FEATURED PRODUCTS: NEW EDA TOOLS, SIGNAL SOURCES, AND TRANSISTORS

INSIDE THIS ISSUE:
- How to Build a Microwave Synthesizer—Part 2
- IP₂ and IP₃ Considerations in Direct Conversion Receiver Design
- Constant Mismatch Analysis of RF Power Devices
- Technology Report—Wireless Receiver Technologies
- Tutorial—A Review of Directional Couplers

Online Edition

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1958-2008

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- Extended Temperature Range available

### Typical Phase Noise Output

<table>
<thead>
<tr>
<th>Model</th>
<th>Bands</th>
<th>Step Size</th>
<th>BW (GHz)</th>
<th>10</th>
<th>100</th>
<th>1K</th>
<th>10K</th>
<th>100K</th>
<th>1M</th>
<th>Output Frequency</th>
<th>Output Power (dBm, Min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTE</td>
<td>L - Ku</td>
<td>1 kHz</td>
<td>2.2</td>
<td>-73</td>
<td>-80</td>
<td>-96</td>
<td>-96</td>
<td>-97</td>
<td>-123</td>
<td>12.72 GHz</td>
<td>13</td>
</tr>
<tr>
<td>MFS</td>
<td>L - K</td>
<td>1 kHz</td>
<td>2</td>
<td>-60</td>
<td>-75</td>
<td>-90</td>
<td>-95</td>
<td>-95</td>
<td>-120</td>
<td>5.3 GHz</td>
<td>13</td>
</tr>
<tr>
<td>CFS</td>
<td>L - K</td>
<td>1 Hz</td>
<td>2</td>
<td>-62</td>
<td>-75</td>
<td>-85</td>
<td>-89</td>
<td>-97</td>
<td>-110</td>
<td>14.84 GHz</td>
<td>13</td>
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<tr>
<td>Ku3LS</td>
<td>X - Ku</td>
<td>1 kHz</td>
<td>2.2</td>
<td>-62</td>
<td>-70</td>
<td>-75</td>
<td>-85</td>
<td>-97</td>
<td>-115</td>
<td>12.50 GHz</td>
<td>13</td>
</tr>
<tr>
<td>C3LS</td>
<td>C</td>
<td>1 kHz</td>
<td>1.1</td>
<td>-63</td>
<td>-88</td>
<td>-90</td>
<td>-100</td>
<td>-100</td>
<td>-115</td>
<td>5.50 GHz</td>
<td>13</td>
</tr>
<tr>
<td>UWB</td>
<td>S - K</td>
<td>1 kHz</td>
<td>Multioctave</td>
<td>-60</td>
<td>-71</td>
<td>-80</td>
<td>-90</td>
<td>-96</td>
<td>-105</td>
<td>12 GHz</td>
<td>13</td>
</tr>
<tr>
<td>MOS</td>
<td>VHF - K</td>
<td>1 kHz</td>
<td>Multioctave</td>
<td>-55</td>
<td>-65</td>
<td>-75</td>
<td>-85</td>
<td>-90</td>
<td>-100</td>
<td>20 GHz</td>
<td>13</td>
</tr>
<tr>
<td>SLS</td>
<td>L - Ku</td>
<td>125 kHz</td>
<td>1</td>
<td>-70</td>
<td>-80</td>
<td>-86</td>
<td>-88</td>
<td>-105</td>
<td>-115</td>
<td>3.3 GHz</td>
<td>13</td>
</tr>
<tr>
<td>SLFS</td>
<td>VHF - Ku</td>
<td>100 kHz</td>
<td>2</td>
<td>-70</td>
<td>-75</td>
<td>-80</td>
<td>-90</td>
<td>-115</td>
<td>-125</td>
<td>5 GHz</td>
<td>13</td>
</tr>
<tr>
<td>LFTS</td>
<td>VHF - Ku</td>
<td>100 Hz</td>
<td>1</td>
<td>-78</td>
<td>-88</td>
<td>-98</td>
<td>-98</td>
<td>-110</td>
<td>-110</td>
<td>350 MHz</td>
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<tr>
<td>VFS</td>
<td>L - Ku</td>
<td>&gt;25 MHz</td>
<td>1.5</td>
<td>-60</td>
<td>-80</td>
<td>-110</td>
<td>-115</td>
<td>-115</td>
<td>-130</td>
<td>12.5 GHz</td>
<td>13</td>
</tr>
</tbody>
</table>

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Our premium line of Johnson sub- and micro-miniature connectors include: SMA, SMP, SMK in various mounting types, including cable mount, bulkhead and board mount versions. A wide selection of alternative niche connectors such as non-magnetic, reverse polarity, reverse thread, end-launch and quick connect versions are available.

In addition, Trompeter Connectivity Solutions offers Twinax and Triax products which are widely used for data rated 1553 Data Bus applications. Trompeter’s high reliability UPL2000 BNC’s are used extensively in the broadcast and premise wiring markets where mission critical infrastructure quality is demanded.

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Wireline, Wireless and Optical Connectivity Solutions.
Just another reason why Emerson Network Power is the global leader in enabling Business-Critical Continuity™.
On the Cover—The background photo behind some of this month’s featured products shows the U.S Navy’s Sea Based X-Band Radar (SBX), a seagoing mobile early warning radar system, at Pearl Harbor in January 2006, enroute to its homeport of Adak, Alaska in the Aleutian Islands.  (U.S. Navy photo)
I’ll admit it—sometimes an editor runs out of ideas for a serious, in-depth editorial column! Instead, this month’s offering is a collection of shorter comments on different subjects.

**CFLs and LEDs**

Despite their energy savings, I’m not much of a fan of compact fluorescent lights (CFLs). It’s not that they cost more than good ol’ tungsten bulbs from Thomas Edison’s era, and it’s not that they contain mercury. No, my problem is that the color of the light is harsh. Even models that claim to be “warm” are simply uncomfortable to live with for long periods of time. So I still use the old fashioned bulbs in those parts of our house where we spend most of our time, and relegate the CFLs to closets, basement, garage and other places where the quantity, not quality of light is important.

Both CFLs and LEDs have high frequency circuitry to make them work—the CFL ballast and the switching power supply or DC-DC converter used in most LED assemblies. I may be able to tell when a problem with a light is causing interference, but I hope they are reliable enough so ordinary consumers don’t experience any mysterious behaviors.

**What is “Green”?**

Continuing the previous theme, one of my pet peeves is the bizarre use of the term “green” to describe everything from simple energy conservation to environmental extremism. The CFL is a good example. Is it green because it saves energy, or is it contributing to pollution because it contains mercury? Is my house green because it’s well insulated and has a high efficiency HVAC system, or is it a problem that the concrete took a lot of energy to produce and it has many materials from non-renewable resources? And why don’t the “green” folks get on the RF interference bandwagon? The electromagnetic spectrum is part of our environment, too!
**Regulatory Balance**

Maybe it is fruitless to discuss politics, but we sure seem to get too much or too little government oversight—rarely the right balance that common sense would dictate.

In the financial world, we have excruciating detail in the rules for IRAs and 401ks, but too little regulation of some parts the investment community that we are supposed to trust with those funds.

In the communications arena, we have the FCC, which continues to operate with the schizophrenic mix of simultaneously promoting and regulating communications. The Commission’s ability to make balanced decisions is further hampered by the reduction of the FCC’s in-house technical capabilities to a bare minimum.

**Science and Math Education**

I use the word “science” instead of “technology” because I mean grade school and high school science and mathematics, where the fundamentals that create technology are first learned ... or not, which is the problem. Somehow, the interest and ability of students in math and science has not advanced much, even with a lot of recent hand-wringing on the subject.

Again this year, I was a judge for the regional high school science fair, where the main problem is not enough entries. The winner and runners up get some serious scholarship money and great credentials for a college admission application, but all the judges expressed disappointment at the turnout. The top couple projects were outstanding, but the quality—especially the originality—dropped off rapidly.

Educators need your creative suggestions! Thirty or more years ago, most of us found it easy to be enthusiastic about science and technology—how do we renew that kind of excitement?

**Internet Pros and Cons**

As an open forum, the Internet is incredibly valuable for the rapid and widespread exchange of technical information. But, only portions of the available material are edited or reviewed. The ability to identify reliable sources and quickly judge the value of content takes as much knowledge and experience as any other part of engineering.

In a sense, the Internet is like early computer-aided design tools—a valuable asset, but very easy for inexperienced engineers to rely on too much, with the potential for obtaining incomplete and possibly incorrect information.
CONFERENCES

July 5-12, 2008
National Radio Science meeting
San Diego, CA
Information: Conference Web site
http://www.apsursi2008.org

August 18-22, 2008
IEEE EMC Symposium
Detroit, MI
Information: Conference Web site
http://www.emc2008.org

September 10-12, 2008
IEEE 2008 International Conference on Ultra-Wideband
Hannover, Germany
Information: Conference Web site
http://www.icuwb2008.org

September 30 - October 2, 2008
34th RF & HYPER Europe 2008
Paris-Nord Villetpinte, France
Information: Conference Web site
http://rfhyper.com/eng/presentation.html

September 30 - October 2, 2008
WiMAX World Americas 2008
Chicago, IL
Information: Conference Web site
http://www.wimaxworld.com

October 27-30, 2008
ISAP 2008—International Symposium on Antennas and Propagation
Taipei, Taiwan
Information: Conference Web site
http://www.isap08.org

October 27-31, 2008
European Microwave Week 2008
Amsterdam, The Netherlands
Including the European Microwave Conference (EuMC), the European Wireless Technology Conference (EuWiT), the European Radar Conference (EuRAD), and the European Microwave Integrated Circuits Conference (EuMIC)
Information: Conference Web site
http://www.eumweek.com

September 4-7, 2008
WCA International Symposium and Expo
San Jose, CA
Information: Conference Web site
http://www.wcai.com

November 16-21, 2008
30th Annual Symposium of the Antenna Measurement Techniques Association (AMTA 2008)
Boston, MA
Information: Conference Web site
http://www.amta2008.org

November 17-19, 2008
MILCOM 2008—Military Communications Conference
San Diego, CA
Information: Conference Web site
http://www.milcom.org

SHORT COURSES

National Institute of Standards and Technology (NIST)
Building One, Lobby
325 Broadway
Boulder, CO
Tel: 303-497-4500
Fax: 303-497-5208
E-mail: wmcbride@boulder.nist.gov
Antenna Parameter Measurements by Near-Field Techniques
Sept. 16-18, 2008, Boulder, CO

Besser Associates
201 San Antonio Circle, Suite 115
Mountain View, CA 94040
Tel: 650-949-3300; Fax: 650-949-4400
E-mail: info@besserassociates.com
http://www.besserassociates.com
Applied RF Techniques I
August 11-15, 2008, San Jose, CA
Frequency Synthesis and Phase-Locked Loop Design
August 11-13, 2008, San Jose, CA
Advanced Wireless and Microwave Techniques
August 11-15, 2008, San Jose, CA
Ultra Linear High Efficiency Power Amplifier Design
August 11-15, 2008, San Jose, CA
WiMAX Broadband Wireless Access
August 11-13, 2008, San Jose, CA
Digital Wireless Audio Systems: Technology and Solutions
August 11-13, 2008, San Jose, CA
Wireless Transceiver Design Techniques
August 11-15, 2008, San Jose, CA
Engineering UHF RFID Systems
August 11-12, 2008, San Jose, CA
Signal Processing for Wireless Communications
August 12-15, 2008, San Jose, CA
Bluetooth: Operation and Use
August 13-15, 2008, San Jose, CA
EMC and Signal Integrity Design Strategies
Go with the flow. Enjoy your speed.

CST MICROWAVE STUDIO® 2008. There’s more behind it.

➤ Speed and accuracy blended into one. Designed to fit your workflow, CST harnesses the power of leading edge software and hardware technology to put 3D EM on the face of the wave.

Don’t just judge the book by the cover though – the software has to perform. Check out the time taken to reach your accuracy requirement and we are convinced that our simulation technology will come out on top. All applications have different needs. CST has the technology to cover them.

CST MICROWAVE STUDIO® [CST MWS] is the first commercial HF 3D EM code to offer the advantages of time and frequency domain, hexahedral and tetrahedral meshing, united in one interface, allowing you to choose the technology best suited to your application. Embedded in an advanced design environment, CST MWS can be coupled with all CST STUDIO SUITE™ solver technology including circuit and thermal simulation.

CST MICROWAVE STUDIO® is the market leading time domain tool for 3D EM simulation. It has benefited from over 30 years experience in the area of numerical field calculation, and is used by industry market leaders worldwide.

➤ Choose the accuracy and speed offered by CST MWS. There’s more to performance than meets the eye.
MEETINGS & EVENTS

August 13-15, 2008, San Jose, CA
Wideband/HF Amplifier Design Techniques
August 13-15, 2008, San Jose, CA
High-Speed Bipolar/BiCMOS Design for Mixed-Signal Circuits
August 14-15, 2008, San Jose, CA
RF Measurements: Principles & Demonstration
August 18-22, 2008, Sunnyvale, CA

R.A. Wood Associates
1001 Broad St., Suite 450
Utica, NY  13501
Tel: 315-735-4217
http://www.rawood.com
Introductory RF and Microwaves
  Sept. 17-19, Syracuse, NY
  Nov. 12-14, Philadelphia, PA
RF and Microwave Receiver Design
  Sept. 22-25, Syracuse, NY
  Nov. 17-20, Philadelphia, PA
RF Power Amplifiers, Classes A-S: How the Circuits Operate, How to Design Them, and When to Use Each
  Sept. 15-16, Syracuse, NY
  Nov. 24-25, Philadelphia, PA

ULCA Extension
10995 Le Conte AVE.
Los Angeles, CA  90024-1333
Tel: 310-825-3344; Fax: 310-206-2815
http://ulcaextension.edu/short
Broadband Mobile Satellite Communications: Systems and Installations Across the MSS and FSS Spectrum
  July 14-16, 2008, Los Angeles, CA
Transiting from Technical to Managerial Responsibilities
  July 14-16, 2008, Los Angeles, CA
Introduction to Error-Control Coding
  July 21-22, 2008, Los Angeles, CA
Ultra-Wideband System Design
  July 21-22, 2008, Los Angeles, CA
Low-Density Parity-Check (LDPC) Codes
  July 23-25, 2008, Los Angeles, CA
FPGAs for DSP and Communications
  July 28-31, 2008, Los Angeles, CA
Multimedia Communications and Networking
  August 4-5, 2008, Los Angeles, CA
High-Speed Digital Design and PCB Layout
  August 4-6, 2008, Los Angeles, CA
EMI/EMC for the Design Engineer
  August 7-8, 2008, Los Angeles, CA

Computer Simulation Technology
http://www.cst.com/Content/Events/Workshops.aspx
CST announces a series of customer workshops focusing on high frequency system design challenges. The series investigates how new technology will benefit designers working in the high speed data, power integrity and EMC/EMI areas, as well as on optical applications. CST offers advanced workflows to cover all major aspects of electromagnetic system design and optimization, and this technology will be explained through a series of presentations. In addition to CST staff, presenting partners include, GM, Verigy, Cisco, Agilent, Finisar and Continental Automotive.
Design Challenges: EMC and SI-PI Simulation
August 18, 2008, Detroit, MI

CALLS FOR PAPERS

2009 Radio Wireless Week
San Diego, CA
Conference Dates: January 16-23, 2009
Including the following conferences:

IEEE Radio & Wireless Symposium
Abstract Deadline: July 14, 2008
Topics:
RWS 2009 sessions will highlight applications including (but not limited to): 3G/4G Wireless communication, wireless sensors and ad hoc networks towards anytime anywhere internetworking, UWB technologies, wireless security and RFID technologies, seamless mobility and all-IP mobile networks, wireless energy transmission, etc.
Information:
Authors must submit a 4-page max. summary electronically using the www.radiowireless.org Web page by 14 July 2008. The only accepted file format is PDF.

