberately chosen for C2 in order to create a high pass response that can compensate for the MMIC's intrinsic gain roll-off at high frequencies. R1 and R2 control the MMIC supply current, and they are dimensioned for 30 mA at Vdd of 3V. R3-R5 limit the PIN diodes' forward bias to ~2.5 mA per diode at VSW of 3V.

Logically, it is possible to further simplify the circuit by using only one PIN diode in D1. However, there is no advantage to doing so as the diode pair occupies the same SOT-23 or SOT-323 package as a single PIN diode, and the price difference is also negligible. Additionally, the PIN diodes pair confers two important performance advantages: (a) the series connection halves the parasitic capacitance, and (b) as the even-order harmonics generated by the anti-series PIN diodes are out of phase, they will self-cancel [12].

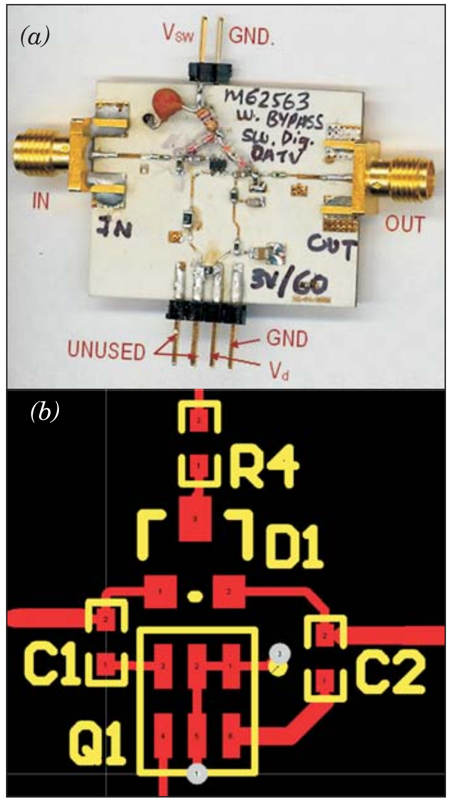

Figure 6 · (a) The "proof-of-concept" prototype; (b) the PCB layout revised to accommodate an SOT-23 surface mount PIN diode pair in the position D1.

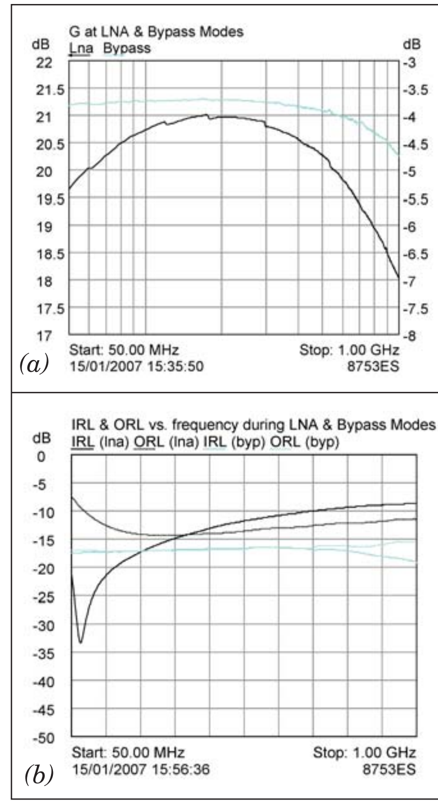

Figure 7 · Test results for both LNA and bypass modes of operation (a) gain vs. frequency and (b) input and output RL vs. frequency.

Assembly of the Prototype

For a quick evaluation of the new design's RF performances, the "proof of concept" prototype was assembled on a printed circuit board (PCB) that has been previously designed for another non-bypassed LNA application [13]. The PCB is composed of micro-strip traces on 10 mil thick Rogers RO4350B dielectric material [14]. The PIN diodes and their associated biasing components were retrofitted to the existing PCB by directly soldering them to the leads/pads of the other components (Fig. 6a). Two pieces of 1N5719 axial-lead glass diodes [15] were used as the switching elements D1. These diodes will be eventually replaced by the SOT packaged PIN diode pair HSMP-3893/E [16] in a later PCB layout iteration (Fig. 6b).

Measurement Results and Discussion

The LNA's median gain is 19.8 dB with a 1.3 dB variation within the frequency range of interest (Fig. 7a). The frequency response is flattened by gently attenuating signals below 200 MHz using the high pass response imparted by an atypically small value of DC blocking capacitor C2. The gain roll-off at the upper frequency end is consistent with the MMIC characteristics and possibly with the negative feedback through the unbiased PIN diodes' parasitic capacitance.

The bypass mode has an attenuation of –3.8 to –4.5 dB over frequency (Fig. 7a). The bypass loss is mainly caused by the PIN diodes' parasitic series inductances. PCB dissipation, the FET terminal impedances and

R4's parasitic parallel capacitance also influence the bypass loss but to a smaller extent. However, no attempt was made to improve the present design's bypass loss as it is well within the customer-requested –5 dB specification limit.

In the bypass mode, both IRL and ORL are consistently good (better than –17 dB) in the specified frequency range. This parameter is primarily affected by how closely the unbiased FET gate and drain approximate open circuits. Both IRL and ORL fare slightly poorer during LNA operation with a worst case specification of –7 dB occurring at the output side on the lowest frequencies. The poor ORL below 70 MHz is caused by the small value capacitance in C2 and is accepted as a trade-off for a flatter frequency response.

Figure 8a compares the LNA noise figure with and without the ferrite bead inductor L1 in the prototype. It is obvious that the target noise figure specification (F ≤ 1.3 dB) cannot be met without L1. Comparing the two noise figure traces, it can be surmised that signal loss attributable to R3's parasitic capacitance is in the 0.3-0.6 dB range and, this has correspondingly pushed the noise figure up by the same amount. There is significantly more noise figure variation in the band with the inclusion of L1 than without (0.5 dB vs. 0.2 dB). However, no remedial action is planned as this is not a critical parameter. We hypothesize that this greater variation is caused by the ferrite bead's progressively reduced choking capability with increasing frequency, especially above the ~100 MHz self resonant frequency (SRF) that was estimated from the manufacturer-provided performance graphs [17].

The LNA's OIP3 is measured at several evenly spaced frequency points within the mobile TV band using a two-tone input power level of –20 dBm. The IIP3 is calculated by subtracting the measured gain from the OIP3 data. Within the measurement range, the OIP3 does not go lower than 30.3 dBm with a maximum 0.8 dB variation within the band (Fig. 8b). The linearity improvement of ~10 dB over the datasheet's nominal value (20 dBm) [10] can be attributed to this design's higher Ids (30 mA vs. 10 mA).

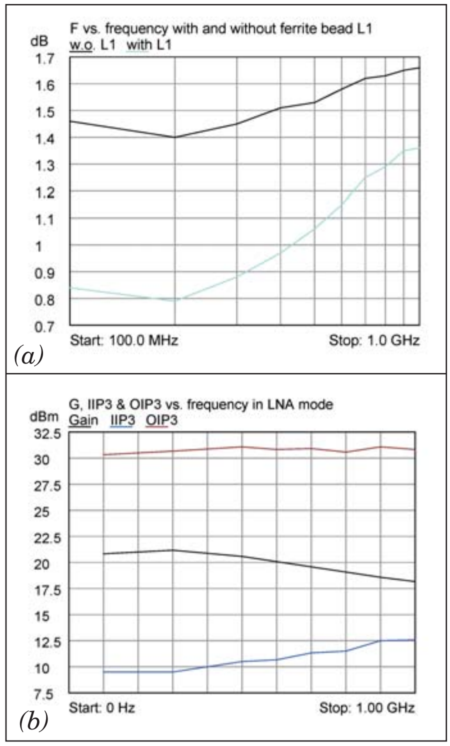

Figure 8 · LNA mode parameters: (a) noise figure vs. frequency when the prototype is tested with and without (w.o.) the L1 ferrite bead inductor and (b) IIP3 and OIP3 vs. frequency.

Conclusion

A wideband LNA with bypass function for mobile TV receivers requiring high overload tolerance was implemented using a combination of low noise pHEMT MMIC and PIN diodes. By increasing the FET Ids three times over the nominal value, the IRL can be improved to the extent of obviating the need for input matching. For cost and space saving reasons, the number of PIN diodes used to bypass the LNA stage was reduced from 4 to 2 by changing from the conventional DPDT switch arrangement to a DPST one. The design also satisfies all other target specifications set by the customer. A promising line of investigation for the future, especially if there is a customer request to further improve the LNA noise figure, is to replace the present ferrite bead inductor with higher SRF versions in order to lessen the noise figure variation with frequency.

