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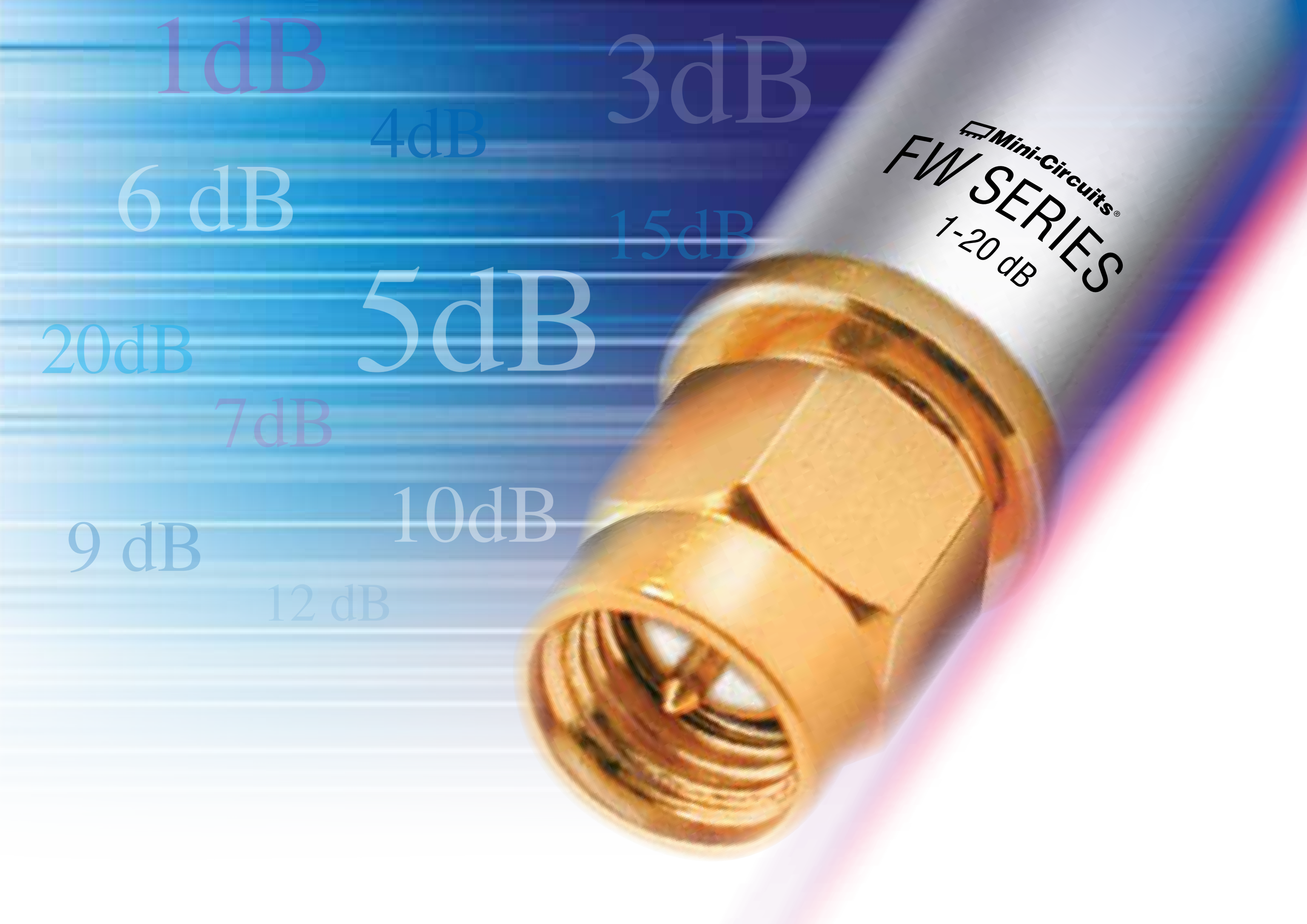
JANUARY 2015

HIGH FREQUENCY ELECTRONICS

Changing the Operating Frequency of an RF Power Amplifier Circuit

IN THIS ISSUE:

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



DC-12 GHz 1W Attenuators

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Model	ATTENUATION Nominal (dB)	Flatness (dB)	VSWR (:1) Midband Typ.	Power (W)
FW-1+	1	±0.15	1.15	1.0
FW-2+	2	±0.15	1.15	1.0
FW-3+	3	±0.20	1.15	1.0
FW-4+	4	±0.20	1.15	1.0
FW-5+	5	±0.20	1.15	1.0
FW-6+	6	±0.25	1.15	1.0
FW-7+	7	±0.25	1.15	1.0
FW-8+	8	±0.30	1.15	1.0
FW-9+	9	±0.30	1.15	1.0
FW-10+	10	±0.30	1.15	1.0
FW-12+	12	±0.30	1.20	1.0
FW-15+	15	±0.35	1.20	1.0
FW-20+	20	±0.50	1.20	1.0

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531 rev. orig.

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For more details, just go to minicircuits.com – place your order today, and you can have these products in your hands as soon as tomorrow!

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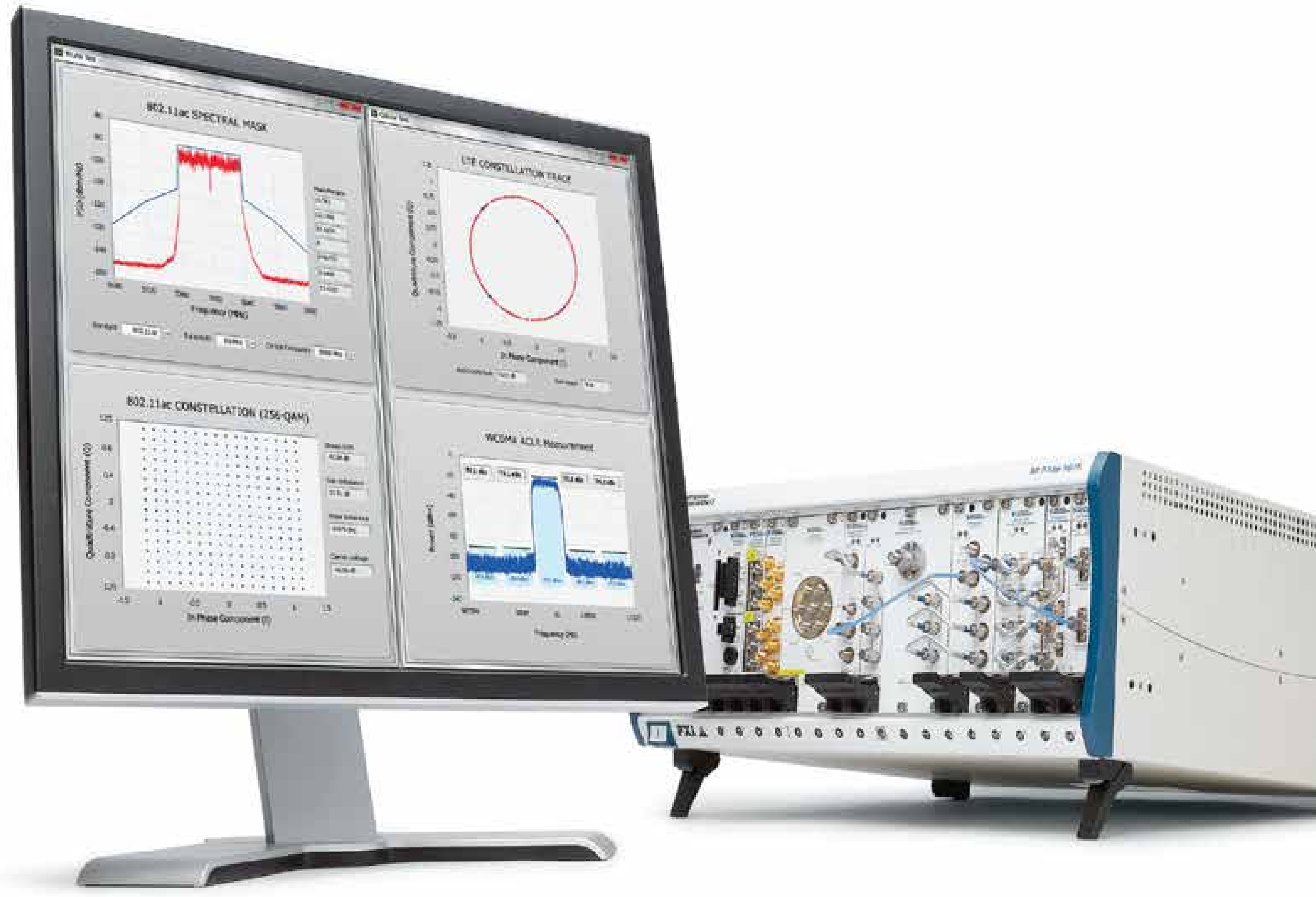
JANUARY 2015
Vol. 14 No. 1

HIGH FREQUENCY ELECTRONICS

Redefining RF and Microwave Instrumentation

with open software and modular hardware



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NATIONAL INSTRUMENTS

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Editorial

CMOS Transceivers and Metamaterials

Scott L. Spencer
Publisher

Fujitsu Laboratories Ltd. recently announced that it has produced a transceiver chip for millimeter-wave radar in 65-nm Complementary Metal Oxide Semiconductor (CMOS) process that can replace Silicon-Germanium (SiGe) transceiver chips in many automotive applications. While enabling lower costs, the firm says it has also improved the performance of the transceiver particularly with respect to short-range detection performance.