The 9th Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems
Abstract Deadline: July 20, 2008
Topics:
Topics include but are not limited to: RF circuits, Si millimeter wave ICs, RF systems and architectures, devices and modeling, materials, IC technologies, passives and MEMS, emerging technologies, etc.
Information:
Authors must submit a 2- to 4-page manuscript in pdf format online. Papers submitted to SiRF 2009 must NOT be submitted to the other two conferences of the Radio and Wireless Week. For complete details see http://www.eng.auburn.edu/~niuguof/sirf.

IEEE Topical Symposium on Power Amplifiers for Wireless Communications
Abstract Deadline: October 15, 2008
Topics:
Papers are solicited in (but not limited to) the following areas: devices for power amplifiers, linearization techniques, measurement techniques, etc.
Information:
Authors should submit a 2-page abstract to John Wood at John.Wood@freescale.com by October 15, 2008. Visit http://pasymposium.ucsd.edu for details.
**SUPER ULTRA WIDEBAND AMPLIFIERS**

+24 dBm output... 0.7 to 21GHz from $845 ea.

Simply calling the ZVA-183X and ZVA-213X "wideband" amplifiers doesn't begin to describe them. The super ultra wideband ZVA-183X amplifier operates from 0.7 to 18.0 GHz while the ZVA-213X amplifier covers even more "spectral ground," with a range of 0.8 to 21.0 GHz. Both super ultra wideband amplifiers deliver +24 dBm typical output power at 1 dB compression by merit of 26 dB typical small-signal gain with ±1 dB typical gain flatness. Both provide wide dynamic range along with the bandwidth, with typical noise figure of 3 dB and typical IP3 of +33 dBm. These versatile amplifiers are ideal for broadband commercial and military applications, from radar systems to test equipment. The ZVA-183X and ZVA-213X amplifiers are unconditionally stable. In fact, they are so rugged, they can even withstand load mismatches as severe as an open or short circuit at full 1dB compression output power.

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---

<table>
<thead>
<tr>
<th>MODEL</th>
<th>FREQUENCY (GHz)</th>
<th>GAIN (dB)</th>
<th>POUT (dBm)</th>
<th>NOISE FIG. (dB)</th>
<th>PRICE (1-9)</th>
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</thead>
<tbody>
<tr>
<td>ZVA-183X+</td>
<td>0.7-18</td>
<td>26</td>
<td>+24</td>
<td>3.0</td>
<td>845.00</td>
</tr>
<tr>
<td>ZVA-213X+</td>
<td>0.8-21</td>
<td>26</td>
<td>+24</td>
<td>3.0</td>
<td>945.00</td>
</tr>
</tbody>
</table>

Note: Alternative heat-sink must be provided to limit maximum base plate temperature.

All models IN STOCK!

---

Mini-Circuits...we're redefining what VALUE is all about!
**Business News**

**Mouser Electronics, Inc.** announced it is now stocking the Johnson® line of SMP blind-mate connectors from Emerson Network Power Connectivity Solutions. The connectors can correct axial and radial misalignment, and they are compatible with all SMP and GPO® connectors.

**XMA Corporation** is proud to announce its acquisition of the esteemed Omni Spectra™ brand of microwave components. Since purchasing the CAT line from MA-COM in 2003, XMA has carried on the Omni Spectra™ tradition by not only producing many of its original designs, but also drafting customized solutions for use in some of the most advanced communications, aerospace, and military applications today. Now, after years of developing high-performance Omni Spectra™ products, XMA has officially trademarked the brand as part of its strategy to become an industry leader in passive microwave and RF components.

**TriQuint Semiconductor®** announced the completion of its acquisition of WJ Communications, Inc. WJ is a leading supplier of radio frequency (RF) solutions for wireless infrastructure. Its devices complement TriQuint’s existing portfolio, broadening the networks market product line while adding RF design expertise to TriQuint’s global facilities through a Silicon Valley site.

**Cinch** and **Meritec** entered into a technology agreement that will combine the collective expertise and leading edge product development of two leading providers in the global high performance connector and cable assembly marketplace. Through a technology license covering the Meritec NX InfiniBand™ Architecture Standard High Speed Cable Assembly product line, Cinch will gain access to Meritec’s extensive knowledge base and unique construction methodology in the area of high-speed connector and cable design, manufacturing and testing. Known for its specialized approach to wire preparation, construction and termination that yields superior-performing end products, and its innovative backshell solutions, Meritec will complement Cinch’s existing connector solutions with its creative approach to problem solving and top-performing products.

**Merrimac Industries, Inc.** announced that it has entered into a Memorandum of Understanding (MOU) with Nitronex Corporation to develop new highly integrated power amplifiers using Merrimac’s proprietary Multi-Mix® multilayer circuit technology and high-power gallium nitride (GaN) transistor technology from Nitronex.

**Northrop Grumman Corporation** recently presented the Gold Supplier awards to 49 companies that routinely demonstrated excellence in product quality, on-time delivery, competitive pricing and other value-added services in 2007. **SV Microwave** is proud to be one of the companies that received Northrop Grumman Space Technology’s rigorous Supplier Rating Program, which requires suppliers and subcontractors to participate in an ongoing performance assessment. Gold suppliers are selected on the basis of a scorecard that rates each supplier’s management, quality, technical, schedule and financial performance.

**Laird Technologies, Inc.** announced receiving the General Motors 2007 Supplier of the Year award for its significant contributions to GM’s global product and performance achievements. The 16th annual award—themed the “Best of the Best”—was presented during ceremonies Saturday, April 26, 2008, at the Sawgrass Marriott Hotel in Jacksonville, Fla.

**Hittite Microwave Corporation** announced it has received its AS9100 B certification for the design, and manufacture of MMIC and MMIC Assemblies for RF and Microwave Applications for the aerospace industry. AS9100 B is a Quality Management System which specifies aerospace industry quality and manufacturing standards that are universally recognized by all major aerospace manufacturers. In addition to receiving this new certification, the company was recertified to the ISO 9001:2000 standard, which it has maintained since 1997. The company was audited and certified by TÜV SÜD America, Inc.

**K-micro** and **AnSem** announced a strategic partnership to develop and deliver advanced chipsets for the home networking market. The first products to be delivered are Analog Front Ends (AFEs). Consumers will benefit from the higher performance and lower cost of home networking devices made with these AFEs.

**SiGe Semiconductor** announced the shipment of more than 250 million integrated circuits (ICs), reinforcing its position among the leading suppliers of RF front-end solutions enabling wireless multimedia in consumer electronics. SiGe has enjoyed 40 percent year-over-year growth with 2007 revenues exceeding $69 million.

**Laird Technologies, Inc.** announced a corporate donation of $100,000 (700,000 RMB) for relief efforts to aid the recovery response of the recent devastating earthquake in Chengdu, China. In addition, individual company employees in China donated over $35,000 (245,000 RMB) in a grass roots effort to assist their fellow countrymen.

**Sales Appointments**

**LadyBug Technologies LLC** recently announced an expanded sales and distribution network to accommodate a 2008 increase in sales inquiries and orders for its line of USB power sensors. **United States:** Northern California, Jay Stone Associates, sales@jasrep.com; New England States, Hi-Tech Sales, jlalla@htssales.com; Mid-Atlantic, Sertech, info@sertech.info; All Other States, LadyBug Sales, sales@ladybug-tech.com. **Canada:** LadyBug Sales,
±0.3dB Accurate RMS Power Measurement to 2.7GHz

Exceptional Accuracy over Temperature from 40MHz to 2.7GHz, with Fast 5µs Settling to 1dB Ripple

The LT®5570 provides fast, accurate RMS RF power measurements of high crest-factor modulated signals. Its >50dB dynamic range meets the most demanding requirements of cellular basestations, WiMAX and wireless infrastructure equipment. And its industry-leading accuracy performance over temperature simplifies design and calibration procedures.

RF Power Detector Family

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Frequency Range</th>
<th>Dynamic Range</th>
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<tbody>
<tr>
<td>LT5570</td>
<td>40MHz – 2.7GHz</td>
<td>60dB RMS</td>
</tr>
<tr>
<td>LT5534</td>
<td>50MHz – 2.7GHz</td>
<td>60dB Log Detector</td>
</tr>
<tr>
<td>LT5537</td>
<td>5MHz – 1GHz</td>
<td>90dB Log Detector</td>
</tr>
<tr>
<td>LTC5505</td>
<td>300MHz – 3.5GHz</td>
<td>46dB Peak</td>
</tr>
<tr>
<td>LTC5507</td>
<td>100kHz – 1GHz</td>
<td>46dB Peak</td>
</tr>
<tr>
<td>LTC5508</td>
<td>600MHz – 7GHz</td>
<td>44dB Peak</td>
</tr>
<tr>
<td>LTC5532</td>
<td>600MHz – 11GHz</td>
<td>42dB Peak</td>
</tr>
</tbody>
</table>

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IN THE NEWS

Modelithics, Inc. announces the appointment of international distributors Ultram Technologies, LTD as the corporation’s exclusive representative covering Israel. Larry Dunleavy, Modelithics’ CEO, and the Director of Ultram, Yossi Yurany, have signed a comprehensive agreement designed to fully support the Israeli market for RF and microwave simulation models and characterization services.

People in the News

Phase Matrix has appointed Suresh P. Ojha to RF & Microwave Engineer, Frequency Synthesis Group. Mr. Ojha is responsible for the microwave engineering activities for a new generation of fast switching frequency synthesizers. Suresh P. Ojha received his BS and MS degrees in electrical engineering with a specialization in RF and Microwaves from UC Davis in 1993 and 1995 respectively. He has previously designed cellular base station power amplifiers and signal sources for Agilent Technologies and Gigatronics.

LadyBug Technologies LLC recently announced the appointment of Scott Conrad as the company’s Vice President of Sales and Marketing. In his new position Mr. Conrad will hold responsibility for LadyBug’s overall sales and marketing strategies worldwide, and will oversee the company’s direct sales force, field representatives, and distribution network. He reports to LadyBug President Richard Hawkins. Mr. Conrad holds a M.S. in Management of Technology from NTU, Fort Collins, Colo.; an M.B.A. in Management Information Systems, University of Minnesota; and a B.S. in Industrial Engineering from the University of Wisconsin.

picoChip announced the appointment of Jackie Barker to the newly-created post of VP operations. A specialist in supply chain management, Ms Barker brings with her nearly 20 years’ experience in a range of strategic and operational roles, and an in-depth knowledge of high technology industries. Ms Barker will focus on maintaining a responsive, agile supply chain that will allow picoChip to continue delivering first class technology throughout a phase of rapid growth. Her previous roles include an extended spell at Hewlett Packard.

Ducommun Technologies is pleased to announce that Rich Crabtree has joined Ducommun Technologies as Director, Business Development Microwave Products. Rich will be responsible for the sale of Ducommun’s microwave products. With over 20 years’ industry experience, he brings a successful background of sales and sales management in the Avionics; Defense and Commercial markets with RF and Microwave components and sub-systems. Prior to joining Ducommun Technologies, Rich was with Renaissance Electronics Corporation, Harvard, MA. Ducommun also announces that Daniel Avina has joined Ducommun Technologies as Sales Representative. Daniel will be responsible for working with customers to promote Ducommun parts and ensure selection of the right components for their individual requirement. Prior to joining Ducommun Technologies, Daniel was with Maury Microwave and the US Marine Corps where he gained experience in quality and calibration laboratories.

Endwave Corporation announced that Chuck Piercy was named Site Manager for the company’s El Dorado Hills, CA facility. Mr. Piercy joined Endwave in April of 2007 with the company’s acquisition of ALC Microwave Inc., a leading provider of logarithmic amplifiers and other integrated subsystems to many US and international defense prime contractors. He also currently serves as a Strategic Business Manager for Endwave’s Defense and Security business unit. As a key member of ALC Microwave since 2004, Mr. Piercy contributed as Senior Design Engineer on many of the integrated subsystems used in early warning radars, threat detection equipment, electronic countermeasures and missile guidance systems. He is a graduate of the DeVry Institute of Technology.

National Technical Systems Inc. is pleased to announce that Rick Smith has joined the NTS Fullerton Operations group. Mr. Smith comes to NTS after 34 years with Wyle Laboratories where he previously held the position of Director of El Segundo Test Operations.

Semtech Corp. announced changes to its executive staff. Effective immediately, Simon Prutton joins Semtech as the Vice President and General Manager of the Power Management Product Group. He takes over the position from Semtech veteran Mike Wilson who is transitioning from that position to the newly established role of Chief Technology Officer and Senior Vice President of Business Development. Both executives report to Mohan Maheswaran, President and CEO of Semtech.

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Industry Association News

SDR Forum Invites Participation in Two New Work Groups
Technology continues to evolve at a rapid rate, often leaving manufacturers, network operators and regulators behind, thus limiting opportunities to effectively advance the market. Two new groups under consideration by the Software Defined Radio (SDR) Forum (www.sdrforum.org) have the power to change this, and a call is now being issued to radio manufacturers and technology providers to participate. Initiated during the recent 58th General Meeting of the SDR Forum in Rome Italy, these new groups, the RF Technologies Task Group and the Commercial Baseband Processor Work Group, will offer industry a unique, neutral and collaborative environment to advance key technology areas and alter the course of their respective markets. The RF Technologies Task Group will bring together leading developers of advanced RF technologies to create a baseline summary on a range of technology areas, including antennas and antenna arrays, RF and IF integrated circuits, broadband amplifiers and frequency agile filters. Similarly, the Commercial Baseband Processor Work Group will aim to break down misconceptions and open up new market opportunities for programmable processing devices. The proposed Work Group will work to educate the market on capabilities and define the necessary specifications and standards.

LXI Consortium Announces First Member and First Product Certification From China
The LXI Consortium (www.lxistandard.org) has accepted RIGOL Technologies as the first member from mainland China. RIGOL Technologies attended the Beijing LXI PlugFest in June 2007 and subsequently became not only the first Chinese company to join the Consortium, but, in February 2008, the first to certify an LXI product. The RIGOL DS1204B digital oscilloscope was certified within six months of the company’s membership. RIGOL Technologies manufactures digital oscilloscopes, functional/arbitrary waveform generators, digital multimeters, and virtual instruments with LXI capability. “By introducing products with a new architecture within six months of joining, RIGOL illustrates how the global adoption of LXI is being accelerated by the simplicity of the LXI certification process,” said Bob Rennard, President of the LXI Consortium. “It also illustrates how attending a PlugFest can facilitate the certification process by providing access to members who are demonstrating best practices, tutorials and presentations, and answering questions on how to build LXI test systems.”

Accellera Announces Formation of New Standards Committee
Accellera (www.accellera.org), the electronics industry organization focused on Electronic Design Automation (EDA) standards, announced today that its Board of Directors answered electronic design verification tool users’ requests by approving the formation of a new verification standards committee. The Verification Intellectual Property (VIP) Technical Subcommittee (TSC) is chartered to define standard technology and/or methods to realize a modular, scalable and reusable generic verification environment. Verification components and environments are currently created in different forms, making interoperability among verification tools or geographically dispersed design teams time-consuming and error-prone. The results of Accellera’s VIP standardization effort will improve interoperability and reduce the cost of repurchasing and rewriting IP for each new project or electronic design automation tool, as well as make it easier to reuse verification components. Overall, the VIP standardization effort will lower verification costs and improve design quality throughout the industry.