Acknowledgement

The author thanks M. Sharifah for assembling the prototypes, R. Waugh for the mentoring on PIN diodes, S. A. Asrul for reviewing the paper, and the management of Avago Technologies for approving the publication of this work.

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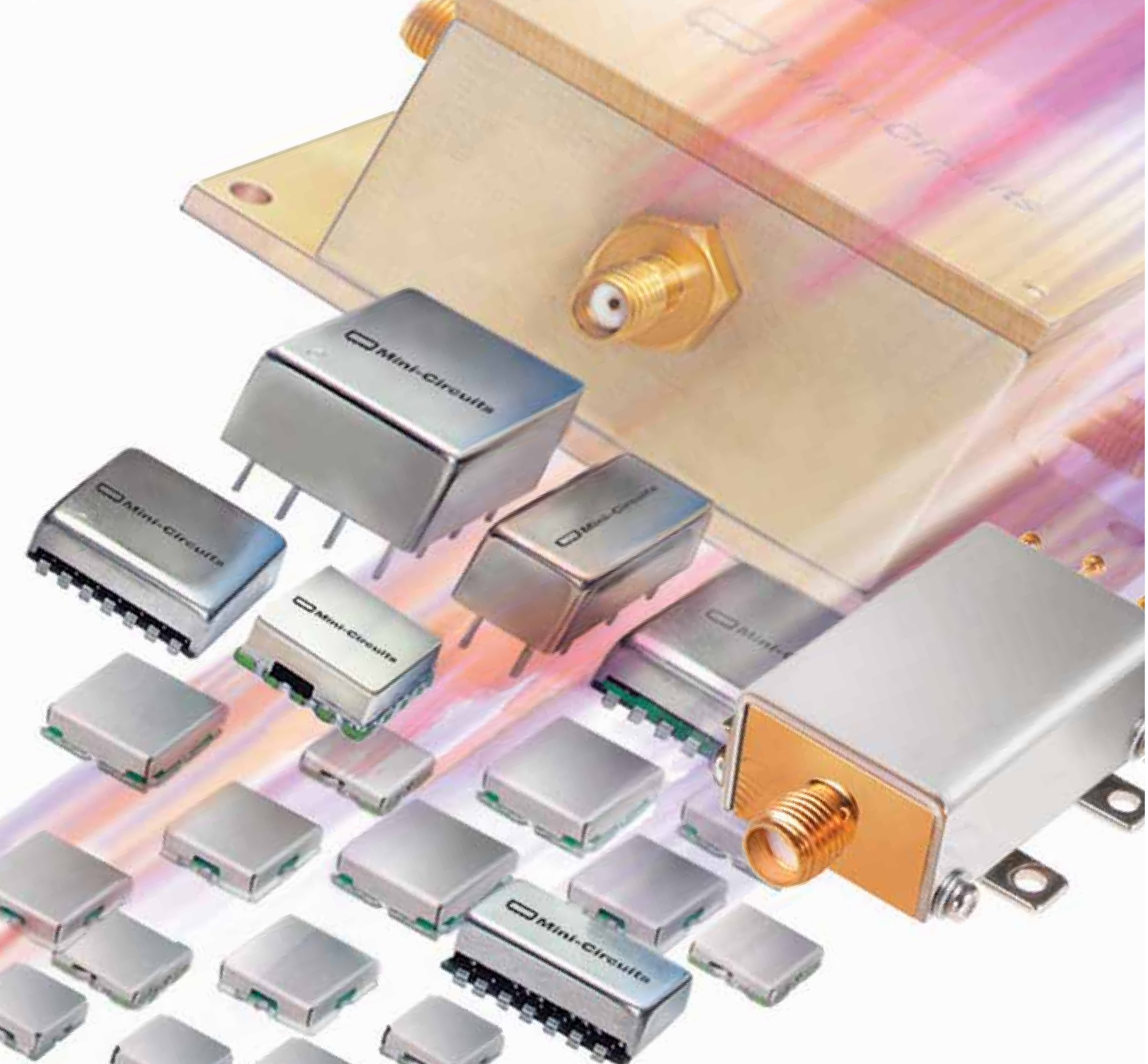
Author Information

Chin-Leong Lim is factory application engineer for RF diodes, discrete transistors and MMICs at Avago Technologies (formerly, HP / Agilent) in Penang, Malaysia. He works primarily in the design of LNA, attenuator, limiter, switch and detector circuits from HF to microwave. He has also worked on RF interference mitigation of manufacturing test stations. Prior to joining Avago in 1997, he was design engineer at Robert Bosch in Penang for 7 years. There he designed automotive receivers for reception of LW, MW, VHF FM and weather band broadcasts. He also set up the facility for EMC/EMI pre-compliance testing. He is a senior member of IEEE. His interest includes radio receiver, PIN diode circuits and amateur radio (9W2LC). He received the B.Tech. (Hons.) degree in electrical engineering from Universiti Teknologi Malaysia, Kuala Lumpur in 1990.



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RF System Design and Analysis Software Enhances RF Architectural Planning

By Dale D. Henkes
Applied Computational Sciences (ACS)

This new software enables convenient simulation of system-level performance, from cascaded gain and noise figure to detailed analysis of spurious signals and harmonics.

Historically, commercial software for designing RF and microwave products at the circuit level matured before equivalent full-featured system level software became widely available. The gap between CAE (Computer Aided Engineering) tools at the circuit level and what was needed for designing at the system level was often filled by designers creating their own system analysis tools in spreadsheets, using common office software such as Excel. There were many drawbacks to the spreadsheet as system analysis tool. Their one-of-a-kind nature, narrow focus on the analysis of one type of problem, and the inability to track the creation and propagation of spurious signals and intermodulation products top the list of drawbacks.

Even when excellent system analysis spreadsheets were developed in-house they were often difficult to maintain, especially if the author(s) were no longer available. They were often hard to adapt to system architectures that were significantly different than the original product or system they were created to analyze.

Eventually, competition in the electronic design automation (EDA) industry lead to easy-to-use GUIs and a more or less standard approach to the operational behavior of most circuit level RF simulation software. Unfortunately, commercial RF system simulation software took a more divergent path. Some software simply commercialized the spreadsheet approach while other software mimicked the spreadsheet with stand-alone cascade budget calculators. Larger, full-featured software applications offered spectral analysis in addition to budget analysis. However, implementa-

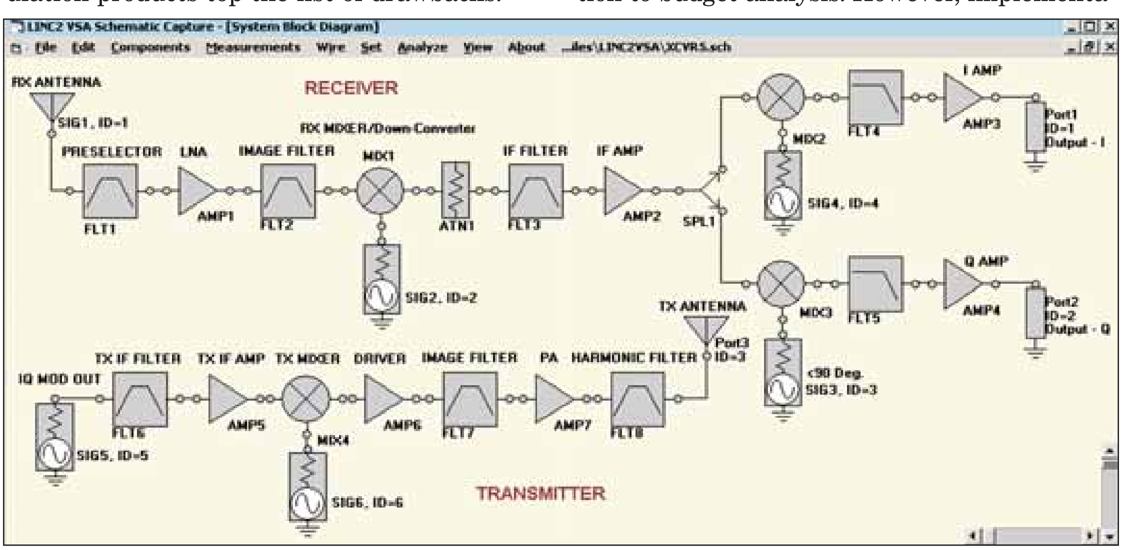

Figure 1 · A typical ACS Visual System Architect system schematic.

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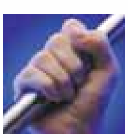

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IF/RF MICROWAVE COMPONENTS

tion varied among vendors, making it difficult for the user to migrate from one package to another.