Most millimeter-wave radar use SiGe transceiver chips. Using CMOS would allow for lower costs and lower power consumption than SiGe, but it is more susceptible to noise, particularly in lower frequency ranges, which has made the use of CMOS for millimeter-wave radar mostly unworkable.

Resistive Mixer

In automotive applications the detection of pedestrians and objects that have weak reflectance is tricky. The challenge for Fujitsu designers was to maintain good high-frequency performance in the receiver chip while reducing low-frequency noise. To accomplish this they used a double-balanced resistive mixer in the frequency-conversion circuit. A resistive mixer can recover IF signals through electricity from LO signals without having to apply power supply voltage. This allows the flow of DC current to a mixer transistor to be kept to a minimum avoiding the increase in low-frequency noise. We know that a frequency-conversion circuit takes the frequency difference (IF signal) that occurs from signals reflecting from objects (RF Signals) and local oscillator signals (LO signals). According to Fujitsu, using the double-balanced construction which synthesizes the differential motion of the resistive mixer, noise increase from DC offset that occurs via LO signals input to the mixer can be reduced. It also has the effect of reducing noise below 10 kHz while maintaining high-frequency characteristics.

Microsoft Entering the RADAR business?

Not exactly, but Microsoft co-founders Bill Gates and Paul Allen head of a group of investors that will fund Echodyne—a spin-out from Seattle based Intellectual Ventures (IV). Echodyne's goal is to bring to market radar products based on metamaterials technology invented by IV in collaboration with Duke University and the University of California at San Diego. According to a press release issued by the company, Gates said, "Echodyne's innovative use of metamaterials holds great promise for a wide range of new radar applications."

Metamaterials are artificially engineered materials that exhibit unusual or difficult to obtain electromagnetic (EM) properties. Metamaterials have represented a major new development in physics and materials science for well over a decade. They are custom-made materials that are not found in nature. Unlike natural matter which exhibits behavior based on its molecular structure, metamaterials exhibit behavior based on the sum of their parts. For some designs materials with the desired characteristics may not exist in nature. Researchers using materials like gold and copper arranged in certain patterns and shapes can combine the properties of different materials to achieve the desired characteristics. These patterns and shapes are engineered to have specific effects on light, acoustics and radio waves. By assembling the material at a scale smaller than the length of the wave you're seeking to manipulate, the wave can, in theory, be bent to will. This makes metamaterials the tool of choice for all sorts of wave-cloaking devices, including the so-called "invisibility cloak," which in theory is a cover to make whatever is inside in effect invisible by bending light waves around it.

Antenna Design

Metamaterials have tremendous potential in the future of antenna design. With the ever-growing need for bandwidth and spectral efficiency antenna technology must keep pace with the complexity of radios and protocols that have climbed sharply in recent decades. Metamaterial technology can enable a new generation of Software Defined Antennas (SDAs) that are lightweight, exhibit high-gain, and are rapidly reconfigurable. Software can be used to directly define a multitude of desired transmit and receive configurations. This is a synergistic match for the new generation of software defined radios (SDRs) which are finding widespread usage as spectrum continues to be an ever more limited resource.

Metamaterial SDAs have the capacity to achieve high gain in an electrically configurable beam that maximizes channel efficiency in a lightweight conformal form factor with active dynamic null generation to that allows for the mitigation of interfering signals in cluttered environments.

Many terrestrial wireless applications can make use of metamaterials technology, from tactical battlefield communications, to cellular systems and high frequency backhaul, and even enterprise Wi-Fi systems.

Low cost radars find applications in a variety of markets such as weather forecasting, aviation, marine navigation, civilian law enforcement, industrial controls and automotive collision avoidance systems that reduce traffic accidents and fatalities.

I expect we will hearing more from the researchers at Echodyne as the New Year unfolds.

Meetings and Events

Conferences & Meetings

2015 IEEE MTT-S Radio Wireless Week (RWW 2015)
25-28 January 2015
San Diego, California, USA
http://www.radiowirelessweek.org/

Radio Wireless Week consists of 5 co-located topical conferences:

RWS: IEEE Radio and Wireless Symposium
PAWR: IEEE Topical Meeting on Power Amplifiers for Wireless and Radio Applications
SiRF: IEEE Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems
BioWireleSS: IEEE Topical Conference on Biomedical Wireless Technologies, Networks, and Sensing Systems
WiSNet: IEEE Topical Meeting on Wireless Sensors and Sensor Networks
Paper Submission Deadline: 25 July 2014

DesignCon 2015
27-30 January 2015
Santa Clara, California, USA
http://www.designcon.com

2015 IEEE International Wireless Symposium (IWS 2015)
30 March-1 April 2015
Shenzhen, China
http://iws-ieee.org/

2015 IEEE Wireless and Microwave Technology Conference (WAMICON 2015)
13-15 April 2015
Cocoa Beach, Florida, USA
http://www.wamicon.org/
Paper Submission Deadline: 5 January 2015

2015 IEEE MTT-S International Conference on Microwaves for Intelligent Mobility (ICMIM 2015)
27-29 April 2015
Heidelberg, Germany
http://www.icmim-ieee.org
Paper Submission Deadline: 20 December 2014

2015 IEEE MTT-S International Wireless Power Transfer (WPTC 2015)
13-15 May 2015
Boulder, Colorado, USA
http://www.wptc2015.org/
Paper Submission Deadline: 16 January 2015

2015 IEEE International Microwave Symposium (IMS2015)
17-22 May 2015
Phoenix, Arizona, USA
http://ims2015.org/
Paper Submission Deadline: 8 December 2014

2015 IEEE Radio Frequency Circuits Symposium (RFIC 2015)
17-19 May 2015
Phoenix, Arizona, USA
http://rfic-ieee.org/
Paper Submission Deadline: 12 January 2015

85rd ARFTG Microwave Measurement Symposium
22 May 2015
Phoenix, AZ, USA
http://www.arftg.org/

2015 IEEE MTT-S International Conference on Numerical Electromagnetic Modeling and Optimization for RF, Microwave and Terahertz Applications (NEMO 2015)
11-14 August 2015
Ottawa, Canada
http://nemo-ieee.org
Paper Submission Deadline: 16 February 2015

Company-Sponsored Training & Tools

Analog Devices
Training, tutorials and seminars.
http://www.analog.com/en/training-tutorials-seminars/resources/index.html

NI AWR
On-site and online training, and open training courses on design software.
http://web.awrcorp.com/Usa/News--Events/Events/Training/

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Online
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LabVIEW Core 2
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Object-Oriented Design and Programming in LabVIEW
Online
http://sine.ni.com/tacs/app/fp/p/ap/ov/pg/1/
Free, online LabVIEW training for students and teachers.
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Market Reports

Estimate: Over 100M 5G Subscribers by 2025

According to a new Market Data forecasts from ABI research, **it will take more than 5 years for 5G to reach 100 million subscriber mark—2 years longer than 4G**. 4G subscriber growth was much faster than with previous generations, fuelled by the capabilities of increasingly powerful smartphones and the availability of 4G devices. 5G subscriber growth will likely be a bit more muted at first due to the increased complexity of 5G cells and networks, but will pick up in 2023.