WiMedia Alliance Announces Additional Certified UWB Wireless Platforms
The WiMedia Alliance® (www.wimedia.org.) has announced that it has certified four more Ultra-Wideband (UWB) platforms. These platforms—from member companies Artimi, Inc. (one platform), NEC Electronics Corporation (two platforms) and Tzero Technologies (one platform)—bring the total number of WiMedia Certified Wireless Platforms (CWPs) to 23, providing additional offerings for ODMs and OEMs wanting to incorporate WiMedia-enabled Wireless USB into their next-generation products. “Now that UWB and Wireless USB-enabled devices have hit the market, greater availability of WiMedia CWPs will help to drive the market forward with more interoperable solutions,” said Brian O’Rourke, principal analyst for In-Stat. “The availability of platforms from a variety of silicon vendors helps fuel adoption by providing interoperable wireless solutions that support PC and multimedia applications with the same ease-of-use and familiarity as wired USB.” Platform certification is the culmination of the Alliance’s comprehensive certification program and designates compliance with the internationally standardized WiMedia UWB specifications. CWPs have been rigorously tested at both the Physical (PHY) and Medium Access Control (MAC) layers, assuring manufacturers that devices built upon WiMedia CWPs will deliver high quality performance and ease-of-use in a variety of regions. The four CWPs announced today continue to build upon the foundation laid by the WiMedia UWB specifications and are capable of signaling rates up to 480 Mbps.
Meet Vikki. Vikki leads a highly experienced team and together they operate one of TriQuint’s world-class wafer manufacturing facilities. Under Vikki’s leadership, the team monitors, tracks and continuously improves the processes and tools which transform customers’ designs into products. Vikki and her management team have more than 120 years of collective GaAs manufacturing experience and are totally dedicated to customer satisfaction. Vikki is one of the people behind the innovation at TriQuint Semiconductor and she’s on your team.

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As discussed in the previous article, a frequency synthesizer can be thought of as a black box containing various components (e.g., oscillators, phase detectors, frequency dividers, multipliers, mixers, amplifiers, etc.), which being properly connected, translate an input reference signal to a number of output frequencies. The synthesizer implementation as well as its ultimate performance depends heavily on characteristics of the individual components used in the design. Although there is no set definition for the term “components” (they can be actually complex connectorized modules), in this article we will mostly refer them as surface-mount parts, which can be placed on a printed circuit board. The characteristics and behavior of the main synthesizer parts are reviewed from the perspective of their use in practical synthesizer designs.

Reference Oscillator

A reference oscillator is one of the most important parts that defines stability and phase noise characteristics of frequency synthesizer. Various reference oscillator schemes are possible as shown in Figure 17. A 10 MHz temperature-compensated crystal oscillator (TCXO) provides low size and cost benefits for low- to moderate-performance applications. Better stability and noise characteristics are achieved by using an oven-compensated crystal oscillator (OCXO), but this is a more expensive and bulky part with a higher power consumption. It is worth mentioning, that using a higher frequency OCXO (e.g., 100 MHz instead of 10 MHz) can potentially result in a better synthesizer noise. There is a comparable noise floor for both parts, but the high frequency reference requires a significantly lower overall multiplication factor.

Even better phase noise performance at higher frequency offsets (100 kHz and above) can be obtained with additional low-noise oscillators (e.g., SAW, CRO, or DRO) locked to the main OCXO. The chain of oscillators (which can include two or even more parts) provides the lowest phase noise profile at any frequency offset and can be used in high-end synthesizer designs. The high-frequency oscillators are usually purchased parts, although, they can be built as a part of the synthesizer design to minimize the overall size and cost. However, building a low-noise microwave oscillator (e.g. a DRO) with adequate phase noise performance is not a trivial task; it requires careful design and optimization.

The phase noise behavior of a microwave oscillator (shown conceptually in Figure 18)
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has been extensively investigated [23-27] and can be represented as follows:

\[
\chi = 10 \log \left\{ \frac{G F k t}{2P} \left[ \left( \frac{f_0}{2Q} \right)^{3} \cdot \frac{f_0}{f^3} + \left( \frac{f_0}{2Q} \right)^{2} \cdot \frac{1}{f^2} \cdot \frac{f_0}{f} + 1 \right] \right\}
\]

where: \( G \) is active device gain, \( F \) is active device noise factor, \( k \) is Boltzman's constant, \( T \) is temperature, \( P \) is RF power applied to the resonator, \( Q \) is resonator loaded \( Q \)-factor, \( f_0 \) is oscillation frequency, \( f_a \) is active device flicker corner frequency, \( f \) is offset frequency. This expression is essentially a modified Leeson’s equation that depicts the oscillator phase noise behavior in the frequency offset domain. Although the formula defines four basic frequency offset regions, in microwave oscillators the \( 1/f \) term is usually ignored due to \( 1/f^2 \) noise domination that leads to a “classical” oscillator phase noise profile shown in Figure 19. For offset frequencies higher than the resonator half bandwidth \( f_0/2Q \), the phase noise is mainly determined by the available RF power level and active device thermal noise. This region shows nearly flat response called “noise floor.” For frequencies between the half bandwidth and flicker corner frequency \( f_a \), the phase noise increases at 20 dB per decade. In the last region, where the flicker noise dominates, the phase noise increases at 30 dB per decade.

This graph gives simplified, but nevertheless, very helpful visualization of the phase noise behavior as well as some intuitive ideas how to reduce its appearance in the oscillator output spectrum. Clearly, utilizing low flicker noise devices (e.g. silicon bipolar transistors) and applying a high-\( Q \) frequency resonator technology are effective, and commonly used ways to minimize the phase noise. Alternatively, the entire noise curve can be shifted down by increasing the oscillator signal-to-thermal noise ratio. This can be practically achieved by maintaining a higher power level in front of the resonator or/and reducing the active device noise factor, while the active device gain should be set to its optimum value (determined be the resonator coupling). Oscillator design methods and phase noise reduction techniques are described in [28-32].

VCO or YIG?

Historically, high-performance PLL synthesizers have relied on YIG-oscillators featuring broadband operation and excellent phase noise characteristics. The YIG is an acronym for yttrium iron garnet, a ferrite material that displays a unique, high-\( Q \) frequency resonance characteristic when exposed to a magnetic field [33-37]. The YIG resonator represents a small (8-20 mils in diameter) sphere placed between two poles of cylindrically re-entrant electromagnet and coupled with small wire loops (Fig. 20). Frequency tuning is possible since the resonant frequency of the spherical YIG resonator in uniform magnetic field is a function of the magnetic field strength. The basic relationship between the resonant frequency \( f \) and magnetic field strength \( H \) is given by: \( f = g H \), where: \( g = 2.8 \text{ MHz/Oe} \) is a physical constant called gyromagnetic ratio. Therefore, the resonant frequency is in direct proportion to the magnetic field, which can be controlled by changing DC current injected into the electromagnet tuning coil. Practical usable frequency range of pure YIG resonators lies between 2 and 50 GHz. While the higher frequency is mainly limited by the magnet saturation and high power dissipation, lower limit is governed by the YIG saturation magnetization. Lower operating frequencies (a
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few hundred MHz) are obtainable adding special dopes (such as gadolinium) that, however, degrades the $Q$-characteristics.

The YIG resonators offer a relatively high $Q$ (greater than 4,000 at 10 GHz) that results in low phase noise performance. The YIG oscillators also feature very linear (and repeatable) tuning characteristics that simplify the synthesizer coarse tuning algorithm in multiloop schemes. The main disadvantages are high power consumption, large size, high cost, and especially low tuning speed due to high inductance of the tuning coil. Typical achievable switching time is in a milliseconds range.

An alternative solution is a voltage-controlled oscillator (VCO) based on either lumped LC or distributed microstrip resonators. Unfortunately, $Q$-factors of these resonators are not so high; typical values are between a few tens and few hundreds dependent on a particular technology and tuning range. The frequency tuning is achieved using varactor diodes, whose capacitance depends on the applied tuning voltage. Unlike YIGs the VCOs are extremely fast; microseconds operation is easily achieved. VCOs are currently available as tiny ICs, whose size, power consumption and cost is negligible in comparison with the YIG devices. However, the noise performance is considerably worse because of the lower $Q$ of the utilized resonators (which is further degraded by the varactor diodes).

What technology is more preferable? The VCO clearly dominates in low-cost, low- to moderate-performance designs. However, for high-performance, broadband, low-noise applications (e.g., test and measurement) the answer is not so obvious. YIG-based solutions are usually simpler since the YIG-oscillator can forgive and mask many design imperfections. One can relatively easily achieve respectable phase noise performance with a simple single or dual-loop PLL by locking the YIG with a 10 kHz loop bandwidth and relying on its free-running noise at higher frequency offsets. Obtaining comparable noise performance with a VCO is much more challenging task since the designer can only rely on the reference oscillator and PLL characteristics. At a 100 MHz output frequency, today’s commercial OCXOs perform at $-160$ to $-176$ dBc/Hz at 20 to 100 kHz offset. These numbers can be potentially translated to $-120$ to $-136$ dBc/Hz at a 10 GHz output. This theoretical performance corresponds to or even exceeds the performance of the best YIG oscillators at the same offset frequencies. However, it is very hard (if possible at all) to provide such an ideal translation since some noise degradation always occurs. Thus, achieving YIG-comparable noise characteristics for a VCO-based design is not a trivial task that calls for advanced multiloop solutions and also requires a great deal of effort to treat various “secondary” effects (e.g. voltage regulator noise, etc.). Nevertheless, the current technology trend toward faster tuning and lower cost puts the VCO in a better position for many practical scenarios.

### Frequency Multipliers

Frequency multipliers are used to multiply reference signals or to extend synthesizer operating frequency bands. The device behavior and practical implementation is very well treated in [6, 17, 38]. It should be highlighted that a frequency-modulated signal is affected by the frequency multiplication process; i.e., phase noise and PM spurs are degraded at $20\log N$ rate, where $N$ is the multiplication factor. Thus, the designer’s primary concern is to avoid any extra degradation above the baseline of $20\log N$. From this point of view, passive, diode-based solutions are obviously preferred.

### Frequency Dividers

A frequency divider is an essential part in a PLL synthesizer. It works in the exact opposite way that multiplier does, i.e., it brings phase noise and spurious improvement at the same $20\log N$ rate. Digital dividers (e.g., counters) are the most commonly used devices. The residual noise is probably the main concern since the divided sig-
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nal can easily hit into the divider noise floor. On the other hand, analog dividers (e.g., a regenerative scheme shown in Figure 21) provide the best noise performance but are rarely used due to their narrowband behavior as well as sensitivity to circuit parameters and signal level [39-41].

It is worth mentioning that the digital frequency divider tends to suppress even harmonics and accents odd products as shown in Figure 22. This is simply because the output of a digital counter is a square-wave signal that ideally contains odd harmonics only. This feature can be utilized to obtain fraction frequency multiplication and division coefficients (e.g., 3/2, 3/4, 5/4, etc.) that can be desirable in certain cases.

Mixers
Mixers are utilized in direct analog architectures as well as indirect schemes where frequency offsetting (mixing) is involved. In contrast to frequency dividers and multipliers, an ideal mixer provides a frequency shift without disturbing signal spurious and phase noise characteristics. A propagation of an FM-modulated signal with –60 dBc spurious level through a hypothetical, ideal multiplier-mixer-divider chain is illustrated in Figure 23 (it assumes that the signal has a pure close-in PM spur; practical scenarios are usually more complicated since AM-to-PM conversion and other effects can take place). Mixers are available in IC form and can be also built from discrete parts [38]. Similar to frequency multipliers, passive (diode-based) solutions are obviously preferable.

Phase Detectors
A phase detector compares two signals and generates a voltage, which is a measure of the phase difference between the signals [17]. The phase detector residual noise is one of the key parameters that affect the performance of a PLL synthesizer. From this point of view, a balanced mixer can be a good candidate for low-noise designs, especially if a high reference signal is used. A harmonic (sampling) mixer can be used as a phase detector as well. It combines an SRD multiplier and mixing diodes in a common package (Figure 24) that leads to considerable reduction in synthesizer component count. It is worth mentioning, however, the sampling detector is very sensitive to circuit parameters; making one work properly is not trivial. The main disadvantages of the mixer-based phase detectors are relatively high undesired signals (e.g., reference harmonics and DC offset) and initial frequency acquisition problem when the PLL is out of lock.

A digital phase-frequency detector is a very popular and frequently used alternative since it provides a frequency-sensitive signal to aid acquisition. The detector can be constructed from discrete logic components as shown in Figure 25; it is also available in IC form (usually with an integrated charge-pump circuit). The main disadvantage of digital detectors is a higher residual noise in comparison with analog, mixer-based parts.

Integrated PLL ICs
Some vendors (e.g., Analog Devices, National Semiconductor and others) provide fully integrated ICs containing all necessary components required to build a whole synthesizer (Figure 26). A nice example is ADF4106 PLL IC from Analog Devices.
Devices, which includes a digital phase detector with an integrated charge pump, RF and reference dividers, lock detector, and other circuits. All division coefficients can be programmed through a built-in 3-wire serial interface (clock, data, and chip select lines). The user can also program charge pump current (to adjust PLL bandwidth), change phase detector polarity (this feature can be very helpful if a frequency mixing employed), monitor frequency lock, or access some internal signals. The IC allows building a simple single-loop PLL synthesizer or can be used in more complex schemes.

Other synthesizer-oriented ICs may include more phase detector/divider sets to build a dual-loop synthesizer, fractional-N dividers, DDS, parallel interface for faster control, on-chip memory, etc.

**Other Components**

Depending on a particular architecture, frequency synthesizers can include many other components both active (e.g., amplifiers, switches, attenuators, phase shifters, etc.) and passive (e.g., resistors, capacitors, inductors, transformers, fixed attenuators, power splitters, couplers, filters, etc.) available in surface-mount packages.

Many passive components can also be printed directly on a PCB, such as the coupler and transmission lines in the assembly shown in Figure 27. The advantages of using printed components are obviously their low cost (just the PCB material itself) and more predictable frequency response due to the absence of package parasitics effects. The main disadvantage is that more “real estate” is required for some components in comparison with packaged versions. And finally, the simplest but very important element of any microwave design is a 50-ohm transmission line used to connect the mentioned above individual parts. The transmission line impedance depends on the line width as well as the thickness and dielectric constant of the board.

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<tr>
<th>Capacitance Range</th>
<th>Standard WVDC</th>
<th>Extended WVDC</th>
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<tbody>
<tr>
<td>0.1 to 47 pF</td>
<td>500 WVDC</td>
<td>1500 WVDC</td>
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<tr>
<td>51 to 100 pF</td>
<td>500 WVDC</td>
<td>1000 WVDC</td>
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<tr>
<td>110 to 200 pF</td>
<td>300 WVDC</td>
<td>1000 WVDC</td>
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utilized PCB material. FR-4 works well at relatively low frequencies (a few GHz), while lower loss materials (such as Rogers 4003C) are preferable at higher frequencies. Also, it is preferred that a solder mask should be removed from high-frequency elements since it introduces extra loss and slightly changes the impedance. It is also worth mentioning that all packaged parts introduce discontinuity effects, which should be minimized (or compensated) to avoid any unexpected issues and provide a robust and reproducible design.

This article will be continued in the next issue, demonstrating the most important aspects of the synthesizer design process. Part 3 will show all design stages from a general block diagram to schematic, PCB layout, assembly, troubleshooting, testing, and documentation release. A simple, single-loop PLL architecture is used to discuss all aspects of the design process.

References


Author Information

Dr. Alexander Chenakin is the Director of the Frequency Synthesis Group at Phase Matrix, Inc., (www.phasematrix.com) where he oversees the development of advanced frequency synthesizer products for test and measurement applications. He earned his degree from Kiev Polytechnic Institute and has worked in a variety of technical and managerial positions around the world. He has led the development of advanced products for Celeritek, Nextek, Micro Lambda Wireless, General Electronic Devices, and other companies. Dr. Chenakin was a lecturer for the 2008 IEEE International Frequency Control Symposium tutorials. He can be reached by phone at 408-954-6409 or by e-mail at achenakin@phasematrix.com.

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<thead>
<tr>
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<th>Icc (mA)</th>
<th>Pout (dBm)</th>
<th>Gain Control Range (dB)</th>
<th>Efficiency (%)</th>
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### SiGe:C MMIC LNA

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### GaAs SPDT Switch

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<td>0.48</td>
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<td>1.0 x 1.0 x 0.37</td>
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Wireless Receiver Design Emphasizes Direct Conversion

From the earliest work on rectifiers to detect spark transmissions to advanced low-noise semiconductors for deep space research, receiver design and component innovations have enabled many advances in communications technology. With the vast majority of current wireless systems employing digital transmission, the simplicity and low implementation cost of direct conversion receivers has brought that technique to the forefront.