Worse than the lack of standardization among products is the fact that within a given product, the user is often required to engage a different "simulation engine" in order to perform different analyses or produce different types of simulation results. For example, some software can do both an RF cascade budget analysis and perform a spectral domain analysis, but not simultaneously. The requirement to remove the budget analysis simulation definition in order to place a Harmonic Balance simulation setup on the schematic, just to produce a spectrum analyzer type display, seems artificial to the user. Then, when it is discovered that another type of simulator is required to complete the desired simulation tasks, the user may have the unpleasant task of configuring the simulator properly in order to get meaningful results. Setup defaults (if provided) rarely apply to the problem at hand and other setup parameters may be confusing or cryptic, even after consulting the manual or Help.

LINC2 Visual System Architect

The new LINC2 Visual System Architect (VSA) software from Applied Computational Sciences (ACS) was designed to eliminate most of these issues. One of the goals of the LINC2 VSA program was to make the software not only easy to use but so completely intuitive that users can be productive with it right out of the box. The program met these objectives through the following enhancements:

- Schematic based system simulation capable of analyzing arbitrary system topologies

  With schematic based simulation, any system that can be drawn on the schematic page can be analyzed, including branches that diverge from the main signal path (using splitters) and multiple independent parallel signal paths.
- One simulation engine (single pass simulation) produces all available analysis results
- Little or no simulation setup required (simply click Analyze and View Results)
- System budget analysis and spectral domain analysis results are available immediately for simultaneous display
- A signal and spur viewer identifies and traces all signals and otherwise unknown spurs through the system all the way back to their origins
- Non-linear power sweep curves display output versus input power, including sweeps through gain compression and saturation
- All analysis results can be exported to spreadsheets (such as Excel) or other programs via standard CSV output files
- Library of built-in component models including non-linear amplifiers and mixers
- Behavior models include frequency translation (mixers) and frequency selective components (filters)
- Splitter model allows analysis of multiple parallel paths (branches) driven by one or more signal sources
- Simultaneous analysis of multiple independent system cascades (parallel paths driven by independent signal sources)
- User-defined equations

  The user can compose equations that relate system component parameters to variables in new ways, creating new relationships between variables and component values that are defined and controlled by the user.
- Variables—The numerical parameter value(s) of any system component can be selected for real-time interactive tuning. Thus, displayed analysis results (such as plots and numerical tables of system response data) are updated as the component's parameter is adjusted, giving visual and numerical feedback on how the system is affected by each selected parameter for any component in the system. Variables can enhance the tuning method in the following two ways: A named variable can be assigned to any number of system component parameters so that tuning results in all these component parameters being assigned the current numerical value of the variable (ganged tuning). As mentioned above, the variable can be mapped through an equation to produce a new value for the component parameter. The variable can also be used with other variables in an equation to produce a more complex relationship between the variables and the assigned component parameter.

The LINC2 VSA System schematic works exactly like the familiar circuit level schematic. System components can be placed anywhere on the schematic page and wired to other components in any configuration desired, so practically any kind of system can be constructed and analyzed. Figure 1 shows a typical system schematic representing a radio transceiver. As indicated, the schematic captures the entire RF system from antenna to the individual I and Q channels.

Several important system analysis capabilities are evident from the schematic in Figure 1. The ability to analyze multiple independent subsystems means that the LINC2 VSA program can produce complete analysis results for both the transmitter and receiver simultaneously. The VSA splitter model enables the analysis of architectures involving parallel branches that depart from the main signal path. In the example in Figure 1, the RX IF signal is split and distributed evenly to the I and Q

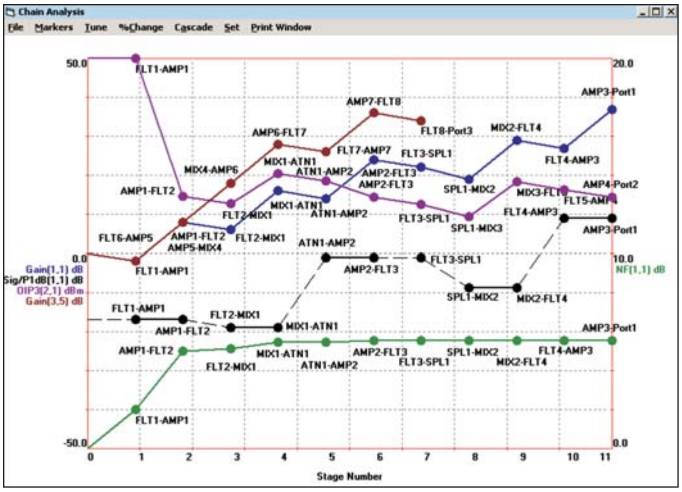


Figure 2 · The VSA's cascade budget plots.

System Performance Analysis - Reports

File Tune %Change Cascade Set Print Window

System Performance Reports

System Parameters	Source Port	Termination Port	Parameter Value	Units
DC PWR	1	1	.126	Watts
Tot PWR	1	1	11.96537	dBm
Efficiency	1	1	12.47861	%
Gain	1	1	28	dB
NF	1	1	5.30116	dB
OIP3	1	1	21.97717	dBm

Figure 3 · The VSA reports table.

down-converters for which the signal path is identical in these two parallel hardware channels (except for the 90 degree phase shift). This example also demonstrates the ability to include frequency translation (mixer models) and frequency selectivity (filter models) in the analysis.

The VSA is part of an integrated EDA software suite from ACS. While providing many new design and analysis capabilities for designing at the system level, the VSA program maintains a common user interface with the ACS LINC2 circuit simulator. With the VSA addition to the LINC2 Pro circuit design and simulation software suite, system level designs created with the Visual System Architect can proceed to the circuit design level, all within a common integrated user interface. Thus, RF and microwave circuit design can be appropriately driven by high level system design that links product specifications to circuit level specifications and subsequently to detailed circuit designs.

Because the program is not limited to a single chain of cascaded components, the user can quickly and easily construct systems of arbitrary topology using a comprehensive menu of system component behavioral models such as amplifiers, mixers, filters, splitters, and attenuators, etc. The VSA renders obsolete the traditional spreadsheets and system cascade calculators. It does this in part by providing the flexibility of schematic entry, the ability to model the spurious products created in non-linear stages, the ability to identify and track spurs back through the system to their origin and by displaying spectrum analyzer type views of all signals and spurs at the output or at selected nodes throughout the system.

VSA Cascade Budget Analysis

Plots of power budget, efficiency, gain, IP3 (intercept point), NF (noise figure) and signal/P_{1dB} (signal level relative to the component's P_{1dB}) are provided on a cumulative or stage-by-stage basis as well as a tabular summary of total system performance. Figure 2 shows a typical system cascade budget plot where each data point represents a particular system performance parameter at each consecutive circuit node or stage. Figure 3 displays the numerical summary of end-to-end system performance.

Non-Linear Power Sweep Analysis

While the traditional budget plots are essential to RF system analysis, the VSA program offers a much wider array of performance measurement methods and analysis tools. For example, the VSA provides input-output power sweeps that are useful in determining the useable dynamic range of a device (such as an amplifier) or an entire system. As shown in Figure 4, the power sweep curves include additional useful information such as P_{1dB}, the power saturation region, and the point at which the fundamental power begins to decrease as more power is shifted into harmonics.

Any component parameter in the system can be selected from the power sweep's tune menu, and its value can be adjusted incrementally up or down using the arrow keys to see the effect the selected parameter has on system linearity and compression curve characteristics. The light curve in Figure 4 shows the (real-time interactive tuning) effect of reducing the gain parameter of a system component while the heavy curve indicates the original (un-tuned) response. Power sweep curves can be plotted for any system output port. Internal nodes (at any stage in the system) can also be accessed to produce power sweeps from any input source up to and including the selected component node.

System Signal and Spur Viewer—The VSA Signal Tree

The file and folder navigation tree found in the Windows Explorer/File Browser has been an integral part of that operating system for as long as most of us can remember. The familiar tree structure is also seen in many other applications as the most efficient way to display and navigate through a complex structure of items (files and folders) and related items (subfolders) that are distributed throughout any number of levels and sublevels. Since the navigation tree is such a powerful and familiar tool, it was the natural choice for the LINC2 VSA signal and spur viewer. The VSA signal tree is a unique tool in the VSA system signal and spur viewer window (Fig. 5) that displays and navigates through all the signals and spurs for the entire system simulation.

As shown in Figure 5, each signal in the VSA signal tree is identified by a text description and a numerical signal identifier. The text describes the most current transformation that the signal has gone through, such as an increase in gain through an amplifier, or how the signal was created if it is new—for example, the second harmonic of an existing signal created by the non-linear function of the current system component. Preceding every signal in the list is a numerical tag that uniquely identifies the signal. The signal identifier tag is comprised of three numbers of the form: Source, Node, Index, uniquely identifying each signal according to the Source that was the ultimate origin, the Node at which the signal exists, and the Index that identifies this signal among the array of signals that may be present at this node.