"There are a number of commonalities between countries that are early builders of 5G networks. They have a large population, of which a large percentage is living in urban areas. They also have many companies pushing the envelope with IoT strategies. These countries will drive 5G subscriber volumes," said Research Director, Philip Solis. "These **are the United States, China, Japan, South Korea, and the United Kingdom in order of 5G subscribers in 2025."**

It is also important to understand the nuances around 5G to recognize where it is headed. "5G will be a spectrum of evolution to revolution—it will be an evolution of the way the core network and network topology is transforming now, but it will be clearly delineated as a fifth generation mobile air interface on which the mobile network of the 2020's and 2030's will be built," added Solis.

5G will encompass spatial division as the foundation of the air interface, leveraging techniques like massive MIMO—achievable in devices because of the high frequency of spectrum that will be used—and 3D beamforming to form narrow beams that divide the space around a 5G basestation. Client devices will have links to multiple cells simultaneously for robust connectivity. Spectrum will be used flexibly and shift as needed between access and fronthaul and backhaul. The waveform and modulation scheme are the least clear aspects of 5G currently.

A 5G network will be a network of small cells and will be practical in urban and industrialized environments for the population density and the reflections in urban canyons; however, expect a scaled down version of 5G to use existing spectrum for macrocells as well in the longer term. One potentially problematic issue, however, will be regulatory issues concerning concentrated RF beams in centimeter and millimeter wave spectrum.

—ABI Research
abiresearch.com

5G Standardization Begins

Work on new technologies that will form the foundation of 5G standards has been occurring for the last few years; however, the formal standards process has just begun. A range of major vendors are working on all aspects of 5G including: **Alcatel-Lucent, Ericsson, Huawei, and Nokia Networks** and device, semiconductor, and IP vendors including **Intel, InterDigital, Qualcomm, Samsung**, various mobile operators, academic bodies, and start-ups as well.

"These companies are all waving their 5G flags, although 5G definitions and visions remain very vague," commented Research Director Philip Solis. "But this is not merely marketing. These companies are most certainly putting a stake in the ground with regards to contributions to 5G that will leverage their work, competitive strengths, and most crucially, patents."

Some highly influential companies, such as Qualcomm, have remained quiet until recently about their vision and plans for 5G. Meanwhile, more companies, previously not very involved with standardization efforts are putting their hands up. Apple's involvement with the NGMN 5G Initiative is a perfect example, as is **Google's acquisition of Alpental**—even if Google might only use a 5G or 5G-like air interface to augment fiber-to-the-home deployments with a combination of fiber-to-the-curb and 5G.

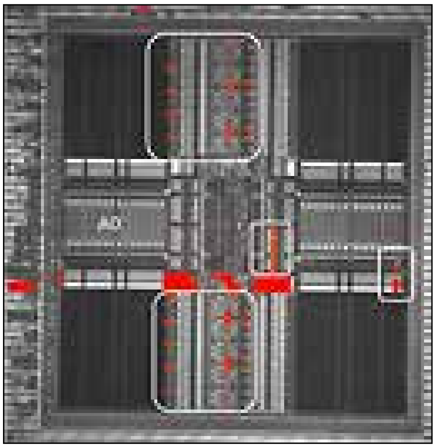
These companies are working together so the standardization process can hit the ground running. They are doing their own work, forming alliances with universities and other companies, and hedging their bets by partaking in different research projects that focus on different parts of the network and air interface, in an effort to dictate the direction of 5G.

"Expect efforts to get intellectual property into standards to be fiercer than with 4G, but naturally much of the existing IP will be in play as well," added Solis. "More companies learned the importance of having a fair amount of IP with 2G and 3G, so the 4G playing field evened up a little. This trend will continue with 5G."

Companies should also move beyond sometimes vague marketing and generalizations around 5G and the IoT and create more definitive messaging around how technology will improve specific applications. **They need to better describe how waveforms and modulation schemes best apply to increasingly mixed-use traffic.** This can only help them with more brand building and influence in the standardization process.

—ABI Research
abiresearch.com

In the News



Under the auspices of DARPA's Integrity and Reliability of Integrated Circuits program, researchers from the **Naval Surface Warfare Center (NSWC) and Air Force Research Laboratory (AFRL)** are collaborating in powerful new ways to determine the **reliability and integrity of microchips** embedded in the some of the nation's most critical military weapon and cyber systems.

Integrated circuits or microchips are ubiquitous, found in virtually all modern appliances and systems ranging from desktop computers, laptops and cell phones to fighter aircraft and munitions. Despite that pervasiveness and criticality, few automated techniques today can verify whether the intended functionality of microchips has been compromised at any stage during design and fabrication.

To ensure performance of integrated circuits in military systems, DARPA, working in concert with its Service partners, developed a **"virtual lab"** with an integrated computer-aided design or CAD and file-sharing environment to transfer the large volumes of data accumulated during microchip analysis and debugging. In addition to file sharing, a website constructed for the virtual lab is facilitating communication between government researchers and program performers from academia and industry.

Military teams patrolling dangerous urban environments overseas and rescue teams responding to disasters such as earthquakes or floods currently rely on remotely piloted unmanned aerial vehicles to provide a bird's-eye view of the situation and spot threats that can't be seen from the ground. But to know what's going on inside an unstable building or a threatening indoor space often requires physical entry, which can put troops or civilian response teams in danger.

To address these challenges, DARPA issued a Broad Agency Announcement solicitation today for the **Fast Lightweight Autonomy (FLA) program. FLA focuses on creating a new class of algorithms to enable small, unmanned aerial vehicles to quickly navigate a labyrinth of rooms, stairways and corridors or other obstacle-filled environments without a remote pilot.**

The program aims to develop and demonstrate autonomous UAVs small enough to fit through an open window and able to fly at speeds up to 20 meters per second (45 miles per hour)—while navigating within complex indoor spaces independent of communication with outside operators or sensors and without reliance on GPS waypoints.

"Birds of prey and flying insects exhibit the kinds of capabilities we want for small UAVs," said Mark Micire, DARPA program manager. "Goshawks, for example, can fly very fast through a dense forest without smacking into a tree. Many insects, too, can dart and hover with incredible speed and precision. The goal of the FLA program is to explore non-traditional perception and autonomy methods that would give small UAVs the capacity to perform in a similar way, including an ability to easily navigate tight spaces at high speed and quickly recognize if it had already been in a room before."

KEYSIGHT TECHNOLOGIES

Keysight Technologies announced the largest in-kind software donation in its longstanding relationship with the **Georgia Institute of Technology**. The donation is valued at approximately $120 million (book value) over three years and will comprise Keysight EEsof EDA software, support and training. The donation is being given as part of the Keysight EEsof EDA University Alliance program. It also includes a tailored, three-year custom license program that provides member companies of ECE's Georgia Electronic Design Center with access to Keysight's EDA solutions.

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Molex announced that it has been honored with the prestigious "Excellent Core Partner - Gold Supplier" Award from **Huawei Technologies**. The award was presented to Molex representatives at the Huawei Core Partner Convention, held at the Huawei headquarters in Shenzhen, China. Molex was previously recognized as a Huawei Excellent Core Partner in 2013, further demonstrating a continuing commitment to provide outstanding next-generation interconnect solutions. "We are honored to again


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In the News

receive the Excellent Core Partner award, which reflects our longstanding dedication and strategic collaboration with world-class partner Huawei," said **Bryan Blankley**, vice president, datacom, Molex.

Lark Engineering announced it has expanded its manufacturing capacity for wire, cable and harness assemblies. The expansion is targeted at: Aircraft Wire Systems; Military Communication Systems Wire Assemblies; Soldier Worn Military Cable Assemblies; Defense Vehicles. "This expansion is a significant addition to our vertical integration strategy in supporting our customers' needs for a more diverse and capable supplier" said **Bob Swelgin**, President of Lark Engineering.

Computer Simulation Technology (CST) announced the winners of the **CST University Publication Award** 2014, an annual event awarding university institutes and researchers for published papers related to electromagnetic simulation applications:

- "High-Isolation X-band Marine Radar Antenna Design," Fang-Yao Kuo, and Ruey-Bing Hwang.
- "Superconducting spoke cavities for high-velocity applications," C. S. Hopper and J. R. Delayen.
- "Footwear Antennas for Body Area Telemetry"; Domenico Gaetano, Patrick McEvoy, Max J. Ammann, Jacinta E. Browne, Louise Keating, and Frances Horgan.
- "Multi-Band Notch UWB Band Pass Filter With Novel Contiguous Split Rings Embedded in Symmetrically Tapered Elliptic Rings"; Anil Kamma, Swapnil R. Gupta, Gopi S. Reddy, and Jayanta Mukherjee.