With digital signals, the shortest path from the analog RF input to a digital signal ready for processing is highly desirable. Direct conversion translates the radio frequency of a signal to an equivalent bandwidth centered on DC (or zero Hz). At this low frequency range, the most inexpensive digital IC technology can be used for processing. Since power consumption of digital devices increases with clock frequency, baseband processing requires the least power for its operation.

As is often the case, the advantages of any design approach may also present new design challenges. In a direct-conversion receiver, the advantage of eliminating IF stages means that the local oscillator is at the center frequency of operation. Exceptional balance and reverse isolation performance is required to avoid excessive radiation of the LO via the receiving antenna.

Conversion to a “DC” baseband can result in a significant DC component in the output to the analog-to-digital converters. Although some applications can accept a bandwidth that filters out this DC component, many do not, so it must be minimized.

These performance issues of direct-conversion receivers are reviewed in the article that follows this report, which extends the discussion to the specific effects of intermodulation distortion products.

Next Generation Direct-to-Digital Receivers

Although it is possible to connect an analog-to-digital converter (ADC) directly to an antenna, few applications currently use this technique. The performance demands for a true “antenna-to-ADC” receiver are sufficiently high that, at present, system performance is more easily achieved using direct-conversion to baseband.

However, it also seems correct to suggest that direct-to-ADC detection is actually the same function as the separate RF and digitizing circuits used in direct conversion. After all, the ADC has a high performance analog front end to condition the input signal, and the threshold detection circuits of the digitizer are more accurately characterized in the continuum of analog signals than the on-off states of digital signals. Thus, a direct-to-ADC receiver simply integrates an RF front end into a digital device with less interface circuitry between them.

In one respect, a step towards integrated RF/digital signal detection has already become common-place. In present RF mixer/detector technology, the highest performance is obtained with switch-mode configurations that require both frequency domain and time domain analysis for their characterization.

Still, this new topology will present designers with additional challenges. The system clock will now perform the LO function and must have the kind of low phase noise (jitter in the time domain) performance of present RF circuits. Instead of baseband, the operating frequency will be presented to the ADC, which puts high frequency analog signals on-chip with high frequency clocked circuitry. These factors, along with other high frequency/high speed design issues, are the types of tasks being addressed for future receivers.

<table>
<thead>
<tr>
<th><strong>ADVANTAGES</strong></th>
<th><strong>DISADVANTAGES</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Superheterodyne:</td>
<td>High performance IF filter(s)</td>
</tr>
<tr>
<td></td>
<td>May have multiple LOs</td>
</tr>
<tr>
<td></td>
<td>Most complex RF architecture</td>
</tr>
<tr>
<td>Direct-Conversion:</td>
<td>Requires high performance front-end</td>
</tr>
<tr>
<td></td>
<td>Potential DC offset problems</td>
</tr>
<tr>
<td></td>
<td>Potential for LO radiation</td>
</tr>
<tr>
<td>Direct-to-Digital:</td>
<td>RF performance challenges</td>
</tr>
<tr>
<td></td>
<td>Limited frequency range</td>
</tr>
<tr>
<td></td>
<td>Needs low-jitter, high frequency clock</td>
</tr>
</tbody>
</table>

Some comparisons among current receiver methodologies.
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IP<sub>2</sub> and IP<sub>3</sub> Design
Considerations for a Direct Conversion I/Q Receiver

By Doug Stuetzle
Linear Technology Corporation

**Direct conversion** receiver architecture offers several advantages over the traditional superheterodyne. It eases the requirements for RF front-end band-pass filtering, as it is not susceptible to signals at the image frequency. The bandpass filters only attenuate strong out-of-band signals to prevent them from overloading the front end. Also, direct conversion eliminates the need for IF amplifiers and bandpass filters. Instead, the RF input signal is directly converted to baseband, where amplification and filtering are less difficult. The overall complexity and parts count of the receiver are reduced as well.

Direct conversion does, however, come with its own set of implementation issues. For example, since the receive LO signal is at the same frequency as the RF signal, it can easily radiate from the receive antenna and violate regulatory standards.

Unwanted baseband signals can also be generated by 2nd order nonlinearity of the receiver. A tone at any frequency entering the receiver will give rise to a DC offset in the baseband circuits. Once generated, straightforward elimination of DC offset becomes very problematic because the frequency response of the post-downconversion circuits must often extend to DC. The 2nd order nonlinearity of the receiver also allows a modulated signal, even the desired signal, to generate a pseudo-random block of energy centered about DC.

Unlike superheterodyne receivers, direct conversion receivers are susceptible to such 2nd order mechanisms regardless of the frequency of the incoming signal. So minimizing the effect of finite 2nd order linearity is critical to the design of such receivers.

Later in this paper we will consider the effect of 3rd order distortion on a direct conversion receiver. In this case, two signals separated by an appropriate frequency must enter the receiver in order for unwanted products to appear at the baseband frequencies.

**Second Order Distortion (IP<sub>2</sub>)**

The second order intercept point (IP<sub>2</sub>) of a direct conversion receiver system is a critical performance parameter. It is a measure of second order non-linearity and helps quantify the receiver’s susceptibility to single and two tone interfering signals. Let’s examine how this nonlinearity affects sensitivity.

We can model the transfer function of any nonlinear element as a Taylor series:

\[ y(t) = x(t) + a_2x^2(t) + a_3x^3(t) + \ldots \]

where \( x(t) \) is the input signal consisting of both desired and undesired signals. Consider only the second order distortion term for this analysis. The coefficient \( a_2 \) is equal to \( \sqrt{[2/\pi \cdot \mathrm{IP}_2]} \) where IP<sub>2</sub> is the single tone intercept point in watts. The more linear the element, the smaller \( a_2 \) will be. Note that the two-tone IP<sub>2</sub> is 6 dB below the single-tone IP<sub>2</sub>.

Every signal entering the nonlinear element will generate a signal centered at zero frequency. Even the desired signal will give rise to distortion products at baseband. To illustrate this, let the input signal be represented by:

\[ x(t) = A(t)\cos \omega t \]
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which may be a tone or a modulated signal. If it is a tone, then \( A(t) \) is simply a constant. If it is a modulated signal, then \( A(t) \) represents the signal envelope.

By definition, the power of the desired signal is \( 1/Z_o = E[A(t)\cos \omega t]^2 \), where \( E[\beta] \) is the expected value of \( \beta \). Since \( A(t) \) and \( \cos \omega t \) are statistically independent, we can expand \( E[A(t)\cos \omega t]^2 \) as \( E[A^2(t)] \cdot E[\cos^2 \omega t] \). By trigonometry this is equal to \( E[A^2(t)] \cdot E[1/2 + (1/2)\cos 2\omega t] \). The expected value of the second term is simply 1/2, so the resulting product is 1/2 * \( E[A^2(t)] \). The power of the desired signal simplifies to:

\[
P_s = 1/(2Z_o) \cdot E[A^2(t)]
\]  

(1)

In the case of a tone, \( A(t) \) may be replaced by \( A \). The signal power is, as expected, equal to \( A^2/(2Z_o) \).

In the more general case, the desired signal is digitally modulated by a pseudo-random data source. We can represent it as band-limited white noise with a Gaussian probability distribution. The signal envelope \( A(t) \) is now a Gaussian random variable. The expected value of the square of the envelope can be expressed in terms of the power of the desired signal as:

\[
E[A^2(t)] = 2Z_o P_s
\]  

(2)

Now substitute \( x(t) \) into the Taylor series expansion to find \( y(t) \), which is the output of the nonlinear element:

\[
y(t) = A(t)\cos \omega t + a_2 (A(t)\cos \omega t)^2 + \ldots \text{higher order terms}
\]

\[
= A(t)\cos \omega t + (1/2)a_2A^2(t) + (1/2)a_2A^2(t) \cos 2\omega t + \ldots
\]

Consider the 2nd order distortion term \( (1/2)a_2A^2(t) \). This term appears centered about DC, whereas the other 2nd order term appears near the 2nd harmonic of the desired signal. Only the term near DC is important here, as the high frequency tone will be rejected by the baseband circuitry.

In the case where the signal is a tone, the 2nd order result is a DC offset equal to:

\[
\text{DC offset} = (1/2)a_2A^2 = a_2P_sZ_o
\]  

(3)

If the desired signal is modulated, then the 2nd order result is a modulated baseband signal. The power of this term is \( 1/Z_o \cdot E[(1/2)a_2A^2(t)]^2 \). This can be expanded to:

\[
P_{bb} = a_2^2(4Z_o) \cdot E[A^4(t)]
\]  

(4)

In order to express this result in terms of the desired signal power, we must relate \( E[A^4(t)] \) to \( E[A^2(t)] \). For a Gaussian random variable, the following relation is true:

\[
E[A^4(t)] = 3 \cdot [E[A^2(t)]]^2
\]  

(5)

The distortion power can then be expressed as \( 3a_2^2(4Z_o^2) \cdot E[A^2(t)]^2 \). Now express the expected value in terms of the desired signal power:

\[
P_{bb} = 3a_2^2Z_o^2P_s^2
\]  

(6)

It is the conversion of any given tone to DC and any modulated signal into a baseband signal that makes second order performance critical to direct conversion receiver performance. Unlike other nonlinear mechanisms, the signal frequency does not determine where the distortion product falls.

Any two signals entering the nonlinear element will give rise to a beat note/term. Let \( x(t) = A(t)\cos \omega u + B(t)\cos \omega v \), where the first term is the desired signal and the second term is an unwanted signal.

\[
y(t) = A(t)\cos \omega u + a_2A^2(t) \cos 2\omega u + \ldots
\]

\[
= A(t)\cos \omega u + (1/2)a_2A^2(t) + (1/2)a_2A^2(t) \cos 2\omega u + \ldots
\]

\[
= A(t)\cos \omega u + \ldots + a_2A(t)B(t)\cos(\omega - \omega_v)u + \ldots
\]

The second order distortion term of interest is \( a_2A(t)B(t)\cos(\omega - \omega_v)u \). This term describes the distortion product centered about the difference frequency between the two input signals. In the case of two unwanted tones entering the element, the result will include a tone at the difference frequency. If the two unwanted signals are modulated, then the resultant includes a modulated signal centered about their difference frequency.

We can apply these principles to a direct conversion receiver. The block diagram of a typical WCDMA base station receiver appears in Figure 1. Here are some key characteristics of this example:

- **Base Station Type**: FDD, Band I
- **Base Station Class**: Wide Area
- **Number of carriers**: 1
- **Receive band**: 1920 to 1980 MHz
- **Transmit band**: 2110 to 2170 MHz

![Figure 1 · Block diagram of a typical WCDMA base station receiver.](image)
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The RF section of this receiver includes a diplexer, a bandpass filter, and at least one low noise amplifier (LNA). The frequency selective elements are used to attenuate out-of-band signals and noise. The LNA(s) establishes the noise figure of the receiver. The I/Q demodulator converts the receive signal to baseband. In the examples illustrated later in this paper, we will use the characteristics of the LT5575 I/Q demodulator as representative of a base station class device of this type. Lowpass filters and baseband amplifiers band-limit and increase the signal level before it is passed to the A/D converters. The diplexer and RF bandpass filter serve as band filters only; they do not offer any carrier selectivity.

The second order linearity of the LNA is much less important than that of the demodulator. This is because any LNA distortion due to a single signal will be centered about DC and rejected by the demodulator. If there are two unwanted signals in the receive band (1960 MHz, for example), then a second order product will be generated by the LNA at the difference frequency. This signal will be demodulated and appear as a baseband artifact at the A/D converter. We need not address this condition, however, because out of band signals emerging from the front-end diplexer will not be strong enough to create distortion products of any importance.

Consider first a single unmodulated tone entering the receiver (see Figure 2).

As detailed above, this tone will give rise to a DC offset at the output of the demodulator. If the baseband cascade following the demodulator is DC-coupled, this offset will be applied to the A/D converter and reduce its dynamic range. The WCDMA specification (3GPP TS 25104.740) calls out an out-of-band tone at –15 dBm, located 20 MHz or more from either receive band edge (section 7.5.1). Compute the DC offset generated in the I/Q demodulator:

- Tone entering receive antenna port: –15 dBm
- Diplexer rejection @ 20 MHz offset: 0 dB
- Bandpass rejection @ 20 MHz offset: 2 dB
- RF gain preceding LT5575: 20 dB
- Tone entering LT5575: +3 dBm
- LT5575 IIP₂, two tone: +60 dBm
- LT5575 a₂: 0.00317
- DC offset at LT5575 output: 0.32 mV
- Baseband voltage gain: 31.6
- DC offset at A/D input: 10 mV

A MATLAB simulation performed using a pseudo-random channel predicts the following:

- Distortion at LT5575 output: –98.7 dBm
- This result agrees well with that given by Equation 6, which predicts a distortion power of –98.2 dBm.

The baseband product that appears at the LT5575 output is a noiselike signal, created from the interfering WCDMA carrier. If this signal is large enough, it can add to the thermal receiver and A/D converter noise to degrade sensitivity. Compute the equivalent thermal noise at the receiver input with no added distortion:

- Sensitivity: –121 dBm
- Processing + coding gain: 25 dB
- Signal to noise ratio at sensitivity: 5.2 dB
- Thermal noise at receiver input: –101.2 dBm

Now refer the distortion signal back to the receiver input:

- RF gain preceding LT5575: 20 dB
- Equivalent interference level at Rx input: –118.7 dBm

The baseband second order product in this case is 17.5 dB below the thermal noise at the receiver input. The resulting degradation in sensitivity is <0.1 dB, so the receiver easily meets the specification of –115 dBm. This is illustrated in Figure 3.

Single WCDMA carriers can also serve as interferers, as detailed in section 7.5.1. In one case, this carrier is offset by at least 10 MHz from the desired carrier but is still in the receive band. The power level is –40 dBm, and the receiver must meet a sensitivity of –115 dBm for a 12.2 kbps signal at a BER of 0.1%. Here are the details:

- Signal entering receive antenna port: –40 dBm
- RF gain preceding LT5575: 20 dB
- Signal entering LT5575: –20 dB
- LT5575 IIP₂, two tone: +60 dBm
- LT5575 a₂: 0.00317
- A MATLAB simulation performed using a pseudo-random channel predicts the following:
  - Distortion at LT5575 output: –98.7 dBm

Single WCDMA carriers can also appear out of band, as specified in section 7.5.1. These can be directly adjacent to the receive band at levels as high as –40 dBm.
Here again, the second order effect of such carriers upon sensitivity is negligible, as the preceding analysis shows. Another threat to sensitivity comes from transmitter leakage in FDD systems, as shown in Figure 4. In an FDD system, the transmitter and receiver are operating at the same time. For the WCDMA Band I case, the transmit band is 130 MHz above the receive band. A single antenna is commonly used, with the transmitter and receiver joined by a diplexer. Here are some typical base station coupled resonator-type diplexer specifications:

- Isolation, Tx to Rx 2110 MHz: 55 dB
- Diplexer insertion loss, Tx path: 1.2 dB

In the case of a Wide Area base station, the transmit power may be as high as +46 dBm. At the transmit port of the diplexer the power will then be at least +47 dBm. Some portion of this high level modulated signal will leak to the receiver input and drive the I/Q demodulator:

Receiver input power: –8 dBm
Rx BPF rejection @ 2110 MHz: 40 dB
RF gain preceding LT5575: 20 dB
Signal entering LT5575: –28 dBm
LT5575 IIP₂, two tone: +60 dBm
LT5575 a₂: 0.00317

A MATLAB simulation performed using a pseudo-random channel predicts the distortion at LT5575 output to be –114.7 dBm. Referring this signal back to the input:

RF gain preceding LT5575: 20 dB
Equivalent interference level at Rx input: –134.7 dBm
Thermal noise at receiver input: –101.2 dBm

This equivalent interference is 33.5 dB below the thermal noise at the receiver input. The resulting degradation in sensitivity is <0.1 dB, so the receiver easily meets the specification of –121 dBm.