The highest level in the VSA signal tree lists all the signals present at a user selected node (the output node, for example). Clicking on any signal at this level opens the next level in the tree for that signal. At this next lower level is the list of all the signals involved in the creation of the selected signal. A "+" symbol in front of a signal indicates that it has an additional history. Repeatedly clicking the "+" at each level expands the signal path to the next lower level until it is traced back to its source. Any signal at any node along the path can be right-clicked to reveal its amplitude, frequency and phase.

VSA Spectral Domain Analysis

Figure 6 shows the LINC2 VSA's Spectrum Analyzer view for an amplifier with multi-tone inputs. The number of input signals is limited by the (RAM) memory available for the computer used. However, there are no restrictions on the relative amplitudes of the tones or their spacing. (Note the different amplitudes and spacing for the ten fundamental signals in Figure 6). Thus, one or multiple signals can be input to the system with complete freedom to independently specify the amplitude, frequency and phase of each input signal.

The spectrum analyzer is an invaluable tool for a number of important tasks involving RF and microwave circuits and systems. It can be used in the design verification process to ensure that desired signals exist where they should, and at the required levels, while unwanted or spurious signals are not present or are below required limits. Ensuring that spurious signals are not generated and propagated through the system to places where they may degrade circuit or system performance is one of the most challenging tasks for an RF designer. The sensitivity of a receiver can be degraded by undesired spurious signals at the antenna port, or by spurious products generated in the receiver itself or in its supporting circuitry. Interfering signals as well as internally generated spurs can put a stage into compression and prevent the modulation on a desired signal from passing through to the next stage in the system properly.

The ability to bring a wireless product to market depends not only on the product meeting certain performance specifications, but also various regulatory requirements that put limits on both in-band and out of band emissions. Designing a product that meets these requirements is a daunting task without the proper tools because thousands of spurs can be generated in the product, including spurs mixing with other spurs, or desired signals mixing with spurs to create even more spurs that could be harmful to system performance. However, the intermodulation of signals as a result of the non-linearity of a device or stage in the system is not the only mechanism for the creation of undesired signals. Leakage paths due to insufficient isolation can cause desired signals to

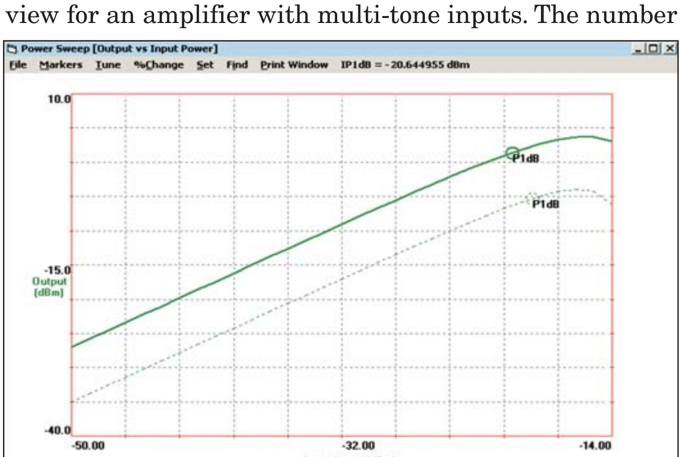


Figure 4 · The VSA's power sweep plots.

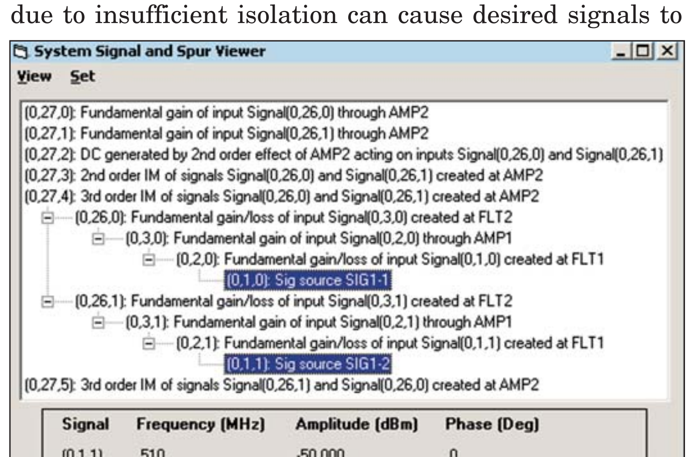
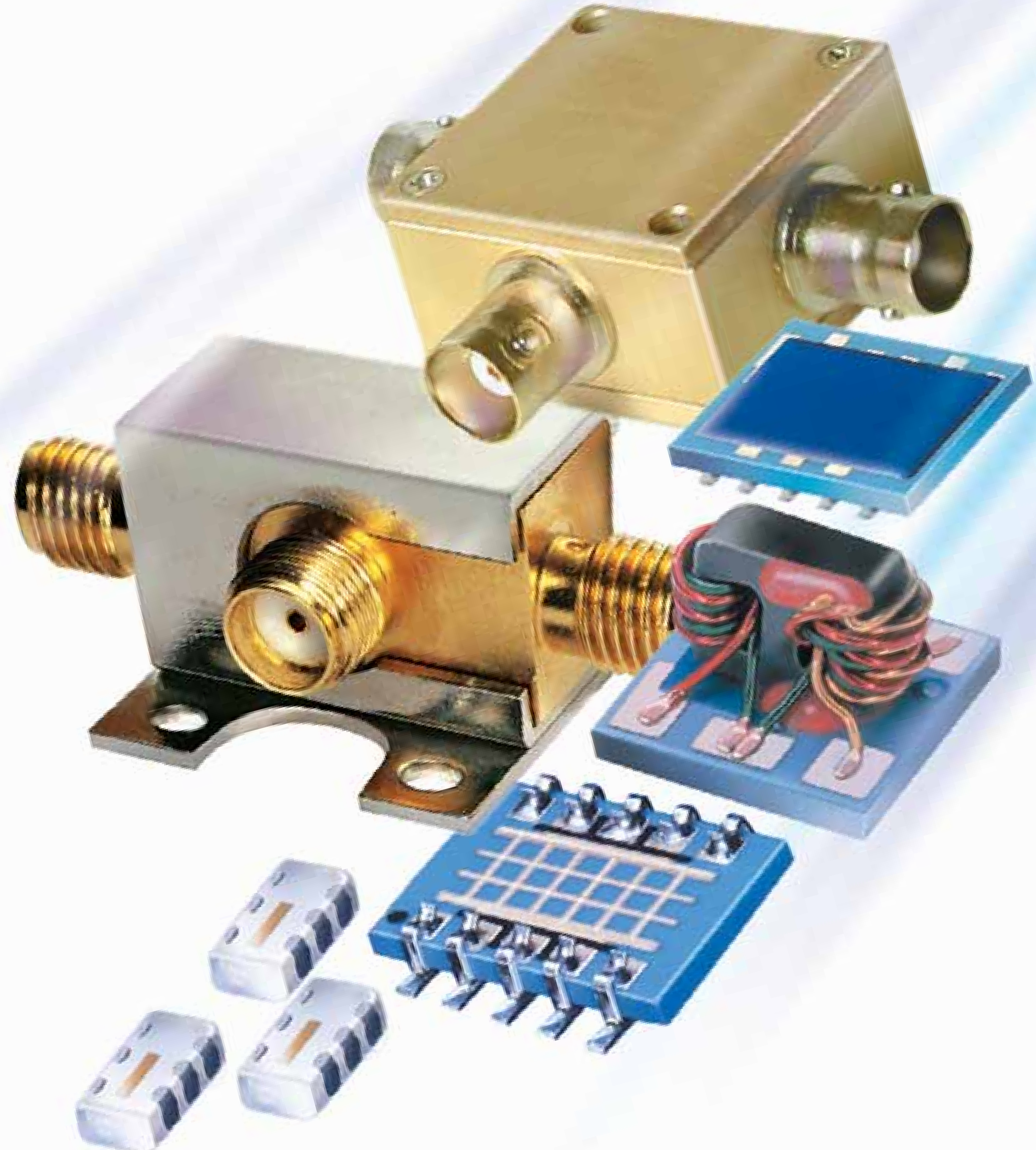


Figure 5 · The VSA system signal and spur viewer.