ROGERS CORPORATION

Rogers Corp. signed a definitive agreement to acquire **Arlon, LLC,** currently owned by Handy & Harman Ltd. for $157 million, subject to closing and post-closing adjustments. The transaction, which is subject to regulatory clearances, is expected to close in the first half of 2015.

In Memoriam

Longtime industry veteran and ***Microwave Product Digest*** New England/Midwest Sales Manager **Jerry Bleich** passed away in October after an extended illness. He was 66. His wife Katherine and children Emily and Jesse were at his side.

An Army veteran, Jerry served proudly during the Vietnam War. His industry career began in 1975 as a technician, and in a series of increasing responsible positions, he rose to engineer and later, sales manager. He joined MPD in 1999. Jerry made many friends in our industry over the course of his long, successful MPD tenure, including those of us on the staff of ***High Frequency Electronics.***

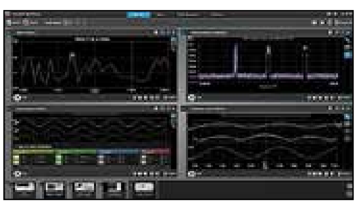
HFE

Featured Products

Power Amp

Model 2170 covers 1 to 3 GHz and delivers 1 kW of broadband output power in a 5U, air cooled chassis. Offering unrivaled size/power advantages and building on a strong design architecture, it provides excellent performance applications including test and measurement, electronic warfare, and communications.

Empower RF Systems
empowerrf.com



Measurement Software

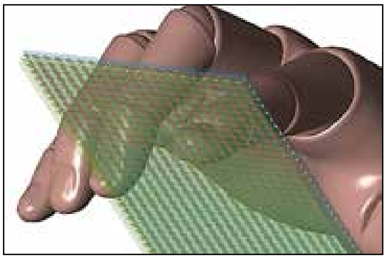
Keysight introduced the next-generation of BenchVue, a PC software application that provides multiple-instrument measurement visibility and data capture that eliminates the need for instrument programming. The second release of BenchVue features expanded data logging capabilities and the ability to work with new types of instruments such as data acquisition units and power sensors.

Keysight Technologies
keysight.com

Amp

RFMW announced support for a 1.25W driver amplifier serving radar, communication and test instrumentation applications from 2.7 to 4GHz. The TriQuint TGA2731-SM contains an integrated attenuator and power detector. Self-biasing circuitry allows operation from a single, 6V supply. The TGA2731-SM's linear power gain is >24dB.

RFMW
rfmw.com



Simulation Software

Remcom announced Projected Capacitive Touch Capability in XFdtd® 3D Electromagnetic Simulation Software. It will be available in the next version, currently scheduled for early 2015. Projected Capacitive Touch Capability is critical for designing electronics with Touchscreen Panel (TSP) technology, including touchscreens for mobile devices and desktop computer monitors, touchpads, proximity sensors, and more.

Remcom
remcom.com

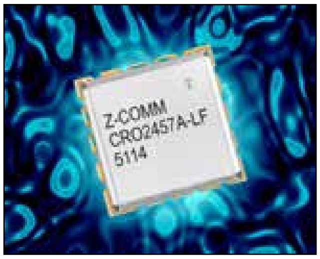
Test Set

Anritsu introduced an option for its MT8852B Bluetooth test set that supports the Data Length Extension associated with Bluetooth Low Energy (BLE) as part of the latest Bluetooth Core Specification version 4.2. Designers and manufacturers can use the MT8852B to conduct radio layer tests in full compliance with the newly adopted Bluetooth 4.2 standard.

Anritsu
anritsu.com

VCO

Z-Communications announced a RoHS compliant VCO model CRO2457A-LF. It operates at 2457 to 2458 MHz with a tuning voltage range of 0.5 to 4.5 Vdc. This high performance VCO features a spectrally clean signal of -115 dBc/Hz @ 10 kHz offset and a typical tuning sensitivity of 8 MHz/V.

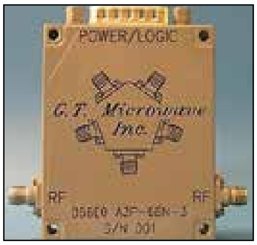


Z-Communications
zcomm.com

Signal Generator

DS Instruments introduced the SG6000L, a small, compact but full featured RF signal generator that covers the 25MHz to 6GHz band. An optional doubler extends coverage to 12GHz. The SG6000 maximum output level is above +6dBm across all its bands. It is fully synthesized to a 10MHz reference using modern fractional N methods.

DS Instruments
dsinstruments.com



Attenuator

Model A3P-68N-3 is a digitally controlled PIN diode attenuator that operates from 6.0 - 18.0 GHz. It is capable of 32 dB range in 0.125 monotonic dB steps with a supply voltage of +/-12 to +/- 15 VDC @ +/- 100 mA. The attenuation flatness is +/- 2.0 dB and the operating temperature range of 0 to +50°C with a coefficient of +/- 0.03 Degrees.

G.T. Microwave
gtmicrowave.com

Featured Products

Combiners

Pasternack introduced a new line of broadband RF power combiners. The broad bandwidth makes them the perfect complement to systems using components such as power amplifiers, antenna feeds, attenuators and switches. A special area of usage is in combining individual power amplifiers together into a large power block in an amplifier system.

Pasternack
pasternack.com

Power Supply

B&K Precision announced the 9200 Series multi-range programmable DC power supply line. This series includes four 200 W - 600 W models that can deliver power in any combination of the rated voltage and current up to the maximum output power of the supply. With voltage and current ranges up to 150 V and 25 A, these are suitable for a wide variety of uses.

B&K Precision
bkprecision.com

Detector

PMI Model Number DD-20-218-5PF-1-N-M-OPT0518 is a 0.5 to 18.0GHz, high speed, high sensitivity, diode detector requiring no bias and offering excellent temperature stability with a response time of less than 5 nanoseconds. The frequency range is 0.5 to 18 GHz.

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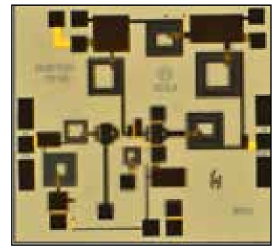
pmi-rf.com



LNA

The CMD219 has a gain of 23 dB, an output of 1 dB compression point of +18 dBm, and a noise figure of 1.1 dB across its operating bandwidth. Typical bias conditions are Vdd = 10 V @ 100 mA and Vgg = -2.3 V, although Vdd can vary from 5 V to 28 V. The CMD219 can also survive input power levels of up to 5 W without front-end a limiter.

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Keysight Technologies announced comprehensive pulsed radar analysis software. The new 89600 VSA software's pulse analysis option (BHQ) is used in radar and electronic counter measure applications for capturing and analyzing threats and jamming responses. The software option gives R&D engineers

the flexibility to define unique pulse characteristics and analyze them in the time and frequency domains.

Keysight Technologies
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Model SWF-60390350-28-L1 is a custom designed Ka-Band waveguide lowpass filter. The filter features low insertion loss and high rejection. It shows 1.2 dB maximum insertion loss from 26 to 60 GHz and greater than 50 dB rejection in the frequency range of 90 to 145 GHz.

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RUDAT-6000-60	0 – 60 dB	±0.8 dB	0.25 dB	✓	-	✓	$625
RUDAT-6000-90	0 – 90 dB	±0.9 dB	0.25 dB	✓	-	✓	$695
NEW RCDAT-6000-60	0 – 60 dB	±0.8 dB	0.25 dB	✓	✓	-	$725
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523 Rev B

Changing the Operating Frequency of an RF Power Amplifier Circuit

By Donna Vigneri

Sometimes only simple tools and a few new components are all that's required.

Standard practice when changing the operating frequency range of an existing RF power amplifier circuit dictates that an entirely new design, extensive simulation, and a new circuit board are required, assuming of course that the new frequency range is within the capabilities of the RF power transistor. However, this is actually not always necessary if the design is single-ended and has no complicated matching sections, and the new frequency range is not too distant from the original. In fact, it can be accomplished using only Smith chart and transmission line calculation software and by replacing a few inexpensive components on the board. The benefits are significant, especially when there is neither the time nor budget for wholesale changes, as it can allow a manufacturer to use a single design for multiple products. This article shows how to change the operating frequency using an actual example that took only one day to complete.