The third order intercept point (IP₃) will have an effect upon the baseband signal when two properly spaced channels or signals enter the nonlinear element. Refer back to the transfer function:

\[ y(t) = x(t) + a₂x^2(t) + a₃x^3(t) + \ldots \]

where \( x(t) \) is the input signal consisting of both desired and undesired signals. Consider now the third order distortion term. The coefficient \( a₃ \) is equal to \( 2/(3Z_oIP₃) \) where IP₃ is the single tone intercept point in watts. Note that the two-tone IP₃ is 4.78 dB below the single-tone IP₃.

Two signals entering the nonlinear element will generate a signal centered at zero frequency, if the spacing between the two signals is equal to the distance to zero frequency. Let \( x(t) = A(t)\cos\omega t + B(t)\cos\omega_2t \), where the first term is the desired signal and the second term is an unwanted signal. The unwanted signal may be a tone or a modulated signal. If it is a tone, then \( B(t) \) is simply a constant. If it is a modulated signal, then \( B(t) \) represents the signal envelope. The output signal is then equal to \( y(t) \):

\[
y(t) = A(t)\cos\omega t + \ldots + a₂A(t)^2\cos\omega t + B(t)\cos\omega_2t + \ldots \]
\[
= A(t)\cos\omega t + \ldots + 3a₂A(t)^2B(t)\cos^2\omega t + 3a₃A(t)B^2(t)\cos^3\omega_2t + \ldots
\]
\[
= A(t)\cos\omega t + \ldots + (3/4)a₃A(t)B^2(t)\cos(2\omega_2 - \omega)t + \ldots
\]

The third order distortion term of interest here is \((3/4)a₃A(t)B^2(t)\cos(2\omega_2 - \omega)t\). In order for this distortion to appear at baseband, set \( \omega = 2\omega_2 \). The power of the distortion is \( 1/Z_o \cdot E\{[(3/4)a₃A(t)B^2(t)]^2\} \), which can be expanded to:

\[
P_{bb} = 9a₃^2/(16Z_o) \cdot E[A^2(t)] \cdot E[B^4(t)]
\]

(7)

Consider the case of a modulated desired signal and a tone interferer; \( B(t) \) may be replaced by \( P \) (see Figure 5). The value of \( E[B^4(t)] \) can be expressed as \( (2Z_oP_u)^2 \), where \( P_u \)
is the power of the tone interferer. We can use Equation 2 to express $E[A^2(t)]$ in terms of the desired signal power as $2Z_o P_s$, where $P_s$ is the power of the desired signal. The power level of the distortion at baseband is then:

$$P_{bb} = (9/2) P_s Z_o^2 a_3^2$$  (8)

If the undesired signal is modulated, use Equations 2 and 5 to express $E[B^4(t)]$ as $3(2Z_o P_u Z_o^2)$, where $P_u$ is the power of the tone interferer:

$$P_{bb} = (27/2) a_3^2 Z_o^2 P_u Z_o^2$$  (9)

In the direct conversion receiver example, Section 7.6.1 of the WCDMA specification calls for two interfering signals as shown in Figure 6. One of these is a $-48$ dBm CW tone, and the other is a $-48$ dBm WCDMA carrier. These are offset in frequency so that the resulting 3rd order product appears centered about DC. Compute the intermodulation product generated in the I/Q demodulator:

- RF gain preceding LT5575: 20 dB
- Signals entering LT5575: $-28$ dBm
- LT5575 IIP3, two tone: +22.6 dBm
- LT5575 $a_3$: 0.0244

A MATLAB simulation performed using a pseudo-random channel predicts the distortion at LT5575 output to be $-135.8$ dBm. This result agrees well with the Equation 8, which predicts a distortion power of $-135.7$ dBm. Referring this signal back to the receiver input:

- RF gain preceding LT5575: 20 dB
- Equivalent interference level at Rx input: $-155.8$ dBm
- Thermal noise @ receiver input: $-101.2$ dBm

The equivalent interference in this case is $54.6$ dB below the thermal noise at the receiver input. The resulting degradation in sensitivity is $<0.1$ dB, so the receiver easily meets the specification of $-121$ dBm.

**Conclusion**

These calculations highlight the importance of 2nd and 3rd order linearity to a successful direct conversion receiver design. For a WCDMA application, 2nd order performance is critical for two reasons. First, there are CW tone interferers as high as $-15$ dBm entering the receiver. To minimize dynamic DC offset, the I/Q demodulator must present a 2nd order intercept point on the order of +40 dBm at the receiver input. Also, there are modulated interferers up to $-40$ dBm that can degrade the effective noise floor of the receiver if the 2nd order intercept point is not high enough. Leakage from the transmitter, which operates simultaneously with the receiver, can have the same effect.

The 3rd order linearity is less important, because interfering signals must be properly positioned to pose a threat to sensitivity. The WCDMA specification does require minimal degradation in sensitivity in the presence of a pair of $-48$ dBm interfering signals. In this case, if the 3rd order intercept point of the receiver is less than 0 dBm, there will be an appreciable loss of sensitivity.

**Author Information**

Doug Stuetzle is a Senior Module Design Engineer at Linear Technology. He has 26 years of experience designing RF and microwave circuits, modules, and systems. His present responsibility is the definition and design of mixed signal micro-modules for the industrial, medical, and automotive markets. He holds an MSEE degree from Santa Clara University and a BSEE from San Jose State University. Product and applications information is available on the company Web site: www.linear.com
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Agilent Technologies Inc. introduced a WVAN wireless library that helps prevent unnecessary wafer spins, thus accelerating deployment of next-generation 60 GHz wireless video area networks (WVAN) for high-volume consumer video equipment. The library is for use with Agilent’s Advanced Design System (ADS) EDA software and includes portions of Version 1.0 PHY as simulation blocks, allowing WirelessHD consortium members to begin verifying transceiver RFIC designs months in advance of prototype circuits or commercial measurement personalities. The library is an option to the Agilent ADS 2008 software. It is available now for purchase with Agilent’s ADS 2008. For a yearly, time-based license, wireless-library pricing starts at less than $10,000.

Agilent Technologies
www.agilent.com

Crystal Oscillators

Bliley Technologies, Inc. has announced its C-Series crystal oscillators (XOs) designed to satisfy the timing support needs of sophisticated wireless and microwave systems, as well as portable electronic devices. Ideal for electronic design engineers seeking a range of available design options where size, cost and power restraints are priorities, Bliley’s C-Series XOs feature RoHS compliant, hermetically sealed, ceramic SMD packaging and a tri-state enable/disable function. With stabilities as low as ±25 ppm (–10º to +60ºC temperature range), there are a number of XOs included in...
Bliley’s C-Series; see the company Web site for a complete list of options.
Bliley Technologies, Inc.
www.bliley.com

TCXO Crystal Oscillator
Raltron Electronics, Corp. has released its new series RTXY-104 TCXO crystal oscillators designed specifically for GPS applications. The RTXY-104 Series comes in a compact package measuring a mere 3.2 × 2.5 mm offering a frequency choice of between 12.8 MHz to 40.0 MHz at a frequency stability of ±0.5 ppm over its temperature range of –30 to +85°C. Input current is at 2.7V at 1.5 mA with a typical low phase noise ratio of –130 dBC/Hz at 1 kHz offset. The Raltron RTXY-104 Series features a voltage control option making it additionally applicable for PLLs, where its low power consumption makes the part additionally suitable for battery powered applications. Delivery for the new Raltron RTXY-104 Series is currently quoted at 8 weeks ARO at price range of from $.80 to $2.50 each depending on customer’s specified frequency and quantity.
Raltron Electronics Corporation
www.raltron.com

2.5-Volt HCMOS Oscillators
Fox Electronics now offers its HCMOS XpressO oscillators with 2.5-volt operation. Featuring a third order Delta Sigma Modulator (DSM) that offers significantly reduced noise levels, the new oscillators are comparable to traditional bulk quartz and surface acoustic wave (SAW) oscillators at a lower cost. The new oscillators operate at the same voltage as the silicon chips to which they are providing timing, resulting in less current and heat generation. The HCMOS XpressO oscillators feature a frequency range of 0.750 MHz to 180.000 MHz, stabilities as tight as ±20 ppm and a frequency resolution to six decimal places. The oscillators offer operating temperatures of –20°C to +70°C (–4°F to +158°F) or –40°C to +85°C (–40°F to +185°F). The RoHS-compliant series has a gold over nickel termination finish and features industry-standard packaging of 5.0 × 3.2 mm and 7.0 × 5.0 mm including footprint and pin-out.
Fox Electronics
www.foxonline.com

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www.samtec.com/pads
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LFTS Synthesizer Series
MITEQ introduces its new LFTS Series of low phase noise synthesizers, which offer state-of-the-art high resolution frequency sources for INTELSAT applications. The LFTS Series comes with standard 100 Hz step sizes, and provides an additional output that may be used as the second conversion LO for dual conversion up and downconverters. This field proven design consumes less power, which contributes to a very high MTBF and increased reliability.

MITEQ, Inc.
www.miteq.com

Dual-Channel Signal Source
Narda, an L-3 Communications company, introduced the Model 10512 programmable signal source that digitally creates frequency-modulated “noise” waveforms and applies them to a carrier whose center frequency can be varied ±50 MHz in less than 100 ns. Its unique characteristics make it well suited for use as a fast-hopping signal generator, programmable noise source, or arbitrary signal generator. Characteristics of the waveforms generated by the Model 10512, such as video bandwidth, dispersion bandwidth (to 400 MHz), and power level, can be programmed by the user or remotely by a host system. The standard model operates to 3 GHz but much higher frequency ranges are available. It consumes only 11 W, measures 4\times4\times0.6 in., weighs less than 1 oz., and is rugged enough to meet military specifications for shock and vibration.

Narda Microwave-East
www.nardamicrowave.com/east

Clock Oscillator and VCXO
MtronPTI announces improvements to their QiK Chip™ clock oscillator and voltage controlled clock oscillator (VCXO) product lines. The improvements further enhance MtronPTI’s ability to provide exceptional product performance from order to ship in 2 weeks. Package flexibility is achieved through the introduction of a new 6-pad design for the M210x and M310x product series. These products are still available in the 9-pad version, but the 6-pad design is being introduced to support more industry standard footprints. Product improvements across the QiK Chip™ series provide an impressive 20 percent improvement in jitter and phase noise performance. With jitter performance better than 0.3 ps RMS for both the QiK Chip™ oscillator and VCXO product lines, product applications requiring solid signal generation have a new option in the QiK Chip™ product line.

MtronPTI
www.mtronpti.com

Transistors

GaN HEMTs For 5 GHz WiMAX
Cree, Inc. announces the sample release of two new gallium nitride (GaN) HEMT transistors for use in WiMAX applications covering the 4.9 to 5.8 GHz frequency band. The new transistors, CGH55015F and CGH55030F, are the first released GaN HEMT WiMAX products specified to operate at up to 5.8 GHz. Significant potential benefits offered by the new 15 watt and 30 watt devices include a four-fold increase in efficiency compared with similar power level GaAs MESFET devices, higher frequency operation compared with commercially available silicon LDMOS, operational capability in the license-exempt 5.8 GHz ISM band as well as 5.3 GHz and 5.47

42 High Frequency Electronics
GHz U-NII bands, and superior linearity of better than 2.5% EVM at average power under a WiMAX signal at 25% drain efficiency covering an instantaneous bandwidth of 5.5 to 5.8 GHz. Both transistors are available with “reference design” amplifier platforms.

Cree, Inc.

Smallest Low Noise FETs for Wireless Applications
Avago Technologies announced the industry’s smallest packaged field effect transistors (FETs), measuring just 1.0 × 0.5 × 0.25 mm. These ultra small devices occupy less than 5% the volume of a standard SOT-343 package. The new VMMK-1218 and -1225 leverage Avago’s chip scale packaging technology, which enables miniaturization of transistors, high-frequency operation and superior thermal dissipation. The VMMK-1225 supports 0.5 to 26.5 GHz frequency ranges with a noise figure of less than 0.95 dB, 12 dB available gain under 50 ohms conditions at 12 GHz, 23 dBm OIP3 and 8 dBm output power. The VMMK-1218 operates from 0.5 to 18 GHz with a noise figure of less than 0.85 dB, 9 dB available gain under 50 ohms conditions at 10 GHz, 22 dBm OIP3 and 12 dBm output power. Pricing for the VMMK-1218 and -1225 begin at $1.19 and $1.32 respectively in 1000-9999 quantities.

Avago Technologies
www.avagotech.com

450-Watt RF Power Transistor
Freescale Semiconductor has introduced a 50-volt LDMOS RF power transistor designed to deliver 50 percent higher output power than current UHF TV broadcast solutions. The MRF6VP3450H delivers more than 450 W peak power (at P1dB) with 50 percent efficiency throughout the UHF broadcast frequency band. The MRF6VP3450H is designed for TV transmitters employing both analog and digital modulation formats. Using a DVB-T 64 QAM OFDM signal at 90 W average output power, the typical 860 MHz 50 V performance is 28 percent drain efficiency and 23 dB gain, with an adjacent channel power ratio (ACPR) at 4 MHz offset of –62 dBc in a 4 kHz bandwidth. The new LDMOS devicek is sampling now, and full production is expected in the third quarter of 2008.

Freescale Semiconductor
www.freescale.com

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A Constant Mismatch Analysis of Power RF Transistors Using EDA Tools

By John Pritiskutch and Craig Rotay
STMicroelectronics

This article presents a method for analyzing RF device behavior under mismatched conditions which may occur during the operation of a power amplifier system.

The proliferation of EDA tools in the RF industry mainstream has narrowed the traditional separation between RF device designers and the users of those devices. The availability of accurate nonlinear large signal models demonstrate device characteristics by simulation rather than performing tedious, expensive or time prohibitive measurements. Thus, RF device designers and users are more easily able to arrive at a common understanding of an application specific result.

Generally, introductory EDA users rely on the embedded circuit analysis templates to provide information on a particular device behavior, but sometimes it is desirable to develop a custom simulation circuit. An example of a custom EDA circuit development is presented here, using Agilent’s EEsof Advanced Design System.

Analysis with Mismatched Loads

Most RF power transistors, at some point during their lifetime, are subjected to non-optimum loads arising from a variety of situations. The transistor’s active characteristics are dictated by these impedances and, in the least, affect the delivered power and dissipation. More specifically, drain load conditions are often defined in terms of VSWR and any mismatch presented to the high impedance side of a matching network, generally 50 ohms, results in the same variation about the optimum drain load impedance. Figure 1 shows a basic example of an impedance matching network with several VSWRs applied to the high impedance port and its subsequent effect at the low impedance port. The circles are high and low impedance 1:1, 2:1 and 8:1 VSWR. Thus, any mismatch present at an amplifier output is also presented to the device.

With respect to an RF power transistor, one might consider passive networks such as antennas, splitters, combiners or filters as simplified “black boxes.” Often such passives are specified with a maximum VSWR. As an integrator of RF PA systems, it is desirable to know the active characteristics of a device having a constant mismatch from the optimum drain load. Usually the RF transistor’s optimum series equivalent drain load impedance takes the form of $R + jX$, and in many cases the reactance is considerable.