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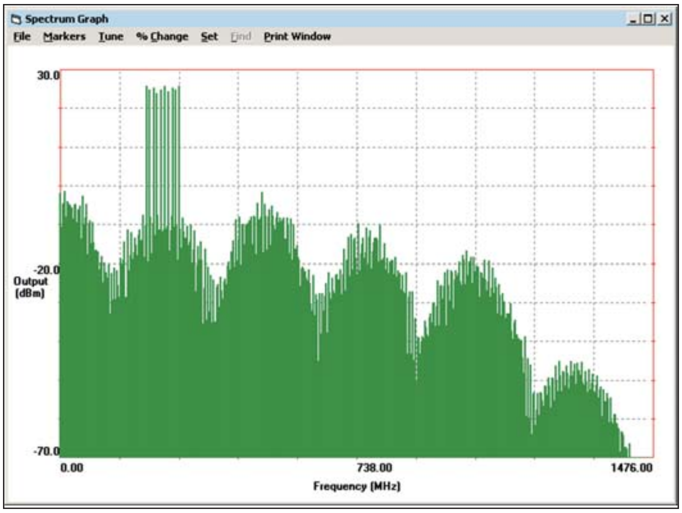

Figure 6 · The VSA's power output spectrum plot.

end up as undesired signals in other places in the system. An example is in the case of a local oscillator signal leaking over to the mixer's RF port and propagating back through the receiver or transmitter chain to the antenna port where it can fail the regulatory requirements for conducted emissions.

Fortunately, the LINC2 VSA software includes spectral domain analysis in the form of spectrum analyzer type graphs that can plot all the signals and spurs in the system. To help isolate the cause and path of any unknown spurs, the VSA spectrum analyzer graph can turn any signal source on or off to see which signals or spurs are related to a given source. Looking at these things early in the system design with the aid of the LINC2 VSA's spectrum analyzer or system signal and spur viewer can help ensure that the product will meet the spectral requirements before valuable time is spent on detailed circuit design and prototyping. At the same time, other product specifications can be verified by employing the VSA's Cascade Budget Analysis tool and the Power Sweep tool.

Summary and Conclusions

The VSA's schematic-based system simulation enhances design productivity by providing the flexibility to quickly and easily construct systems of arbitrary topology. "What if" scenarios can quickly be investigated by simply dragging components to new locations on the schematic page or by selecting and dragging system component models from the Components menu into new lineup configurations.

The VSA maintains a common user interface between system level and circuit level schematics making it easy to transition from system design to detailed circuit design and back without having to learn or become reacquainted with a different operational behavior. LINC2 system simulation and circuit simulation is also operationally similar and both have the same easy to use operator interface-simply enter schematic, set output options, click "analyze" and "view results/reports."

The program includes all the system budget analyses that are essential for the successful design and analysis of RF and microwave systems. System design productivity is further enhanced by the ability to perform output versus input power sweeps that reveal the linear and compression curve characteristics of the system (including P_{1dB} and saturation/PSat region). VSA spectral domain analysis provides an invaluable combination of spectrum plots and the VSA Signal Tree for viewing signals and spurs at any system node or tracing their paths back through the system to their sources.

Documenting system performance and report generation is easy since the VSA software can export the tabular data from the reports page, as well as all data from cascade budget analysis, power sweeps, and spectrum analysis graphs, into standard CSV files that can be imported into spreadsheets such as Excel. The data is also compatible with a wide variety of other programs through the common CSV format.

ACS has offered design automation with the LINC2 circuit simulation software for nearly 15 years. Over the last decade the LINC2 Pro software suite has included circuit design, synthesis, simulation, optimization and statistical yield analysis. Now with the addition of the Visual System Architect, RF and microwave circuit design can be appropriately driven by system design in a process that more accurately flows product specifications down to the circuit design level. This linkage between product specifications (properly distributed over components at the system level) and circuit specifications is essential to minimize or eliminate expensive and time consuming rework or redesign after prototyping when the product enters the design verification stage.

Author Information

Dale D. Henkes is the owner of Applied Computational Sciences (ACS), LLC, and has more than 25 years of professional experience in RF design/electrical engineering. He earned his B.S. degree in engineering at Walla Walla University, College Place, Washington. He is a member of the IEEE Microwave Theory and Techniques Society and the author of more than a dozen articles in prominent trade publications. He may be contacted via email at: henkes@appliedmicrowave.com.

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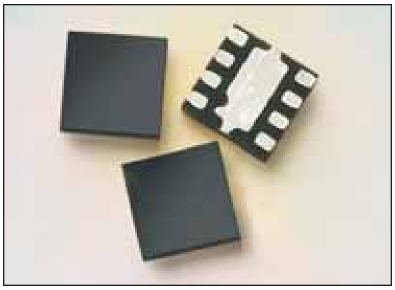

GaAs MMIC Amplifier

Avago Technologies announces a new Gallium Arsenide (GaAs) active bias amplifier for use in cellular infrastructure applications. Avago's MGA-633P8, which is a GaAs MMIC LNA, has a compact footprint and a common printed circuit board layout. The MGA-633P8 is designed to be used as a first stage LNA for cellular base station transceiver radio cards, tower mounted amplifiers, combiners, repeaters and remote/digital radio heads. Housed in a compact 2.0 × 2.0 × 0.75 mm 8-pin Quad-Flat-Non-Lead (QFN) package, the MGA-633P8 is designed to enable cellular applications that operate within the 450 to 2000 MHz frequency range.

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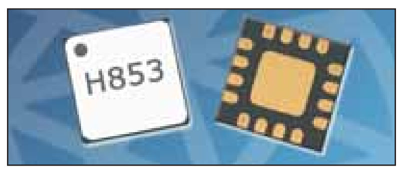
Skyworks Solutions, Inc. introduces the SKY73134, a wideband integer-N frequency synthesizer with an approximate 6 GHz locking range. The integrated phase noise from 100 Hz to 100 kHz measures less than 0.6 degree RMS at 960 MHz frequency. In addition, the phase noises at 100 kHz, 1 MHz and 3 MHz frequency offsets are –115 dBc/Hz, –143 dBc/Hz and 150 dBc/Hz respectively. Volume production of the SKY73134 is scheduled to begin in April 2010.

Skyworks Solutions, Inc.
www.skyworks.com



SMT D-Type Flip-Flop

Hittite Microwave Corporation has launched its first D-Type Flip-Flop, which supports 28 Gbps data transmission and clock rates up to 28 GHz. The HMC853LC3C operates with clock signals up to 28 GHz, and the input is broadband from DC to 28 GHz. The HMC853LC3C also features an output level control pin, which allows for signal loss compensation or optimization, allowing the differential output voltage swing to be adjusted from 700 mVp-p to 1300 mVp-p. The HMC853LC3C is specified for operation from –40 °C to +85 °C and operates from a –3.3 V DC supply, while consuming 240 mW.

Hittite Microwave Corporation
www.hittite.com

NXDN Options

Anritsu Company introduces two Next Generation Digital Narrowband (NXDN) options for its S412D LMR Master Land Mobile Radio (LMR) handheld analyzer. Both the NXDN Tx Signal Analyzer Option (#0530) and NXDN Talk–Out Coverage Option (#0532) support the 6.25 kHz and 12.5 kHz bandwidths. This allows the analyzer to accurately measure the narrow 6.25 kHz modulation format used in existing NXDN systems, as well as be used in future narrowband applications after the current 12.5 kHz spectrum becomes full. In addition, Anritsu has developed new GPS enhanced frequency accuracy for the S412D LMR Master.

Anritsu Company
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Lightning Protection Products

Times Microwave Systems has introduced the new LP-BTR50 series as part of its Times-Protect™ line of RF lightning and surge protection products. These devices address the protection of RF equipment for applications from 125 through 1000 MHz. Among the most noteworthy features of the new LP-BTR50 series of RF lightning protection products are: DC blocking technology, exceptional longevity, excellent multistrike performance, outstanding S parameters over the operating frequency band, and superior surge performance.

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S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	-0.4, +0.9
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	-0.4, +0.8
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60

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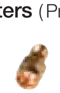

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IF/RF MICROWAVE COMPONENTS

screen and remotely via RS422, RS232 or Ethernet. The Controller extends the capability of the amplifier to control; T/R switches, sub-octave filters, system interlocks and other miscellaneous internal and external features. The Ethernet option builds on the strong features of the LCD Controller and allows the end user to control the amplifier over a LAN using any common Web browser.

Empower RF Systems, Inc.
www.EmpowerRF.com

50 GHz DC Blocks

Aeroflex/Inmet's new high frequency SMPM DC blocks are ideal for use in a variety of modulation schemes common amongst optical networking equipment providers who require either external DC blocking capability or AC coupling between modules. These DC blocks offer both a low cost of ownership and a high quality of design. This model, 8535MP, operates from 16 kHz to 50 GHz and combines excellent RF characteristics and a proven mechanical design. The SMPM push-on connectors mate with GPPO connectors and provide reliable high performance in a compact package.