The Challenge

The evaluation board used in this discussion (Figures 1a and b) was created using Freescale Semiconductor's 7-W AFT09MS007N Airfast LDMOS RF power transistor. The unmatched device delivers 7 W CW with 120 mW of drive with efficiency up to 70% over its 136 to 941 MHz frequency range. It is designed for use in battery-operated, handheld radios that have a supply voltage of about 7.5 VDC. The device can operate into a VSWR greater than 65:1 at all phase angles without degradation, even when driven at twice its rated drive power and 30% overvoltage. It includes an internal electrostatic discharge protection circuit that protects the MOSFET gate structure from short duration, high-voltage discharge that may be encountered during assembly. Documentation and tools for the AFT09MS007N are available from Freescale[1].

It's important to note that the steps described below can be applied to other RF power transistors, RF output powers, frequency range conversions, and bandwidth extensions.

Figures 1a and 1b • Original (a) and revised circuit in evaluation board (b).

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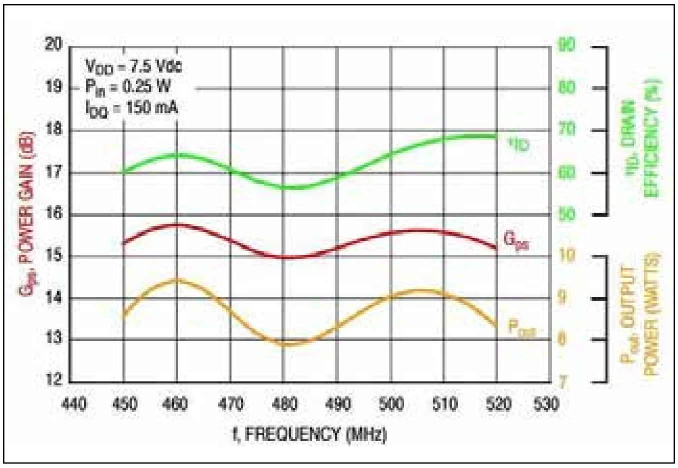


Figure 2 • Power gain, RF output power, and drain efficiency of original 450 to 520 MHz circuit versus frequency and a constant RF input power (7.5 VDC).

The original design required that the amplifier cover a 70 MHz bandwidth between 450 and 520 MHz. However, a subsequent specification required that the device cover a 120-MHz frequency range of 350 to 470 MHz while maintaining the same gain, RF output power, and efficiency of the original design (Figure 2). As there was no time for extensive additional simulations or a new PC board, it was obvious that a different approach was required to effect the change.

Rather than resorting to the use of a “full-up” design suite (which anyway was not available on short notice), the Iowa Hills Smith Chart program from Iowa Hills Software[2] was used instead to facilitate the frequency shift. This software is one of many free Smith chart programs available on the Web. The transmission line parameter calculator from Clemson University[3] was used to estimate the degrees of separation and impedance of the transmission line. Other calculators are also available, including the Freescale Engineering Tools 3 app for Android and iPhone[4], Transmission Line Calc for iPhone from Black Cat Systems[5], and TX-LINE, a Windows-based transmission line calculator from AWR[6].

Experimental tuning was first employed in an attempt to shift the frequency directly from the test bench and was based on tuning notes compiled during the 450 to 520 MHz design. This allowed a 70-MHz bandwidth from 400 to 470 MHz to be achieved, and more tuning resulted in a bandwidth of 85 MHz from 380 to 465 MHz. However, the desired 120-MHz bandwidth from 350 to 470 MHz remained elusive. Performance at the high end of the frequency range was acceptable but at lower frequencies around 350 MHz the total impedance was probably too low to also allow matching. The apparent bandwidth might have been the result of a high Q factor. To test if this was the cause, the match was revised using the Smith Chart.

The Solution

To achieve the 120-MHz bandwidth, the current PC board, its microstrip transmission lines, and the position of the lumped element were retained to save time and money. The transmission line impedances were calculated in the transmission line program based on the material properties of the board. The number of matching sections used in the original design was maintained and component values were optimized using the Smith Chart. An adjustment of the transmission line characteristics between these lumped components would have required a new PC board because applying copper tape bridges and cutting PC board traces would not be practical for large-scale manufacture.

The Iowa Hills Smith Chart program uses a combination of fixed and optimized values to achieve the desired impedance transformation. The starting position in a 50-ohm system at the RF input or output is assumed to be 50 + j0 ohms, so the Z_0 of the Smith chart is then 50 ohms. For the AFT09MS007N, the gate and drain impedances were each expected to be around 2 to 3 ohms based on interpolation between known narrowband impedances at 136 MHz and broadband impedance from 450 to 520 MHz (the bandwidth of the original circuit). The impedance of LDMOS transistors typically increases as frequency decreases because the reactive part of the impedance is more capacitive, which causes the impedance to be inversely proportional to frequency. The capacitive reactance $XC=1/(2\pi \times f_0 \times C)$.

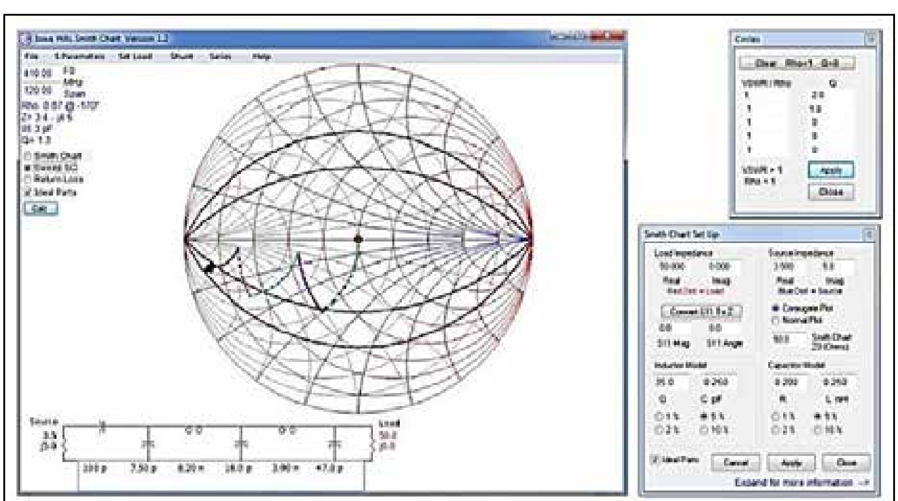
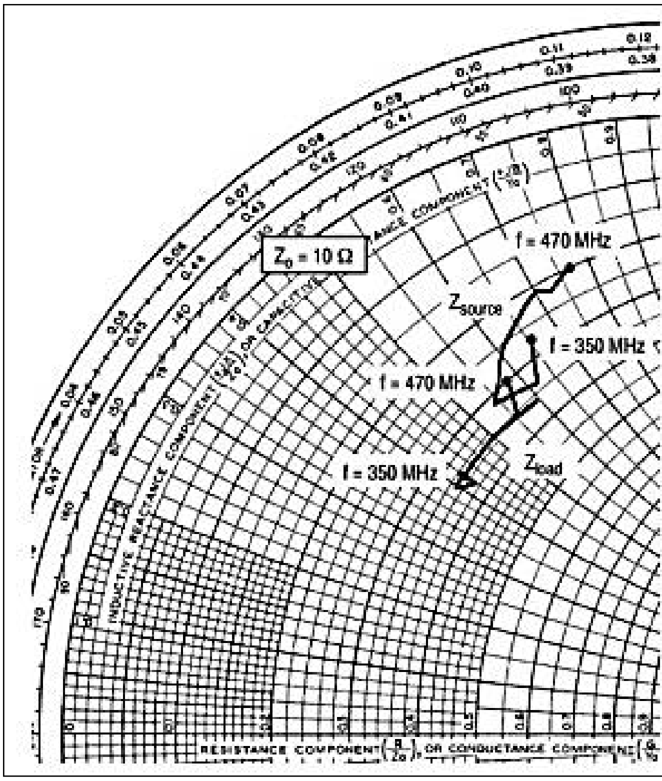


Figure 3. Smith chart for 350 to 470 MHz.