Standard EDA embedded load pull analysis templates provide a means to simulate device characteristics such as constant gain, power compression and drain efficiencies using an impedance center and RHO radius of reflection coefficients [1]. However, these characteristics do not easily relate to performance into a constant VSWR.
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<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>1 WATT MODEL 9171</th>
<th>5 WATT MODEL 9165A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Frequency</td>
<td>20 (\text{MHz})</td>
<td>20 (\text{MHz})</td>
</tr>
<tr>
<td>Gain</td>
<td>37 (\text{dB})</td>
<td>45 (\text{dB})</td>
</tr>
<tr>
<td>(P_{\text{1dB}})</td>
<td>28.0 (\text{dBm})</td>
<td>45.0 (\text{dBm})</td>
</tr>
<tr>
<td>(P_{\text{5dB}})</td>
<td>30 (\text{dBm})</td>
<td>37 (\text{dBm})</td>
</tr>
<tr>
<td>IP3/IP2</td>
<td>40/50 (\text{dBm})</td>
<td>46/60 (\text{dBm})</td>
</tr>
<tr>
<td>Noise Figure</td>
<td>2.8 (\text{dB})</td>
<td>3.0 (\text{dB})</td>
</tr>
<tr>
<td>In/Out VSWR</td>
<td>1.51/2:1</td>
<td>1.51/2:1</td>
</tr>
<tr>
<td>Maximum Input</td>
<td>+18 (\text{dBm})</td>
<td>+18 (\text{dBm})</td>
</tr>
<tr>
<td>DC Power</td>
<td>500 (\text{mA})</td>
<td>725 (\text{mA})</td>
</tr>
<tr>
<td>Operating Voltage</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>Humidity</td>
<td>0 (%)</td>
<td>0 (%)</td>
</tr>
<tr>
<td>Altitude</td>
<td>0 (\text{ft})</td>
<td>0 (\text{ft})</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-20 (\text{°C})</td>
<td>-20 (\text{°C})</td>
</tr>
<tr>
<td>RF/DC Connectors</td>
<td>SMA/Pins</td>
<td>SMA/Pins</td>
</tr>
<tr>
<td>Dimensions</td>
<td>2.212&quot; (x) 1.625&quot; (x) 0.565&quot;</td>
<td>Inches Fin Option height: 1 watt 1.313&quot; 5 watt 1.813&quot;</td>
</tr>
</tbody>
</table>

Common specifications to both models are in lighter type face.

<table>
<thead>
<tr>
<th>CONDITIONS</th>
<th>1 Watt Model 9171</th>
<th>5 Watt Model 9165A</th>
</tr>
</thead>
<tbody>
<tr>
<td>May Specify for 1 watt: 10V to 15V, 5 watt: 20V to 28V</td>
<td></td>
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<tr>
<td>Non-Condensing</td>
<td></td>
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<td>ft</td>
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<tr>
<td>°C</td>
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5 Watt Model 9165A with Fin Option package that is available on either model

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Using a complex impedance center of 4.1 + j3.2 ohms with the embedded load pull circuit template shows that a 10:1 load pull cannot be accomplished, as the radius of the reflection coefficients is reduced to prevent impedances from being negative (Figure 2). Trying to circumvent this by normalizing the \( Z_0 \) of the load pull sweep to the actual complex impedance using a RHO radius to give a 10:1 mismatch produces negative impedances (Figure 3, \( Z_{\text{at}_m3} \)). This can be calculated by the complex multiplication of the \( Z_0 \) and un-normalized impedances of marker 3, \((4.1 + j3.2) \times (0.128 + j0.522) = -1.15 + j2.55\). Sweeping around complex impedance in terms of RHO will not produce a constant VSWR in all cases.

A constant VSWR sweep around a complex impedance requires an EDA phase shifter tool, having a characteristic impedance set equal to the optimum drain load, and a termination set equal to the required VSWR. Figure 4 shows a 1:1 to 10:1 constant VSWR all phase angle sweep around 4.1 + j3.2 ohms. In practice, an RF power combiner may have a maximum input VSWR specification of 2:1,
but a snapped-off antenna may present a 10:1 VSWR, including the losses of the cable.

An example analysis is presented using an SD2941-10 RF MOSFET model, which, not coincidentally, has an optimum 100 MHz drain load impedance of $4.1 + j3.2$ ohms. Figures 5 and 6 depict a large signal EDA circuit with the load mismatch instrument's associated components attached to the device's drain terminal. The relevant large signal constant mismatch device behavior is shown in Figure 7.

**Application of the Technique**

With relative ease, the load mismatch simulation instrument provides RF and PA system designers rapid feedback for a variety of applications. For example, a designer might need to estimate the change of power dissipation for each device in a pair of combined transistors in order to take precautions against exceeding maximum ratings, or to choose an adequately rated product for a more robust design.

A second potential use for a rapid simulation tool would be to tailor the phasing of an expected failure mode to ensure the device will see an impedance that results in minimum power dissipation. A further application would be to examine device performances with small perturbations of load VSWR around the drain load as a means of optimizing a circuit design for additional tolerance to mismatch conditions.

It is shown that constant mismatch analysis, when used with accurate large signal transistor models, provides RF and PA systems designers with valuable and rapid feedback for a variety of applications.

**Reference**


**Author Information**

John Pritiskutch and Craig Rotay are Staff Engineers specializing in all aspects of high power RF device design at STMicroelectronics RF Power Design Center located in Quakertown, PA.

Interested readers may request the Agilent ADS archived Constant Mismatch project file by contacting Serge Juhel, STMicroelectronics' RF Product Marketing and Technical Support Manager, by e-mail at: serge.juhel@st.com.
A Review of Common Line-Section Directional Couplers

By Gary Breed
Editorial Director

An ideal directional coupler will sample (for measurement) the forward- and reverse-moving waves in a transmission line, keeping the two directions separated, without disturbing the direct signal path through the coupler. Of course, such an ideal device is impossible, thus we have specifications that describe a coupler’s performance in each of these areas:

Directivity—The degree of rejection (in dB) for the unwanted signal direction. Typical couplers may have directivities from 20 to 40 dB.

Coupling—The ratio (in dB) of the incident power to the coupled power output. Higher operating power levels require higher coupling values to avoid overload of external circuitry. A higher coupling ratio typically has less effect on the through path.

VSWR—The VSWR of the coupler alone, terminated with an ideal load. This is a measure of the effect on the through path. As noted above, this is related to the coupling value, but is also affected by the physical design of the coupler.

Frequency response—All couplers have frequency-dependent performance resulting from fixed-size structures. Different physical designs have varying performance, and electrical design may include frequency compensation circuitry.

Directional Coupler Operation

First, we assume that a directional coupler operates in an operational signal path. This is in contrast to a VSWR bridge, which may include lossy elements and is intended as a temporarily installed measuring device. I make this clarification because both devices may be used to obtain the same data (VSWR).

Figure 1a shows a coaxial transmission line segment (the line may also be stripline or microstrip), showing the voltage between the center and outer conductors, and the direction of current flow of the forward RF energy. The conventional notations of source, load and direction of power flow are also shown. Figure 1b shows how a typical directional coupler samples voltage and current. In various references, the probe may be referred to as a “loop” or a “short line section” depending on the author’s perspective. A combination of both is probably most accurate.

In a coupled-line sampler, there are two...
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coupling mechanisms. The first is simple capacitive coupling between the sampling probe conductor and the center conductor. This creates a voltage divider made up of this capacitive coupling and the impedance of the sampling circuit to the reference plane (“ground”). Thus a sample of voltage is obtained.

The second mechanism is inductive coupling between the current traveling on the through line, and the inductor represented by the “loop” of the sampling line. Because magnetic forces have a direction (remember the “right hand rule”), \(I_{FWD}\) and \(I_{REV}\) will be exactly opposite when the sampling line is exactly orthogonal to the magnetic lines of force resulting from those currents. This property enables the directivity in this type of coupler.

To see this directivity on a measuring instrument (e.g., a voltmeter), the sampling line is first terminated on one end by a resistor, typically 50 ohms to establish a standard “source” impedance for the measuring circuit. The sampling line is initially oriented so \(V_{RF/COPLED}\) and \(I_{FWD/COPLED}\) are in-phase, and therefore, summed.

The “forward power” sample is the sum of the coupled RF voltage, and a second voltage across the terminating resistor, which results from the coupled forward current. Actually, the net current induced will be reduced by \(I_{REV/COPLED}\).

Then, the sampling line can be physically reversed (as in some directional wattmeters), or the termination can be switched to the opposite end of the sampling line. Now, the output is the difference of \(V_{RF/COPLED}\) and \(I_{FWD/COPLED}\), which is nearly zero, and the contribution of \(I_{REV/COPLED}\) is at its maximum. This results in the “reverse power” sample from the coupler.

The above conditions depend on either precise mechanical construction or an adjustable means of balancing the amplitudes of \(V_{RF/COPLED}\) and \(I_{FWD/COPLED}\) with a “perfect” impedance match so that \(I_{REV/COPLED} = 0\).

Finally, these types of couplers are often used in instruments that calibrate a rectified voltage output so that it corresponds to power into the design load impedance (e.g., 50 ohms). In this case, the indicated forward power will become inaccurate as the VSWR increases. The actual power will be the difference between the indicated forward and reverse power.

With careful mechanical design and application of relatively simple compensating circuitry, this type of coupler can achieve useful performance over a two octave bandwidth or more, or it can be calibrated for repeatable high accuracy over a narrower bandwidth.

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The Legacy RF Wattmeter Meets the Computer Age

By Dave Distler (ddistler@coaxial.com)
Coaxial Dynamics (www.coaxial.com)

The venerable in-line portable RF power meter, or wattmeter, has been a staple in the broadcast, military, scientific and two-way radio markets since the 1950s. Some newer manufacturers have offered a less expensive, less robust mechanical design, with broader bandwidth but tend to have lower accuracy. In contrast, some of the legacy wattmeters, though initially more expensive, are still in use after many decades and many owners. However, most of these earlier designs had failed to join the computer age until recently.

Some of the manufacturers of these legacy wattmeters are still producing their designs that incorporate a taut band meter movement similar to a watch spring. This is essentially a “frictionless” suspension of the needle and armature via a ribbon of metal. Full-scale meter indications are achieved with very low current and the movement or deflection of the needle is exceptionally smooth across the full deflection range. Taut band meters are highly resistant to particulate (dust, moisture, salt spray, aerosol, smoke, etc.) contamination in the environment.

RF power detection on most all analog style wattmeters typically uses germanium diodes dielectrically coupled to a feed-through transmission line. These classic wattmeters couple or detect the RF via “elements” or “slugs” placed with tight mechanical tolerances near a solid center conductor (Figure A). The center conductor is suspended with air as the dielectric within a solid metal cast or machined 7/8-inch line section. This design features precise impedance matching to 50Ω and is well suited for power levels approaching 10 kW due to its low insertion loss, ability to dissipate heat and lower risk of arcing compared to stripline designs using PC boards as the dielectric with thin, flat copper transmission lines. In addition, it uses no ferrite or toroidal cores that could become saturated at higher power levels.

While the analog meter display has continued to perform admirably for decades, the real secret to its success is in the RF power detection. The mechanical configuration of the 7/8-inch line section is very broadband and is capable of a broad dynamic range thanks to the use of plug-in elements. RF power measurements from 100 mW to 10 kW translates into a +20 dBm to +70 dBm, or a 50...
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The rigid line has a multi-octave bandwidth, permitting accurate power measurement from 450 kHz to 2.3 GHz. Individual plug-in elements are specifically calibrated for high accuracy in specific power/frequency bands, and are less expensive than buying additional fixed coupler/detector assemblies or an entirely new wattmeter for different applications. The early wattmeters have sold in the hundreds of thousands. These products have never required a fundamental redesign for the basic functions of detecting and displaying forward and reflected RF power for over 50 years. However, nearly all of these wattmeters lack a function that prevents them from broadening their user-base today: a computer interface.

One of the manufacturers of these analog meters, Coaxial Dynamics, is introducing a USB Wattmeter for FM and CW average power measurements, with the same mechanical and electrical advantages as the legacy units (Figure B). Accuracy of ±5% of full scale is maintained, and the power display options have expanded greatly beyond the basic analog meter. The PC performs the number crunching to display the calculated SWR and Return Loss. Forward and reflected RF power are displayed in both watts and dBm.

The proprietary circuit technology introduced in the USB Wattmeter is a combination of two new microcontrollers with on-board e²proms that sample and condition the element’s DC output. Only using the USB bus means no additional power cabling is required. Other than the RF input and output cabling, the USB Wattmeter is a single cable system, drawing less than 100 mA total current when using the PC.

Limiting the cabling to and from power supplies or remote sensor/detectors reduces the potential of induced RF fields traveling along cables. Eliminating the maze of additional wires or cables is not only a cleaner installation, but reduces the possibility of loose or improperly grounded wires acting as antennae.

The microcontrollers and DC conditioning amplifiers of the USB Wattmeter are fully shielded within the metal enclosure of the wattmeter itself. This limits the potential of RF traveling along wires from remote sensors/detectors. This also means the wattmeter is just as portable as the original units. With the USB cable disconnected from the back of the wattmeter, it can be taken anywhere in the field without the need for any source of power, since the analog meter requires only the RF signal to indicate a forward or reflected power measurement.

The unique design blends the advantages of the original wattmeter with the functionality of modern computing. Figure C shows the USB Wattmeter computer display. It incorporates simulated needle movements for analog aficionados along with numeric and color-coded bar graph indicators. Forward power, reflected power and SWR are dynamically shown plus the conversion from watts to dBm and the automatic calculation of SWR and Return Loss. The software provides a “switch” that temporarily stores the forward power measurement while the plug-in element is replaced or rotated to the reflected power position.

Typically, the reflected element’s full-scale power range is 1/10 that of the forward power element for best resolution. Since there have been hundreds of thousands of legacy wattmeters sold over the years, there are certainly more elements than that in use today. These same elements, built by several manufacturers over the years, will work with the new USB Wattmeter. Special elements or custom remote couplers are not required.

The original RF wattmeter has finally entered the computer age and has built upon, and maintained, its original advantages. The USB Wattmeter option is available with newly purchased units as the Coaxial Dynamics model 81040 or as a retrofit kit. The PC display software is included at no additional cost.
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NEW PRODUCTS

**CATV Power Doubler Amplifier**

California Eastern Laboratories (CEL) has announced the addition of a new GaAs Power Doubler to its broad family of NEC CATV hybrid amplifiers. Designed to deliver 1 GHz of frequency bandwidth, the new MC-7896 enables cable operators to carry more bandwidth-consuming services on their networks. The MC-7896 features high return loss across the frequency band, plus 27.0 dB of linear gain (at 1 GHz). It also features stable gain performance over temperature, allowing for simple linear correction of any temperature-related effects. Assembly and DC/RF testing of these CATV hybrids is fully automated at NEC, ensuring products that are consistent and reliable, even in the face of extreme environmental conditions. Housed in an industry-standard, RoHS compliant 7 pin package, the MC-7896 is in stock and available now.

California Eastern Laboratories
www.cel.com

**Surface Mount Combline Filter**

Lark Engineering Company introduces a new family of surface mount combline filters from 5 to 15 GHz, with a 3-20% bandwidth and exceptionally low insertion loss of .5-1.5 dB combined with return loss of 14 dB min/ 17 dB typical and a package size of 0.75" x 2.25" x 0.5" x 0.5". These filters meet military environmental specifications too.

Lark Engineering Company
www.larkengineering.com

**Universal Cable Test Kit**

RF Connectors, a division of RF Industries, introduces the RFA-4028-WIFI universal cable test kit. The kit contains a Unidapt RF cable tester (RFA-4018-20) with an assortment of 30 universal adapters, including male and female MMCX, N, reverse polarity TNC, reverse polarity SMA, TNC, BNC and SMA connector interfaces. The RFA-4018-20 coaxial cable tester is a solid-state continuity checker that measures for opens and shorts. The LED display indicates continuity for the shield and center conductor, as well as check for shorting across conductor paths. An additional continuity tester is included for testing CAT5/5E/6E straight through or crossover RJ-45, UTP, 10Base-T, 100Base-T, 1000Base-T EIA/TIA 568A/568B network cables. The LED display on the tester identifies the cable pairs and indicates a correctly wired cable. It’s housed in a foam-lined impact resistant plastic case.