Aeroflex / Inmet
www.aeroflex-inmet.com

Bluetooth Radio Modules

Laird Technologies, Inc. announced the release of its enhanced BTM410/411 and BTM420/421 Bluetooth® radio modules. The BTM410/411 and BTM420/421 modules are designed for data applications and are fully integrated, sub-miniature Bluetooth data-oriented modules based on a market leading chipset. Incorporating a full Bluetooth stack and supporting Serial Port Profile (SPP), the modules provide a UART interface and a comprehensive AT command set to allow an easy interface to a host processor. It is the fastest method of adding a Bluetooth wireless data link to an embedded product with wireless connection.

Laird Technologies, Inc.
www.lairdtech.com

GaN Product

TriQuint Semiconductor has expanded its revolutionary wideband, high power RF transistor family with the new T1G6003028-SP, a 25 W (P_{1dB}) GaN device operating from 20 MHz to 6 GHz. This PowerBand™ discrete SiC HEMT product delivers high-efficiency, high-power performance across an exceptionally wide bandwidth. The T1G6003028-SP is ideal for commercial applications such as WiMAX and professional radio systems, as well as wideband defense communications systems.

TriQuint Semiconductor, Inc.
www.triquint.com

Coaxial Fixed Attenuator

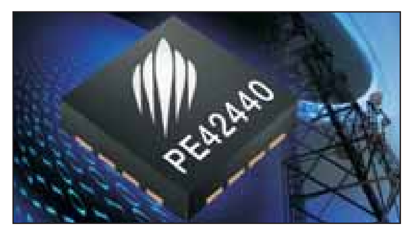
EMC Technology announces the 42WXX, a high performance precision SMA coaxial fixed attenuator. In EMC tradition, this product is offered in commercial or high reliability versions for all applications you may require. EMC offers a standard test plan or up-screen product to your custom requirements. This product is offered in values from 0 to 10 dB in one dB increments and up to a maximum frequency range of 18.0 GHz. The rugged construction of this device ensures reliability and continuous performance in the most demanding environments.

EMC Technology
www.emct.com

High-Q Porcelain Capacitors

DLI has introduced the new C18 series of enhanced voltage high-Q porcelain capacitors. With voltage ratings up to 2000V, the C18 is designed to be the most robust "1111" high-Q capacitor available. The C18 is available in both our ultra stable (0±15 ppm/°C) CF and temperature compensating (+90 ppm/° C) AH dielectrics, and is form-factor compatible with our existing line of C17 "1111" capacitors.

Dielectric Laboratories
www.dilabs.com



SP4T RF Switch

Peregrine Semiconductor Corp-oration announced the new PE42440 SP4T (single pole four throw) RF switch. The PE42440, designed on Peregrine's green UltraCMOS™ silicon-on-sapphire (SOS) process technology, features broadband RF performance from 50 MHz up to 3 GHz. It delivers an IIP3 of +67 dBm and P_{1dB} of 41.5 dBm; insertion loss of 0.45 dB; and isolation of 34 dB (at 1 GHz). The 50-ohm switch handles maximum +33 dBm input power (500 MHz to 3 GHz) with ESD tolerance of 4.0 kV HBM on the RFC pin. Features include integrated CMOS control logic, decoder for 2-pin control that accepts 1.8 V and 2.75 V control logic levels, and a low 4.5 ohm series ON resistance. Available in volume and priced at $0.67 each (100k units).

Peregrine Semiconductor Corporation
www.psemi.com

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Honorable Zachary J. Lemnios

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2010 IEEE International Microwave Symposium is proud to announce this year's keynote speaker, The Honorable Zachary J. Lemnios. Mr. Lemnios currently serves as the Chief Technology Officer (CTO) for the Department of Defense. Prior to acceptance of his current role, Mr. Lemnios has held many key and influential positions which have helped advance technology. His remarkable career includes positions, within MIT Lincoln Laboratory, eventually serving as CTO. His responsibilities in this role called for strategically coordinating technology and growth to support current and future laboratory missions. Mr. Lemnios was also the Director of the Defense Advanced Research Projects Agency (DARPA) Microsystems Technology Office (MTO) as well as the Deputy Director of Information Processing Technology Office (IPTO).

Mr. Lemnios has served on numerous DoD, industry and academic committees. Mr. Lemnios has authored over 40 papers, holds 4 patents in advanced GaAs device and MMIC technology and is a Senior Member of the IEEE.

We encourage your participation in joining us during this exciting Plenary Session to be held May 25th, 2010. Due to Mr. Lemnios' busy work schedule, this is a rare opportunity you will not want to miss! To learn more about Mr. Lemnios and his upcoming discussion, please visit our website at **www.ims2010.org.**

We look forward to your visit. To see what is new at IMS2010, visit www.IMS2010.org.

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Torque Wrench

Binder-USA announces the release of a new torque wrench for its 7/8” Series 820 connectors. The tool is designed to aid in connecting and disconnecting 7/8” field-attachable cable connectors with hex shaped locking nuts. The 7/8” connectors are ideally suited for DeviceNet applications in industrial automation environments. The tool is designed to tighten hex nuts to the correct torque value as well as ensure Series 820 connectors are mated properly guaranteeing an IP67-rated connection. The tool also allows connectors to be easily unmated as it locks when motion is reversed. The jaws of the tool are replaceable and easily removed for cleaning purposes.

Binder-USA
www.binder-usa.com

RMS Power Detector

Maxim Integrated Products announces the MAX2203 RMS power detector. Designed to operate from 800 MHz to 2.0 GHz, the MAX2203 accepts an RF signal at the input, and outputs the same voltage regardless of the peak average of the input signal. This RMS power detector is ideal for WCDMA, cdma2000®, and HSDPA/HSUPA. The output voltage and input power is linear in dB. The device has a –25 dBm to +3 dBm detection range, and every dB change in input power gives 40 mV typical change in output voltage. The MAX2203EWT+T operates from a 2.5V to 4.2V supply. Fully specified over the –40 degrees C to +85 degrees C extended temperature range, it is available in an ultra-small, 6-pin WLP. Prices start at $0.50 (1000-up, FOB USA).

Maxim Integrated Products
www.maxim-ic.com

Communications Tester

Rohde & Schwarz has designed the R&S CMW270 as a flexible communications tester that can handle applications well beyond classic cellular mobile radio. As a solution for development and production, the tester is capable of handling WiMAX™ plus WLAN, Bluetooth®, GPS and various broadcasting standards. The tester can be equipped with additional technologies to accommodate specific requirements. It is a preconfigured version of the R&S CMW500 multitechnology platform and can be upgraded to full functionality when the need arises.

Rohde & Schwarz
www.rohde-schwarz.com

Push-On SMA Plug

Response Microwave, Inc. announces the availability of a new push-on SMA male connector that accommodates universal mating to all threaded SMA female connectors. The interface is ideal for use as a connector saver in ATE applications and more so, as a means to interconnect modules within a tight sub-system where torque wrenches cannot reach. The series operates DC-18 GHz and offers typical VSWR of 1.05:1 across the band. Current versions are available in straight configurations for RG402 and RG405 conformable or semi ridged and crimp versions for RG179 and RG316 flexible cable.

Response Microwave, Inc.
www.responsemicrowave.com

Ultralow Noise EMC DC/DC µModule Regulator

The LTM®8031 is an electromagnetic compatible (EMC) 36V, 1A DC/DC µModule® buck converter designed to meet the radiated emissions requirements of EN55022. Included in the package are the switching controller, power switches, inductor, filters and all support components. Operating over an input voltage range of 3.6 to 36 V, the LTM8031 supports an output voltage range of 0.8 to 10 V, and a switching frequency range of 200 kHz to 2.4 MHz, each set by a single resistor. The LTM8031 is packaged in a thermally enhanced, compact (9 × 15 mm) and low profile overmolded LGA package suitable for automated assembly by standard surface mount equipment.

Linear Technology
www.linear.com

Octave Tuning VCOs

Synergy Microwave Corporation is announcing the DXO400800-3 and DXO400800-5, 0.3" × 0.3" × 0.08" packaged octave tuning voltage controlled oscillators. These VCOs are designed for +3 and +5 volt supplies and cover the frequency band of 4-8 GHz, with ultra-low power consumption of less than 100 mW and fast tuning for agile synthesizer applications.

Synergy Microwave Corporation
www.synergymwave.com

Voltage Controlled Oscillator

Crystek’s CVCO55CC-2580-2650 VCO operates from 2580 to 2650 MHz with a control voltage range of 0.5~4.5 V. This VCO features a typical phase noise of –110 dBc/Hz at 10 kHz offset and has excellent linearity. Output power is typically

+3 dBm. Engineered and manufactured in the USA, the model CVCO55CC-2580-2650 is packaged in the industry-standard 0.5 × 0.5 in. SMD package. Input voltage is 5 V, with a max current consumption of 40 mA. Pulling and pushing are minimized to 1.5 MHz and 1.5 MHz/V, respectively. Second harmonic suppression is –15 dBc typical. The CVCO55CC-2580-2650 is ideal for use in applications such as digital radio equipment, fixed wireless access, satellite communications systems, and base stations.