V_{DD} = 7.5 Vdc, I_{DQ} = 200 mA, P_{out} = 7.3 W

f MHz	Z_{source} Ω	Z_{load} Ω
350	2.7 + j6.6	3.5 + j4.2
370	3.3 + j6.2	3.7 + j4.2
390	3.1 + j5.4	3.5 + j4.0
410	2.6 + j6.1	3.5 + j5.0
430	2.1 + j7.1	3.6 + j5.9
450	2.2 + j7.3	3.6 + j5.6
470	2.0 + j7.7	3.0 + j5.8

Z_{source} = Test circuit impedance as measured from gate to ground.

Z_{load} = Test circuit impedance as measured from drain to ground.

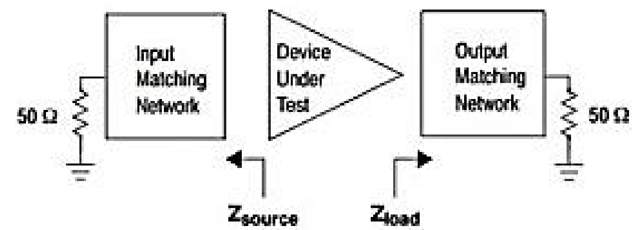


Figure 4 • Series equivalent series circuit source and load impedance (350 to 470 MHz).

As can be seen from the Smith chart (Figure 3), the transformation plot follows a tighter Q circle than the actual measurements portray, probably because ideal components and approximations are used in the plotting program. The impedance was transformed with three matching sections of shunt capacitor plus series inductor, following a reasonable Q circle across the Smith chart (Figure 4). The Q was determined via the classic method, Q=center frequency/bandwidth.

Optimization

The process of optimization in the Smith Chart program consisted of checking multiple frequencies across the band of interest, making sure that the resulting impedances for 350 and 470 MHz were not too distant from each other, which is a hallmark of broadband design. Once an optimal output match was determined in the Smith Chart program, the components were changed, and focus moved to the input-side transformation. The same process was followed: The components on the RF input were modified and the new circuit design was taken to the test bench.

Using a vector network analyzer, S 11 was checked and a few components were adjusted on the input match to improve the input return loss so that high gain could be achieved and the frequency response could be centered. It became obvious from this exercise that the new match was superior to the old one, which was saved for comparison. The new match improved the return loss by twice the original value and over a wider frequency range.

At this point, large-signal testing was performed and although efficiency was initially low the desired output power was achieved across the entire 120-MHz bandwidth and actually beyond, to 300 MHz. After about a half hour of tuning, the bandwidth was tightened to the 350 to 470 MHz specification, the efficiency met the required minimum of at least 60% across the band, gain was reasonably flat, and output power with a fixed input power of 250 mW was at least 7 W. In short, the frequency shift was accomplished in less than one day. A reference design for this circuit is available[7].

The original board required 25 passive components (19 unique values), and the new board required 27 (with 21 unique values) so the cost of increasing the bandwidth from 70 MHz to 120 MHz was negligible. The gain, RF output power, and efficiency of the final circuit are shown in Figure 5.

Summary

The process of shifting the frequency of the original design was achieved using only Smith chart and transmission line calculation software, illustrating that simple tuning and review with a Smith chart can eliminate the need for an extensive, time-consuming, costly redesign.

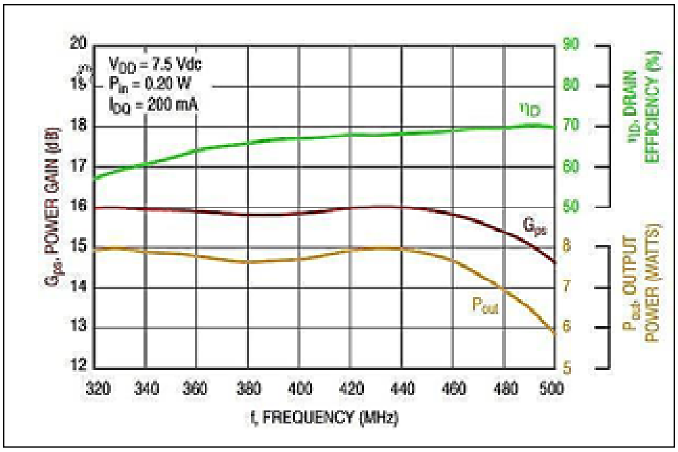


Figure 5 • Power gain, drain efficiency, and RF output power versus frequency at a constant RF input power of the revised design covering 350 to 470 MHz.

As stated earlier, frequency conversion can be achieved in this manner only when the original and revised frequency ranges are reasonably close to each other. So if the original design was centered at 20 MHz (for example) and the new one is centered on 500 MHz, it's unlikely that the conversion can be achieved. In addition, if the conversion is to a higher frequency, component values get smaller, but transmission lines may have to be widened to reach the desired impedance. If the conversion is to a lower frequency, transmission line widths can probably remain the same as in the original design, but component values get larger. Finally, if the change also requires increasing the RF output power, all new components, the board, and the microstrip line must be able to handle the increased power.

About the Author

Donna Vigneri is an RF applications engineer in the RF Group at Freescale Semiconductor, where she designs many types of power amplifiers and provides global applications support for industrial, scientific, medical, and avionics applications. She received her BSEE from Florida Institute of Technology, is an active radio amateur (KF7SJF), president of the Freescale Amateur Radio Society (club station W7FSL), and supports educational outreach with the Society of Women Engineers and Arizona Science Outreach with the goal of drawing more young people into the field of engineering.

Additional Reading

Chris Bowick, RF Design, 2nd Edition, 2008, pp. 69–102 (for Q and Smith chart impedance matching).

David M. Pozar, Microwave Engineering, 3rd Edition, 2005, p. 272, Table 6.1 (for common equations used in RF circuit design).

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Procedure for how to use the N, TNC and 7/16 Push-On male. Push-On Connectors mate with any standard female connector of the same connector style.

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4. The Connection has been completed, easy and fast. The connector has been locked on safely.

5 . To unlock (when “Back Nut” is in unlocked mode) push the “Lock Nut” forward and stop reverse movement by setting your fingers onto the “Back Nut”.

6. Keep fingers on “Back Nut” to ensure that “Lock Nut” cannot slide back and pull the connector off.

Procedure for how to use the SMA male and SMA female Push-On connectors. SMA Push-On Connectors mate with any standard connector of the same but opposite connector style.

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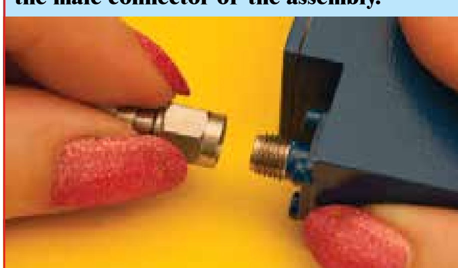
2. Your standard SMA male cable assembly is converted into an SMA male Push-On Assembly.

3. Just slide the Push-On SMA male Connector onto any standard SMA female. The connection is securely completed in seconds.



4. To disconnect, just pull the connector off.

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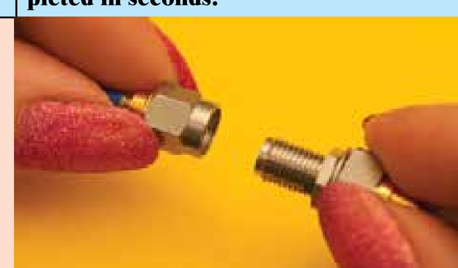

1. Convert your standard cable assembly into a Push-On Assembly by threading the standard female side of the adapter onto the male connector of the assembly.

2. Your standard SMA male cable assembly is converted to a Push-On SMA female Cable Assembly.

3. Just slide the Push-On SMA female Connector onto any standard SMA male. The connection is securely done in seconds.

4. To disconnect, just pull the connector off.

Achieving First Pass Success in PCB-Based Filter And Matching Circuit Designs

By Scott Muir, Larry Dunleavy, and Tom Weller

Three fabrication techniques to generate a low pass filter design.

Introduction

This paper provides a comparison of three fabrication techniques used to generate a simple three element 250 MHz low pass filter (LPF) design measured and modeled to address in-band and out-of-band response through 5GHz. For each of the three scenarios, the filter will be fabricated using the values of the passive lumped elements obtained in the ideal LPF design process; it is expected that the measured data will differ from the ideal LPF design due to the parasitic effects present at high frequencies. Parasitic elements are added incrementally to the design in order to illustrate the progression towards better measured to model agreement; the final full parasitic LPF model design will contain transmission line (TL) elements and Modelithics® CLR Library models for the passive lumped elements.