RF Connectors
www.rfindustries.com

**Nonlinear VNA Capability**

Agilent Technologies Inc. announced nonlinear vector network analyzer (NVNA) capability for its PNA-X microwave network analyzer, establishing a new standard for RF nonlinear network analysis from 10 MHz to 26.5 GHz. Requiring minimal external hardware, the Agilent NVNA software effectively converts a 4-port PNA-X into a high-performance nonlinear analyzer. Featuring nonlinear component characterization, new nonlinear scattering parameters called X-parameters, and nonlinear pulse envelope domain capabilities, it is ideal for R&D engineers and scientists researching and designing active RF components. The NVNA capability is based on a standard PNA-X microwave network analyzer and therefore provides all the measurement capability of the PNA-X for linear measurements. It can then easily switch into the NVNA mode for nonlinear measurements. One of the NVNA’s key capabilities is its ability to measure the calibrated amplitude and cross-frequency relative phase of measured spectra from 10 MHz to 26.5 GHz. Component characterization is enabled by measuring and displaying both the amplitude and phase of the full spectra—fundamental, harmonics and cross-frequency products—in the familiar and powerful PNA-X network analyzer. Another key feature is its ability to provide nonlinear scattering parameters called X-parameters. Such functionality extends linear scattering parameters into the nonlinear operating region and enables an accurate portrayal of both nonlinear device and cascaded nonlinear device behavior using measurement-based data. Agilent’s new nonlinear vector network analyzer options for the Agilent N5242A PNA-X are priced starting at $56,000.

Agilent Technologies, Inc.
www.agilent.com
Strength, ruggedness, and reliability…supercharged! That’s what you get when you choose Mini-Circuits ultra-flexible precision test cables. Engineered to be a workhorse for your day-to-day test operations, these triple shielded cable assemblies are qualified to at least 20,000 bends, employ an advanced strain relief system, and are equipped with passivated stainless steel connectors, so you can rely on them to flex, connect and disconnect over and over and over again! They’re so rugged, each test cable is backed by our 6 month guarantee! With low insertion loss and very good return loss, you can also rely on getting good performance over the wide DC-18 GHz band. Need them right away? Overnight shipment is available. So make Mini-Circuits your test cable connection! Mini-Circuits…we’re redefining what VALUE is all about!

### Frequency Range: DC-18 GHz, Impedance: 50 ohms

<table>
<thead>
<tr>
<th>Models</th>
<th>Connector Type</th>
<th>Length (Ft.)</th>
<th>Insert. Loss (dB)</th>
<th>Return Loss (dB)</th>
<th>Price $ ea. (qty.1-9)</th>
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<tbody>
<tr>
<td>CBL-1.5FT-SM+</td>
<td>SMA</td>
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### Female to Male

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<th>Price $ ea. (qty.1-9)</th>
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<td>146.95</td>
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Get info at www.HFeLink.com

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For detailed performance specs & shopping online see Mini-Circuits web site

The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: www.minicircuits.com

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ALL NEW

Custom sizes available, consult factory.

*Mini-Circuits will repair or replace your test cable at its option if the connector attachment fails within six months of shipment. This guarantee excludes cable or connector interface damage from misuse or abuse.
High Frequency Electronics
NEW PRODUCTS

MM-Wave Four-Way Power Divider
Narda, an L-3 Communications company, has introduced a high-performance four-way power divider for millimeter-wave applications that provides an unparalleled combination of low insertion loss, high isolation, and amplitude and phase stability. It is well suited for applications ranging from electronic warfare and electronic countermeasures to radar, communications systems, and test equipment. The Model 4318-4 operates over a frequency range of 18 to 40 GHz, with insertion loss of 1.7 dB or less, isolation of at least 16 dB, amplitude balance of 1.0 dB or better, phase balance or 10 deg. or better, and input/output VSWR of 1.9:1 or less. The Model 4318-4 can handle 500 mW average power into a 3:1 VSWR and 3 W into a 1.2:1 VSWR. It weighs only 1.4 oz (40 g) and has 2.92-mm connectors. It is in stock and available for immediate delivery.

Narda Microwave-East
www.nardamicrowave-com/east

Lowest Jitter SerDes Chipset
A new serializer and deserializer (SerDes) chipset from National Semiconductor Corp. delivers output jitter performance of 35 ps peak-to-peak and input jitter tolerance of 0.9 units interval (UI) with a bit error rate (BER) of 10^-15. The SerDes chipset serializes data up to 3.125 Gbps and is well-suited for industrial and medical imaging, communications infrastructure, commercial displays, and test and measurement systems. The highly integrated chipset includes the DS32ELX0421 serializer and DS32ELX0124 deserializer. They feature advanced on-chip signal and clock conditioning circuitry that extends data transmission reach of CAT-6 (shielded 23 AWG) cable beyond 20 meters. The SerDes also support a wide variety of interconnect media, including CAT-5 cable, optical fiber, 50-ohm or 75-ohm coaxial cable and FR-4 backplanes. Available now and priced at $18 each in 1,000-unit quantities.

National Semiconductor
www.national.com

Simultaneous RF and DC Measurement
Connecticut Microwave offers 7/8” EIA coupler model 490174. Specifications are: Frequency 72 MHz, Power 10 kW, RF Coupling 60 ±1 dB, DC 1 volt, VSWR<1.05:1, Directivity >20 dB, Insertion loss <0.2 dB. Using this, combined coupler, minimizes system calibration time. The size, frequency and power may be scaled up/down to meet specific requirements.

Connecticut Microwave Corp.
www.connecticutmicrowave.com

RF Transceiver Module
Intuicom, Inc.™ announced the release of the C1000µ, an ultra-small spread spectrum OEM RF transceiver module with “leap-ahead” performance technology. Designed for integration into military/aerospace instruments and commercial systems where size, weight, and power consumption are critical design issues, the C1000µ is ideally suited for unmanned vehicles, robotics, and portable devices. The C1000µ is offered in two configurations. Available in late Q2 2008, the standard version provides up to 115 kbps throughput for backwards compatibility with legacy Intuicom infrastructure. The high speed 1.2Mbps version will begin shipping in Q4 2008. Single unit pricing starts at $400.

Intuicom, Inc.
www.intuicom.com

Wide Band Solid State Programmable Attenuator
Trilithic’s RF & Microwave Components division recently introduced a new high performance programmable attenuator. Model SPA-53095-1S-5V-TTL-R features a dynamic range of 95dB in 1 dB steps over a wide frequency range of 400-3000 MHz. Attenuation accuracy is ±0.4 dB or 2.5% over the entire range. VSWR is 1.5:1 maximum and insertion loss is 5.5 dB maximum. Switching speed is <100 nS and the operating temperature range is 0 to +70 degrees C. The control protocol is TTL and via a 10-pin connector. The RF connectors are SMA female. This programmable is an ideal solution where high reliability, fast switching speed and flexible configurations are required such as RF simulation, OEM test equipment and telecommunication lab application.

Trilithic
www.trilithic.com

Low Jitter SerDes with Easy FPGA Interface
Data Rates up to 3.125 Gbps

Simultaneous RF and DC Measurement
Available From Stock !!

LMR
LMR-75
LMR-FR
LMR-UltraFlex
LMR-PVC
LMR-DB
LMR-LLPL
TFlex 402
TFlex 405
StripFlex
StripFlex II

Connectors & Accessories

LMR® TFlex® and StripFlex®
are Registered Trademarks of
Times Microwave Systems
Ultra Broadband, SP32T Switch with Decoder

American Microwave Corporation is proud to offer a port to port phase matched, SP32T switch, model number MSN-32DT-05-DEC-MP with options 100M20, PM10, which operates within the 100 MHz to 20 GHz frequency range. The switch has an amplitude balance of ±1.2 dB maximum, and is phase matched to ±10° maximum. The switch has a 5-bit binary TTL compatible decoder. The insertion loss is 13 dB typical (14 dB maximum) and the isolation is 80 dB typical (70 dB minimum). The VSWR is 2.0:1 and the size is 13" × 10" × 2".

American Microwave Corporation
www.americanmicrowavecorp.com

Traffic Collision Alerting System DC-2 GHz

The D2-729B003 SPDT switches high frequency RF signals between the top and bottom fuselage mounted antennas and numbers 1 and 2 systems transponders. The D2-729B003 switch is directly applicable to all TCAS systems, such as Honeywell and Rockwell/Collins. Air Agency Certificate No.: MMP-S46-40; Weight (max.): 11.5 oz; RF Impedance: 50 ohms nominal; Operating temperature: –36°C to +71°C ambient; Operating life: 1,000,000 cycles; Switching time: 35ms max. Ducommun Technologies has design Engineers who can create custom versions for your specific applications.

Ducommun Technologies
www.dt-usa.com

Linear Power Amplifier

Mimix Broadband, Inc. introduces a QFN packaged GaAs MMIC linear power amplifier with +39 dBm OIP3 and 26 dB small signal gain. This power amplifier, identified as XP1035-QH, covers 5.9 to 9.5 GHz and includes an integrated temperature compensated on-chip power detector. The amplifier comes in an RoHS compliant, industry standard, fully molded 4 × 4 mm QFN package and includes on-chip ESD protection structures and DC bypass capacitors to ease implementation and volume assembly. The XP1035-QH is ideal for wireless communications applications such as point-to-point radio, LMDS, SATCOM and VSAT applications. Mimix performs 100% RF testing on the XP1035-QH. Samples and production quantities are available from stock.

Mimix Broadband
www.mimixbroadband.com

Smallest RF Amplifier

Avago Technologies announced the world’s smallest RF amplifier. With miniature 0402 package dimensions and no wirebonds, the innovative VMMK-2x03 amplifiers experience almost no signal loss and minimal parasitics. Its ultra-small size and fully matched SMT design are optimized for 500 MHz to 12 GHz frequencies to support a variety of radio architectures. The VMMK-2x03 leverages Avago’s recently announced WaferCap chip scale packaging (CSP) technology. Measuring an ultra small 1 × 0.5 × 0.25 mm, the VMMK-2x03 takes up 5% of the volume and uses only 10% of the board area of a standard SOT-343 package. In some cases, the amplifier can effectively reduce PCB area by more than 50%. The miniature VMMK-2x03 family of amplifiers provide high gain, high IP3, low NF and integrated 50-ohm input and output matching networks to simplify system design. Covering frequency ranges from 500 MHz to 12 GHz, these miniature amplifiers can be used in any radio architecture, such as any mobile device, radios, sensors and military communication applications. Their flexibility in size and superior high-frequency performance also make them suitable for applications in wireline, fiber optic, base station, CATV, and instrumentation. VMMK-2x03 amplifiers are currently sampling and can be requested through Avago’s direct sales channel and worldwide distribution partners. The family of RF amplifiers will be generally available in Q4 2008. Pricing is less than $1.00 in volume.

Avago Technologies
www.avagotech.com

New Web Site

The Phoenix Company of Chicago, Inc. has launched a new Web site at www.phoenixofchicago.com featuring new products with a part number search, product configurator, an interactive map, and downloadable literature. The Web site also features links to affiliated company Web sites. The Phoenix Company of Chicago is a global manufacturer of RF connectors, blind mate connectors and cables assemblies.

Phoenix Company of Chicago
www.phoenixofchicago.com
High Gain/Wideband GaAs HEMT LNAs

Hittite Microwave Corporation announces a newly acquired family of GaAs HEMT high gain and wideband LNA products in chip form that operate over the 1 to 32 GHz frequency band. The HMC-ALH311 and HMC-ALH364 are high gain GaAs HEMT LNA die products covering the 22 to 32 GHz frequency band. The HMC-ALH444, HMC-ALH102, HMC-ALH482, HMC-ALH435, HMC-ALH216 and HMC-ALH476 are wideband GaAs HEMT LNA die products covering the 1 to 27 GHz frequency band. Due to their small size, these wideband LNA die products are ideal for integration into microstrip, multi-chip modules and hybrid circuits. Individual die product samples of the HMC-ALH311, HMC-ALH364, HMC-ALH444, HMC-ALH102, HMC-ALH482, HMC-ALH435, HMC-ALH216, and the HMC-ALH476 are available from stock and can be ordered via the company’s e-commerce site or via direct purchase order. Packaged versions of these wideband LNA products will be introduced in the coming months.

Hittite Microwave Corporation
www.hittite.com

Family of Power Amplifiers

Skyworks Solutions, Inc. announced several new front-end solutions supporting Qualcomm’s newest code division multiple access (CDMA) and HSDPA enhanced data for GSM evolution (HEDGE) reference platforms: The SKY77166—a 450 MHz PA for CDMA handsets and WLL applications in a 4 × 4 mm package; The SKY77183 (3 × 3 mm PA for the cellular band) and the SKY77184 (3 × 6 mm dual-band PA for cellular and PCS bands with integrated coupler) — Skyworks’ first PAs with full bypass mode; The SKY77336 PAM—designed in a compact 5 × 5 mm form factor for quad-band cellular handsets for GSM, GPRS and EDGE. The chips will support multiple wireless platform customers. The companies will manufacture these solutions, with mobile devices incorporating these designs available as early as later this year.

Skyworks Solutions, Inc.
www.skyworksinc.com

Resistor Networks On Silicon and Ceramic Substrates

TT electronics BI Technologies offers its thin film resistor networks on both silicon and ceramic substrates. The S Series precision resistor networks are constructed using a silicon substrate, while the Model 660 precision thin film networks utilize a ceramic substrate. Both families of thin film networks feature isolated and bussed circuits along with a unique passivation coating to eliminate moisture concerns. Additional benefits for ceramic substrates include low electrical parasitic losses, low NRE/NRT costs and small minimum order quantities. The silicon substrates feature a lower cost in high order quantities. The S Series networks feature a resistance range from 1K to 100K ohms for the isolated networks and 1K to 30K ohms for the bussed networks. Typical pricing starts at $0.75 each in quantities of 1000 pieces. Lead times are from 12 to 14 weeks.

BI Technologies
www.bitechnologies.com

ProbePoint™ CPW-μStrip Adapter Substrates

A full featured, modestly priced, manually operated probe station developed for engineers and scientists. Measure Microwave, RF and DC parameters of Semiconductors Devices. Packages and Assemblies with NIST traceability.

• Precision CPW to μStrip Adapter Substrates
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• Standard & Custom Calibration Standards
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Manual Probe Station

Very Low Cost High Function 6” or 8” Chuck

A full featured, moderately priced, manually operated probe station developed for engineers and scientists. Measure Microwave, RF and DC parameters of Semiconductors Devices. Packages and Assemblies with NIST traceability.

• Benchtop Size (<18") • Vacuum chuck • Slot out X-Y-Z stage
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• Accessories for Thermal Chucks and Probe Carriers
• Compatible with Magnetic Mount Positioners
• Test wafers, microstrip packages and surface mount components

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Laboratory (RF)MicroProbe Station

Extremely Low Cost < $10,000 US DC/RF/Microwave Test

A ultra compact, manually operated probe station for engineers, scientists and students. Measure Microwave, RF and IV parameters of Semiconductors Devices. Characterize MEMS, wireless, photonic and nanoelectronic components and assemblies.

• Benchtop Size (<18") • 2” Vacuum chuck with pump • X-Y-Z stage with z-Axis
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• 10X/30X Stereo zoom microscope • Fluorescent Illuminator • Compatible with additional Magnetic Mount Positioners (optional)
• Compatible with industry standard microwave probes (optional)

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signal generators without any add-on equipment. The R&S FSQ and the R&S FSU high-end analyzers can also be upgraded with the VOR/ILS analysis option. The R&S FSMR with the R&S FS-K15 option is used to calibrate VOR/ILS signal generators and generator parts of air navigation testers. The one-box solution is designed for calibration labs of airline companies, air-traffic-control authorities and the military. The R&S FSU and R&S FQS high-end analyzers with the R&S FS-K15 are most often used in VOR/ILS development applications. The R&S FS-K15 VOR/ILS option for the R&S FSMR measuring receiver and for the R&S FSQ and R&S FSU spectrum analyzers is now available. A typical configuration consisting of the R&S FSMR and R&S FS-K15 starts at $83,290.

Rohde & Schwarz
www.rohde-schwarz.com

12-Watt 2-Way Power Divider

BroadWave Technologies has developed a new 12-watt power divider for antenna sharing, defense and test applications. Model 151-234-002 is a 12-watt average, 2-way power divider with SMA female connectors. This 50-ohm unit operates from 2400 to 2500 MHz with 25 dB typical isolation. Maximum VSWR is 1.40:1 while insertion loss above the theoretical split is 0.6 dB maximum. This device is also available in a 4-way configuration that exhibits 1.2 dB insertion loss above the theoretical split. Larger configurations, broader frequency ranges and other connector types are also available.