Crystek Corporation
www.crystek.com

GaN Pallet Amplifier

RFHIC Corporation has released a GaN pallet amplifier for LTE/WCDMA RRH system, RTP-21010. This amplifier, when combined with DPD, produces over 40% efficiency at whole frequency band of 2100~2180 MHz, 45 dB gain and 10 W at LTE/WCDMA 4 channel at 28 V. It has been developed based on internally matched GaN on SiC device and Doherty technology. RTP-21010 has built-in DC/DC function, isolator, coupler, thermo pad and connectors all within 2.4 × 4.5 × 0.86 in. physical size. This amplifier produces different output power according to input voltage, 10 W at 28 V, 16 W at 36 V, 20 W at 47 V.

RFHIC Corporation
www.rfhic.com

Sensor Chips

State of the Art, (SOTA) Inc., has introduced a new line of microwave heater sensor chips utilizing platinum on alumina and oxidized silicon. These new heater/sensors can be utilized in a host of applications in areas from microelectronics to biomedical engineering. Available with two design options, the TM365 with two thermal sensors in close proximity to the heater for extremely stringent temperature control, and the TM364 single sensor design with moderate temperature control. Both designs come with operating temperatures up to 250° C. The self-heating of the sensors is below 4 mW/° C. Applications specific, custom designs can also be developed based on the customer's drawings.

State of the Art, Inc.
www.resistor.com

250-Watt Microwave System

AR Modular RF has introduced a new Class AB solid-state power amplifier that delivers in excess of 250 watts CW power into a 50-ohm load over the frequency range of 1750 MHz to 1850 MHz. The Model KAS2010M12 is a 19-inch rack-mount unit that features overdrive protection, infinite mismatch tolerance/VSWR protection, and over-temperature protection. Included in the the KAS2010M12 is the KMS2010 module. The KMS2010 is also available separately. It provides up to 150 watts of power over the 1.75 to 1.85 GHz frequency range.

AR Modular RF
www.ar-worldwide.com

UHF Wide Band Circulators

Raditek's low frequency, 225-400 MHz UHF wide band circulators are used mainly for military, aviation and government communication. Our newest coaxial circulator model, RADC-225-400-N23-200WR covers the full band 225 to 400 MHz with guaranteed specifications of 0.7 dB insertion loss, 17 dB isolation, and 1.40:1 VSWR over the full operating temperature range 0 to 50°C. Standard power options range from 1 to 400 watts. These units are proven in the field and are fully ROHS compliant.

Raditek
www.Raditek.com

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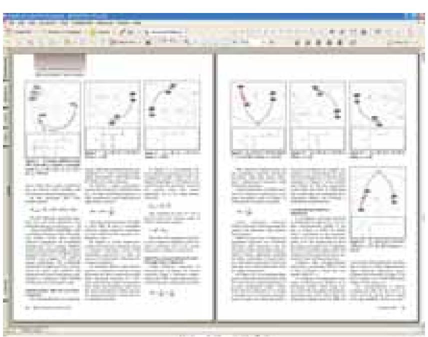

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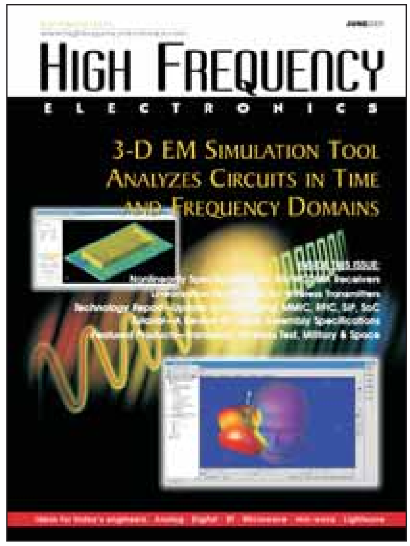

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Data Acquisition Switch

Agilent Technologies Inc. introduced a data acquisition switch unit that easily connects, configures and acquires data at the bench, on the network or in a remote application. The Agilent 34972A 3-slot LXI Class-C compliant data acquisition switch unit includes a built-in 6 1/2 digit DMM, eight optional plug-in modules, 1 Gb LAN and USB 2.0 ports. This gives engineers involved in R&D and functional test the connectivity options they need, yet it easily connects to a PC or Laptop using standard PC IO.
www.agilent.com

GaAs Power Amplifier

California Eastern Laboratories (CEL) is now shipping its new uPG2251T6M GaAs power amplifier. The new PA eliminates the need for RF component matching, which reduces component count, saves BOM cost, and simplifies procurement. Applications include Bluetooth modules that are designed into notebooks, mobile phones, and headsets as well as 802.15.4/ZigBee modules.
www.cel.com

875-1010 MHz Bandpass Filter

The Mini-Circuits ZX75BP-942+ ceramic coaxial resonator based filter offers outstanding close-in rejection in the PCS/DCS communication band. Built using Mini-Circuits proven unibody construction which integrates the RF connectors with the case body, the ZX75BP-942+ takes very little space, and includes a multi-section low pass filter to prevent second harmonic re-entry that is characteristic of typical ceramic resonator filters.
www.minicircuits.com

X-Band Amplifiers

MITEQ has introduced a new line of low profile, lightweight and small volume high power X-Band amplifiers. The new PA family offers a unique combination of features and performance in an extremely small footprint. The high speed pulsed DC feature and 12V supply allows for extremely efficient operation suitable for high temperature, portable or airborne applications. Numerous models cover 8.5 to 10.5 GHz, in various sub-bands up to 1 GHz wide, with power levels of 8 to 12W.
www.miteq.com

SMA Transfer Switch

RLC Electronics' Micro Miniature SMA Transfer Switch is a compact design. The switch incorporates SMA connectors to allow high-density packaging and excellent electrical performance through 26.5 GHz. The switch is available in failsafe and latching configurations with a choice of three different frequency ranges and three different coil voltages.
www.rlcelectronics.com

PXA Signal Analyzer

Agilent Technologies Inc. demonstrated how new advanced measurement applications embedded in the Agilent N9030A PXA signal analyzer are used to test radio frequency (RF) transmitters. The demonstration took place at the 2010 Mobile World Congress. The advanced measurement applications test a variety of signal standards in cellular communication and digital video. Signal standards include LTE-FDD, LTE-TDD, W-CDMA/HSPA/ HSPA+, DVB-T/H and ISDB-T.
www.agilent.com

USB *Smart* Power Sensor

OQE06GHs+ (RoHS compliant) is a USB *Smart* power sensor that offers a 50 dB dynamic range over frequency range of 1 to 6000 MHz, with software that turns the PC into a power meter. The PWR-6THs+ is a HIG (human interface device), which does not require driver installation. The PWR-6GHS+ also comes with an N-Type female to SMA male adapter for enhanced utility.
www.minicircuits.com

HMPA/HHPA Amplifiers

Renaissance Electronics Corporation/HXI is pleased to announce our lines of HMPA and HHPA medium and high power amplifiers, which cover the frequency range from 8 to 100 GHz. New models for 2010 include 28-32 GHz and 32-36 GHz units as well as several new designs in V-band and W-band. A wide variety of gain and bandwidth combinations are available to provide solutions for radar systems, communications systems and other applications.
www.hxi.com

Double Balanced Mixer Pre-Amp

MITEQ's new X-Band double-balanced mixer with integral IF amplifier for radar, communications, and related test systems applications provides 25 dB conversion gain for low level, 20 to 40 MHz, and IF signals. Model DA0812/3010 mixer with pre-amplifier covers from 8 to 12 GHz and provides a noise figure of 9.5 dB with conversion gain to a RF output level of 9 dBm at P_{1dB} This model meets rugged environmental MIL specs, operates over a –54 to +85°C temperature range, and is ideal for rugged military systems applications
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L-Network Design Procedure

For maximum power transfer, source and load impedance must have a conjugate match. For many circuits with modest bandwidth requirements, a simple *L-network* comprising two reactive components is the simplest method of achieving that match. This note is a quick review of L-network design.

Figure 1 shows the sequence of steps for matching two impedances, either of which can be considered "source" or "load." Fig. 1a shows only the resistance of these impedances; their reactances will be dealt with later. Most often, one of the impedances is a common system impedance. For this example, we'll assume that R_1 = 50 ohms, then arbitrarily choose R_2 = 10 ohms.