The purpose of this work is to provide insight into a "good, better, best" progression through fabrication techniques used to generate and measure a LPF. One objective of this work is to highlight how the progressive modeling of the parasitic effects present at high frequencies will provide better measured to model agreement. The best approach also utilizes on-board RF-probing and related thru-reflect-line calibration, whereas the other two approaches utilize standard coaxial connectorized measurements using a commercial short-open-load-thru calibration along with subsequent connector modeling/de-embedding.

The same techniques discussed herein for a simple filter design apply equally for PCB-based matching circuit designs and should be of interest to anyone committed to improved simulation-based design success.

Filter Design Approach

The LPF shown in this document is one of three constant-k Butterworth[1] tee junction filter designs that belong to the 5th laboratory assignment of the Wireless Circuits & Systems Lab course offered at USF[2]. A Butterworth filter is a device designed to have as flat of a frequency response as possible in the pass band; for a LPF, the pass band exists prior to the cut-off frequency. The cut-off frequency of a LPF is the frequency where the signal power has been reduced by half (the frequency where the signal experiences 3dB of loss). This 3dB loss is seen in the forward transmission coefficient (S21) of the LPF S-Parameters. The S-Parameters of the LPF can be calculated using the ABCD parameter equations derived for a general tee junction formed by three elements with given impedances. Also shown below is a table listing the capacitor and inductor values calculated to have LPFs with cut-off frequencies of 100, 250, and 500 MHz; also

LPF Cut-Off Frequency (MHz)	L1 and L2 (nH) (calculated / selected from vendor)	C1 (pF) (calculated / selected from vendor)
100	79.55 / 82	63.65 / 68
250	31.84 / 33	25.46 / 27
500	15.92 / 15	12.73 / 12

Table 1 • Calculated and vendor capacitor and inductor values used for three LPF designs.

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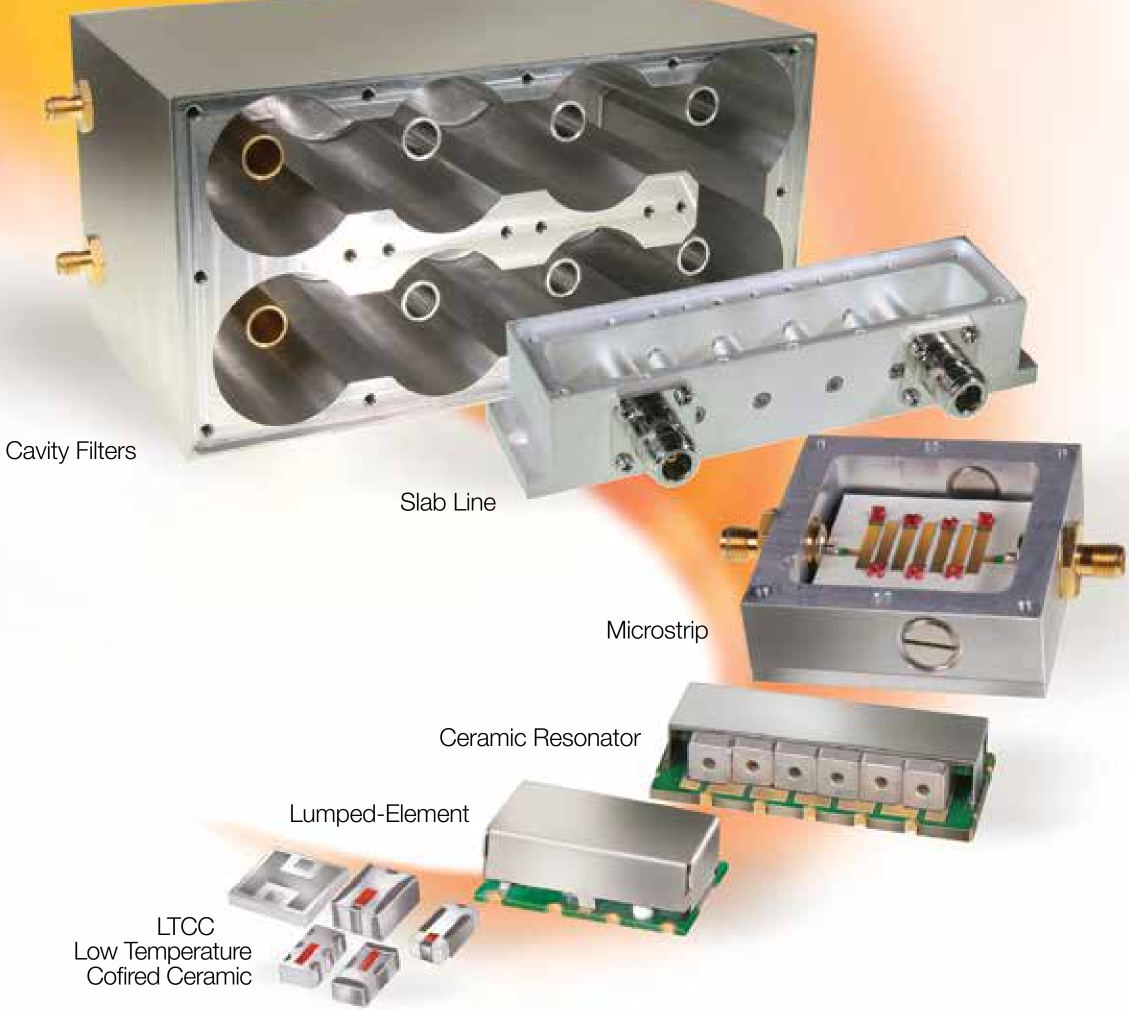

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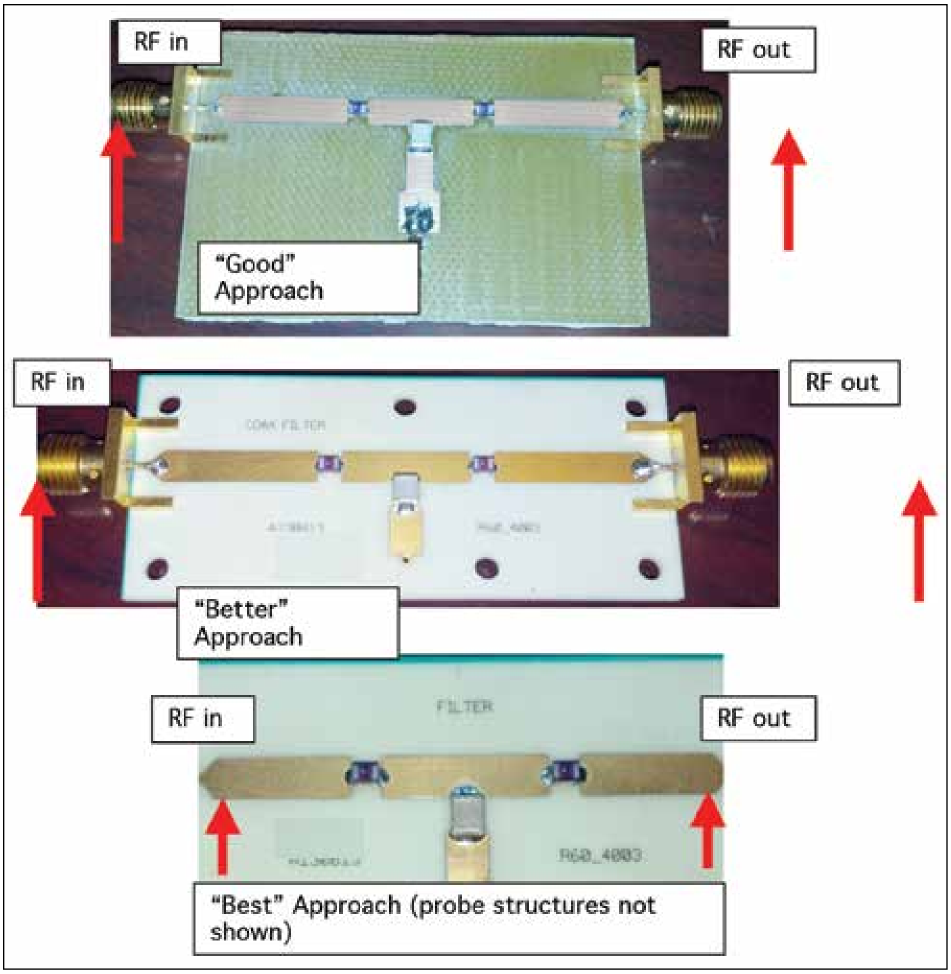


Figure 1 • Fabricated 250 MHz LPFs. "Good" approach (top image), "Better" approach (middle image), "Best" approach (bottom image); measurement reference planes indicated by the red arrows.

shown in the table are the passive values selected from the vendor datasheet. Note: the passive lumped element values used in the simulations and fabrication are the values obtained from the vendor datasheets for the ideal design.