BroadWave Technologies
www.broadwavetech.com

QMA Adaptor

Times Microwave Systems has recently introduced a new QMA adaptor for use with the Bird Electronics wattmeter. The 4-hole flange mount QMA jack is designed to Bird Electronics specifications for connectors that mate to its popular bench top wattmeter. The new adaptor designated 3191-202EA complements the SilverLine-QMA, quick mating test leads and adaptors that replace aging BNCs in 2-way radio test applications. Times Microwave part number 3191-202EA replaces Bird Electronics part number 4240-XXX. Used in conjunction with a SilverLine-QMA test lead and a QMA radio test adaptor (also available from Times) the user now has a complete fast mating, push-on, pull off, two-way radio test system. A QMA-equipped SilverLine test lead has the added feature of changeable interfaces.

Times Microwave Systems
www.timesmicrowave.com

High Frequency Contacts

To meet the requirements of customers looking to simplify system level interconnect, SV Microwave is proud to introduce a new family of high frequency contacts for Series 1 and 3 MIL-DTL-38999 connectors. Based on SV’s proven blind mate technology to accommodate misalignment during mating, the product line consists of size 8 contacts with the option of 18 GHz or 40 GHz performance and size 12 contacts operating to 65 GHz, all of which fit into standard cavities and are fully removable using standard extraction tools. Designs are available for common cable sizes, custom versions can be produced for special cables and pcb mounted applications.

SV Microwave, Inc.
www.svmicrowave.com

Signal Analysis Option

Rohde & Schwarz is expanding the capabilities of its R&S FSMR measuring receiver by making a VOR/ILS signal-analysis option available. The R&S FS-K15 enables the instrument to perform a complete calibration of VOR/ILS

Linear Technology Corporation
www.linear.com

Ultralow Supply Current Monitors

Linear Technology Corporation introduces the LTC2934 and LTC2935, ultralow power supply monitors that only draw 500 nA of quiescent current. Battery life is of the utmost importance in portable applications, where it is essential to reduce the amount of supply current the device draws during normal and standby operation. These single-channel voltage monitors fulfill these functions in tiny 2 × 2 mm DFN or ThinSOT™ packages, making them ideal for compact, single-cell applications. The LTC2935 has three binary inputs that allow selection of one of eight integrated reset thresholds, from 3.3V down to 2.25V in 150mV increments. The LTC2934 allows an external resistive divider to finely set the reset threshold anywhere from 1.6V to 6V. The reset thresholds in both devices are ±1.5% accurate over temperature and are available today in production quantities.

Linear Technology Corporation
www.linear.com
Broadband High Power Amplifier

MITEQ introduces a new addition to its family of broadband high power amplifiers. Model AMF-6B-06001800-70-40P-PS is a self-cooled 3RU rack-mount high power amplifier, covering 6-18 GHz and delivering approximately 10W of power. The SMA connectorized box is 3.47" high, 16.99" wide excluding brackets, and 12.12" deep including fans. This model can be horizontally or vertically mounted. Housing is EMI shielded, CE certified and can operate in ambient temperature up to 50°C. PA includes over temperature protection in addition to full internal regulation. DC on/off switch is optional so is input connector through the front panel. Nominal small-signal gain is 47 dB, ±3.5 dB flat, while noise figure is typically 6 dB across the full band. Output IP3 is a typical of 45 dBm. Input/output port VSWRs are typically 2:1. It runs from 90-240 VAC, 40-400 Hz. Typical power draw is 150W.

MITEQ, Inc.
www.miteq.com

DC-6 GHz Switch Matrix

The Renaissance DC-6 GHz multi-functional WiMax custom matrix is compact and designed with instrumentation to the DUT ports that are synthesized to your RF configuration. With a total of two DUT ports, six instrument ports, and six auxiliary ports, this RF head-end switch matrix contains combiners, switches, programmable attenuators, and required components for RF modulation. The industry standard 19-inch rack mounted switch matrix occupies 2 units of space. The six auxiliary ports aid in the calibration of six corresponding instrument ports and is controlled using a GPIB/IEEE-488.2 interface.

Renaissance Electronics Corp.
www.rec-matrices.com

RDS PC Mount Series

RelComm Technologies, Inc. has available a new miniature 1P2T PC mount relay. This device is configured with .036 diameter RF pins and solderable ground pins for maximized circuit transition. The relay also features through hole mounting to accommodate edge circuit launch and solderable DC pins on the same solder plane for ease of mounting. RF Performance is rated to 3 GHz. High performance plastics allow a power rating of 325 WCW and derating to 200 WCW to 3 GHz. This device can be provided in a break-before-make pulse latching configuration with choice of 12 or 28 volt operating voltage.

RelComm Technologies, Inc.
www.relicommtech.com

50-Watt Power Amplifier

Stealth Microwave’s SR30825-47 is a solid state GaAs FET amplifier designed for various applications requiring superior gain flatness and high linearity. The $P_{1dB}$ is +47 dBm, the linear gain is 55 dB, and the gain flatness across the band is ±1.2 dB max. The unit’s 3U 19” rack chassis incorporates many standard and optional features suitable for use in a variety of commercial and military applications.

Stealth Microwave
www.stealthmicrowave.com

RF T/R Modules

Endwave Corporation has announced the release of a new line of integrated transceivers called Smart T/R™ Modules, which incorporate digital micro-controller technology for improved performance. Micro-controllers allow the Smart T/R Module to optimize the bias, control and monitoring of key transceiver components. The digital “smarts” compensate for the lot-to-lot variations in the RF semiconductor devices that form the heart of the subsystem, so the result is more robust, worry-free, consistent module performance. This automatic adjustment reduces the manual touch-time needed to set-up, tune and center the module performance, thereby improving the quality and reliability for the systems they enable.

Endwave Corporation
www.endwave.com

GaN Broadband PA

Aethercomm Model SSPA 0.020-1.000-20 is a high power, broadband, GaN RF amplifier that operates from 20 to 1000 MHz. The bandwidth can be extended to 1200 MHz+ with similar performance. This PA is ideal for broadband military platforms as well as commercial applications over a multi-octave bandwidth with excellent power added efficiency. It operates with a base plate temperature of 85°C with no MTBF degradation for the GaN devices inside, and is packaged in a modular housing approximately 3.4” × 6.4” × 1.06”

Aethercomm
www.aethercomm.com
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Despite the vast array of applications and technologies they are working on, our readers have something in common. They all require knowledge of a specific set of engineering principles—frequency-dependent behavior, transmission line and waveguide principles, electromagnetic radiation and propagation. Their career success requires a unique combination of academic study, focused personal learning and practical experience. *High Frequency Electronics* readers can look to us for a significant part of that information combination. Our Editorial Calendar includes many of today’s essential topics, and we will cover many more beyond that listing in response to the evolving needs of the engineering community.

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### Advertiser Index

<table>
<thead>
<tr>
<th>Company</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Technical Ceramics (ATC)</td>
<td>25</td>
</tr>
<tr>
<td>Applied Wave Research (AWR)</td>
<td>21</td>
</tr>
<tr>
<td>Besser Associates</td>
<td>52</td>
</tr>
<tr>
<td>California Eastern Laboratories</td>
<td>27</td>
</tr>
<tr>
<td>CST</td>
<td>9</td>
</tr>
<tr>
<td>C.W. Swift &amp; Associates</td>
<td>Cover 2</td>
</tr>
<tr>
<td>DAICO</td>
<td>45</td>
</tr>
<tr>
<td>Emerson Network Power</td>
<td>4</td>
</tr>
<tr>
<td>J microTechnology</td>
<td>59</td>
</tr>
<tr>
<td>J microTechnology</td>
<td>59</td>
</tr>
<tr>
<td>J microTechnology</td>
<td>59</td>
</tr>
<tr>
<td>Krytar</td>
<td>43</td>
</tr>
<tr>
<td>Labtech</td>
<td>47</td>
</tr>
<tr>
<td>Linear Technology</td>
<td>13</td>
</tr>
<tr>
<td>Micro Lambda Wireless</td>
<td>19</td>
</tr>
<tr>
<td>Microwave Components</td>
<td>57</td>
</tr>
<tr>
<td>Mini-Circuits</td>
<td>2-3</td>
</tr>
<tr>
<td>Mini-Circuits</td>
<td>11</td>
</tr>
<tr>
<td>Mini-Circuits</td>
<td>15</td>
</tr>
<tr>
<td>Mini-Circuits</td>
<td>29</td>
</tr>
<tr>
<td>Mini-Circuits</td>
<td>37</td>
</tr>
<tr>
<td>Mini-Circuits</td>
<td>38-39</td>
</tr>
<tr>
<td>Mini-Circuits</td>
<td>51</td>
</tr>
<tr>
<td>Mini-Circuits</td>
<td>55</td>
</tr>
<tr>
<td>MITEQ</td>
<td>1</td>
</tr>
<tr>
<td>MITEQ</td>
<td>Cover 4</td>
</tr>
<tr>
<td>Molex RF</td>
<td>Cover 3</td>
</tr>
<tr>
<td>Programmed Test Sources</td>
<td>31</td>
</tr>
<tr>
<td>RelComm</td>
<td>49</td>
</tr>
<tr>
<td>RLC Electronics</td>
<td>23</td>
</tr>
<tr>
<td>Samtec</td>
<td>41</td>
</tr>
<tr>
<td>Teledyne Cougar</td>
<td>7</td>
</tr>
<tr>
<td>TriQuint Semiconductor</td>
<td>17</td>
</tr>
<tr>
<td>WiseWave/Ducommun</td>
<td>33</td>
</tr>
</tbody>
</table>

---

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Explore Software Defined Radio on a Budget

Many engineers and other technology-minded individuals are using their amateur radio hobby to explore software defined radio (SDR). The results of their work include creative front-end hardware design, using baseband interfacing with high performance personal computer sound cards, supported with signal processing, decoding and display software.

For a very small investment (and a good personal computer) it is possible to obtain a receive-only SDR system, with several options for monitoring and decoding software. Typically, the radios are configured as I and Q direct-conversion demodulators, with the two baseband output channels fed to the inputs of a high quality, high sampling rate audio sound card. Currently, sound cards are readily available with a 96 kHz sampling rate, with 192 kHz sampling rate cards available at slightly higher prices. The bandwidth that can be processed is approximately one-half the sampling rate, so a 192 kHz sound card can be used for digital processing of a 96 kHz slice of the radio spectrum.

Resources

A very economical means of exploring SDR is to build the popular “SoftRock” receiver kit, originally developed by the American QRP Club, and continued by other interested experimenters. The SoftRock receiver is essentially a USB port module that is a fixed LO receiver at the user’s choice of frequency. The demodulated I and Q outputs go to the PC sound card for processing. SDR software is not part of the radio package. The SoftRock kit will cost from US$30 to US$50, depending on shipping requirements and a few options. www.softrockradio.org is the Web address of the providers of these radios.

Another collaboration on radio design can be found at http://hpsdr.org, where the name is an acronym for High Performance SDR. According to the Web site, “The HPSDR is an open source (GNU type) hardware and software project intended as a ‘next generation’ Software Defined Radio (SDR) for use by Radio Amateurs (‘hams’) and Short Wave Listeners (SWLs). It is being designed and developed by a group of SDR enthusiasts with representation from interested experimenters worldwide.”

One company providing a complete solution, including the DAC (no sound card required), is RF Space (www.rfspace.com). Their SDR-IQ model samples the 100 kHz to 30 MHz spectrum and delivers data for any 190 kHz bandwidth for processing. The company’s proprietary demodulation software provides a number of spectral analysis and demodulation capabilities. This unit is priced at US$499. The higher performance (mainly resolution bandwidth) model SDR-14 has additional features, including external input to the ADC. This unit is priced at US$1099.

The RF Space products are marketed to both hobbyists and to professionals for analysis of ultrasound, RF/IF and other signals in the frequency and bandwidth ranges they support.

SDR Software

As noted above, RF Space has its own software package, and HPSDR is developing software as well as hardware. One of the most popular SDR packages is the “Rocky” freeware from Alex Shovkoplyas (www.dxatlas.com), which is often used with the SoftRock radio for a very low cost introduction to SDR.

Other software authors or groups include Duncan Munroe (www.m0kgk.co.uk/sdr/), whose “KGKSDR” is under constant development and improvement, and TAPR (Tucson Amateur Packet Radio, www.tapr.org), which is developing the “Penelope” SDR software in conjunction with HPSDR. TAPR deserves a special historical note. This organization of amateur radio enthusiasts, many of whom are also hardware or software professionals, has been in existence since 1981. It was originally formed to develop packet data communications and is credited by some observers as launching what is now a continuing phenomenon of digital communications over radio. For example, some of the original “laptop in a police car” data communications systems were based on the amateur packet protocols developed by the members of TAPR.

Other resources for investigation can be found via links from the above Web sites, or by intelligent searching using your favorite search engine.
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### Typical Phase Noise Output

<table>
<thead>
<tr>
<th>Model</th>
<th>Frequency Range</th>
<th>Type</th>
<th>10</th>
<th>100</th>
<th>1K</th>
<th>10K</th>
<th>100K</th>
<th>1M</th>
<th>Output Frequency</th>
<th>Output Power (dBm, Min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XTO-05</td>
<td>5-130 MHz</td>
<td>Ovenized Crystal</td>
<td>-95</td>
<td>-120</td>
<td>-140</td>
<td>-155</td>
<td>-160</td>
<td>-160</td>
<td>100 MHz</td>
<td>11</td>
</tr>
<tr>
<td>PLD</td>
<td>30-130 MHz</td>
<td>P.L. Crystal</td>
<td>-95</td>
<td>-115</td>
<td>-140</td>
<td>-155</td>
<td>-155</td>
<td>-155</td>
<td>100 MHz</td>
<td>13</td>
</tr>
<tr>
<td>PLD-1C</td>
<td>130-1000 MHz</td>
<td>P.L. Multi. Crystal</td>
<td>-80</td>
<td>-100</td>
<td>-120</td>
<td>-130</td>
<td>-135</td>
<td>-135</td>
<td>560 MHz</td>
<td>13</td>
</tr>
<tr>
<td>BCO</td>
<td>100-16.5 GHz</td>
<td>P.L. Single Loop</td>
<td>-65</td>
<td>-75</td>
<td>-80</td>
<td>-90</td>
<td>-95</td>
<td>-95</td>
<td>16.35 GHz</td>
<td>13</td>
</tr>
<tr>
<td>VFS</td>
<td>1-14 GHz</td>
<td>Multiple Freq. Dual Loop</td>
<td>-60</td>
<td>-75</td>
<td>-110</td>
<td>-115</td>
<td>-115</td>
<td>-115</td>
<td>12.5 GHz</td>
<td>13</td>
</tr>
<tr>
<td>DLCRO</td>
<td>0.8-26 GHz</td>
<td>P.L. CRO Dual Loop</td>
<td>-60</td>
<td>-85</td>
<td>-110</td>
<td>-115</td>
<td>-115</td>
<td>-115</td>
<td>10 GHz</td>
<td>13</td>
</tr>
<tr>
<td>PLDRO</td>
<td>2.4-40 GHz</td>
<td>P.L. DRO Single/Dual</td>
<td>-60</td>
<td>-80</td>
<td>-110</td>
<td>-115</td>
<td>-120</td>
<td>-120</td>
<td>10 GHz</td>
<td>13</td>
</tr>
<tr>
<td>CP</td>
<td>8.3-3.2 GHz</td>
<td>P.L. CRO Single Loop</td>
<td>-80</td>
<td>-110</td>
<td>-120</td>
<td>-130</td>
<td>-130</td>
<td>-130</td>
<td>2 GHz</td>
<td>13</td>
</tr>
<tr>
<td>ETCO</td>
<td>1.24 GHz</td>
<td>Voltage Tuned CRO</td>
<td>-70</td>
<td>-100</td>
<td>-120</td>
<td>-130</td>
<td>-130</td>
<td>-130</td>
<td>2.4 GHz</td>
<td>13</td>
</tr>
</tbody>
</table>

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