The design process begins with a shunt component (Xp in Fig. 1b) connected in parallel with the higher resistance (R_1). The parallel combination will result in a lower resistance, which we want to be equal to R_2 (10 ohms). Because X_P is reactive, the resulting lower resistance will now have an associated reactance. This is cancelled by the L-network's series reactance X_S, which is the negative of the reactance introduced by X_P. Thus, the series and shunt components are of opposite reactances—a shunt inductor and a series capacitor, or vice versa.

The design calculation starts by determining circuit Q according to the ratio of the two resistances:

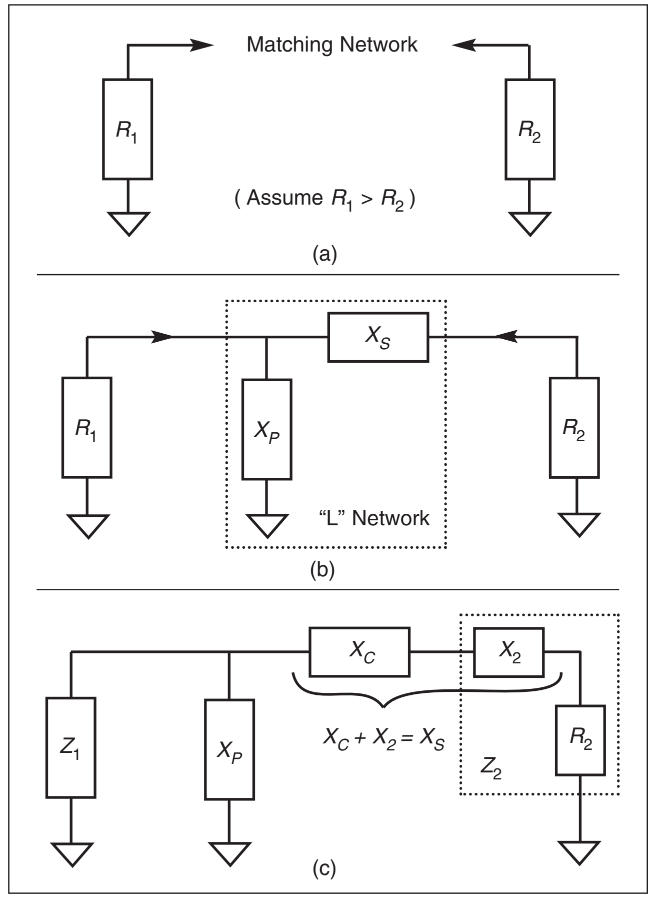

Figure 1 · L-network design sequence.

$$Q_S = Q_P = \sqrt{\frac{R_P}{R_S} - 1}$$

where R_P is the resistance adjacent to the parallel leg of the network, and R_S is the resistance at the series-connected end. Q may not be negative, so R_P must be the higher of the two resistances. In our example, $R_1 = R_P$ and $R_2 = R_S$. Note that Q is determined by the source and load, not be user-selected as is typical when designing higher order networks.

The calculation continues as follows:

$$Q_S = \frac{|X_S|}{R_S} \quad \text{or,} \quad |X_S| = Q_S R_S$$

$$Q_P = \frac{R_P}{|X_P|} \quad \text{or,} \quad |X_P| = \frac{R_P}{Q_P}$$

where the reactances are given as magnitude only, since X_S and X_P may be either capacitance or inductance, but as noted above, cannot both be the same.

Applying these equations to our example, we find that Q = 2, $|X_S|$ = 20 ohms and $|X_P|$ = 25 ohms. Before assigning a sign to each reactance, let's look at our example with complex impedances at Z_1 and Z_2, as in the circuit of Fig. 1c. Since we assumed a system impedance, let $Z_1 = 50 \pm j0$ ohms (same as R_1). Then let's say that $Z_2 = 10 - j10$ ohms.

In Fig. 1c we see that X_S has been split into two parts: X_2 is the reactive part of Z_2, and X_C is the final circuit value that makes X_S equal to the sum of X_C and X_2. We have two choices for the signs of the network reactances, and can examine the effect of each for obtaining practical values of X_C and X_P.

If X_S = +20 ohms, then X_C must be +30 ohms. X_P will be –25 ohms.

If X_S = –20 ohms, then X_C must be –10 ohms. X_P will be +25 ohms.

One common choice is selecting the configuration to enable or block DC continuity. Let's say that Z_2 is a transistor output being matched to a 50 ohm transmission line. Since X_C = –10 ohms, it is a capacitor and will be useful for blocking DC.

Finally, if Z_1 is complex, X_P would be combined with the reactive portion of Z_1 to compute the actual circuit component value, as was done to find X_C.

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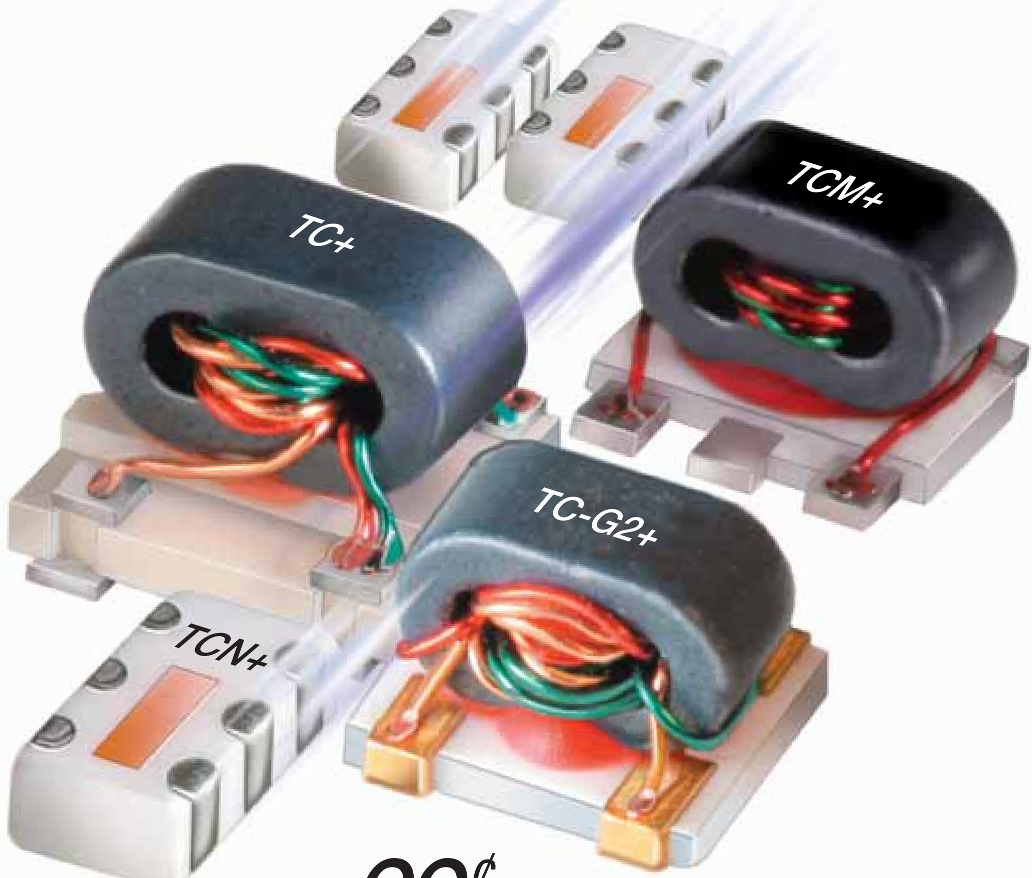

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MFS	L - K	1 kHz	2	-60	-75	-90	-95	-95	-120	5.3 GHz	13
CFS	L - K	1 Hz	2	-62	-75	-85	-89	-97	-110	14.84 GHz	13
Ku3LS	X - Ku	1 kHz	2.2	-62	-70	-75	-85	-97	-115	12.50 GHz	13
C3LS	C	1 kHz	1.1	-63	-88	-90	-100	-100	-115	5.50 GHz	13
UWB	S - K	1 kHz	Multioctave	-60	-71	-80	-90	-96	-105	12 GHz	13
MOS	VHF - K	1 kHz	Multioctave	-55	-65	-75	-85	-90	-100	20 GHz	13
SLS	L - Ku	125 kHz	1	-70	-80	-86	-88	-105	-115	3.3 GHz	13
SLFS	VHF - Ku	100 kHz	2	-70	-75	-80	-90	-115	-125	5 GHz	13
LFTS	VHF - Ku	100 Hz	1	-78	-88	-98	-98	-110	-130	350 MHz	13
VFS	L - Ku	>25 MHz	1.5	-60	-80	-110	-115	-115	-130	12.5 GHz	13

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