Once the ideal design has been obtained, the next step would be to begin accurately modeling the parasitic affects of the physical device present at high frequencies in order to better predict the device behavior. These effects are caused by the passive devices, the pads each device is mounted on, the grounding and transmission line elements and the coaxial connectors (where applicable).

In some cases, a design engineer can obtain S2P data for passive devices directly from the vendor. While these data files represent actual measured data for the passive device being used in the design, there is a degree of uncertainty as to how that data was obtained. The fixture used by the vendor to obtain the S2P data may be quite different from the fixture used by the designer. Differences can exist in the pad dimensions and substrate selection that can drastically affect device performance. The frequency range of interest to the designer also may not be included in the S2P data.

The steps of iteratively modeling the parasitic affects of the physical device will be demonstrated later in the paper.

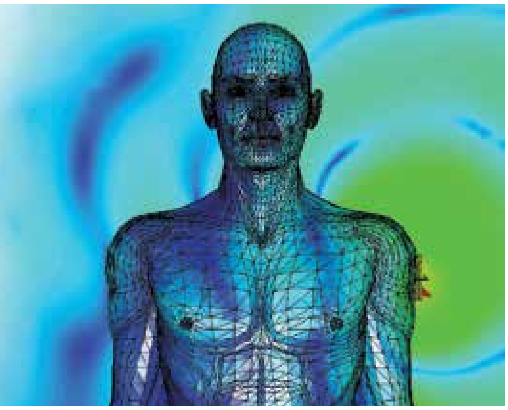
Fabrication

The first fabrication technique used a milling machine, with the procedure performed by a University of South Florida (USF) Center for Wireless and Microwave Information Systems (WAMI Center) teaching assistant. This is the least accurate approach to fabrication and is labeled the "good" approach. This technique is the least accurate since it utilizes soldered slip-on coaxial connectors as a means of measurement and is grounded with a wire soldered between the TL and the ground plane. This rudimentary grounding is not optimal and is used in the USF WAMI lab to reduce course costs. The substrate used in this fabrication is 59 mil FR4 (Er = 4.3).

The second fabrication technique was performed professionally by an outside board manufacturer with chemical etching as well as plated through via holes; however soldered slip-on coaxial connectors are still used as a means of measurement. This grounding technique is the preferred method at high frequencies since it is provides reliable and repeatable fabrication as well as minimizing the parasitic inductance present between the TL and ground plane. This approach is labeled as the "better" approach. The substrate used in this fabrication is 60 mil Rogers 4003C (Er = 3.65).

The third fabrication technique uses the same board and plated through via hole technology as the "better" assemblies. This technique is labeled the "best" due to the use of probe pads allowing ground-signal-ground RF wafer probes to be used as a means of measurement. The use of probe tip structures provides yet another degree of reliable and repeatable measurements by removing the uncertainties that can exist when using soldered slip-on coaxial connectors.

Related information highlighting the importance of the measurement of noninsertable devices can be found in the product note "Agilent 8510-13"[3].



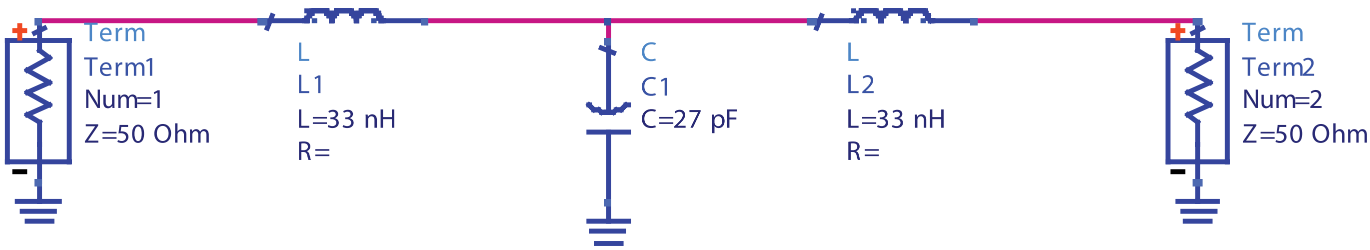


Figure 2 • Ideal LPF.

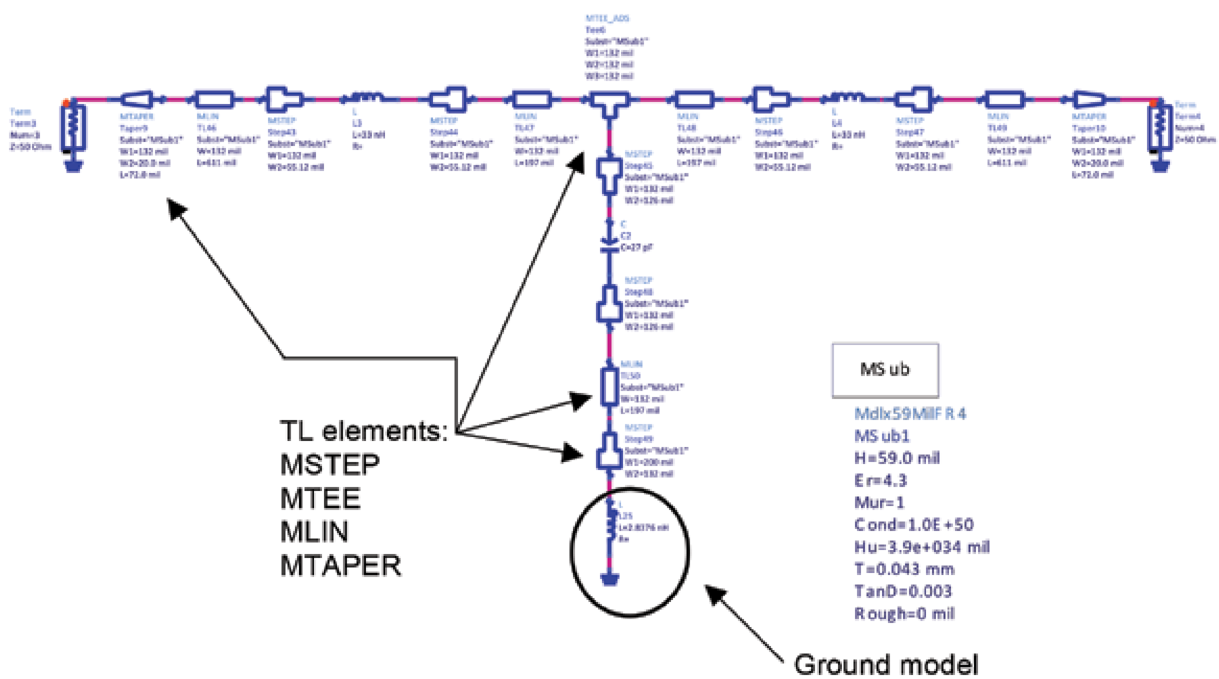


Figure 3 • Ideal "good" LPF containing TL and ground models.

"Good" Approach: Measured vs Model

Figures 2 through 4 show the transition from ideal design to full parasitic design. The dimensions of the TL elements were obtained from the CAD design of the "good" LPF.

Plots of the ideal LPF model performance can be seen in Figure 5; Figures 6 and 7 show plots of measured data vs modeled performance of the "good" LPF.

As the parasitic elements are added incrementally, the measured to model agreement improves. However, even in the final full parasitic model, there are still discrepancies between the measured data and model performance. These discrepancies can be attributed to the less than ideal fabrication techniques used: in house milling on the USF campus, use of coaxial connectors as a means of measurement, and using a wire soldered between the TL and ground planes.

"Better" Approach: Measured vs Model

Figure 8 shows the full parasitic design; the ideal design can be seen in Figure 2. The dimensions of the TL elements were obtained from the CAD design of the "better" LPF.

Plots of the "better" LPF measured data vs modeled performance can be seen in Figure 9; compare this to the ideal model performance in Figure 5. For the "better" approach, there has been a drastic reduction in the discrepancies between the full parasitic LPF model performance and the measured data when compared to the "good" approach.

"Best" Approach: Measured vs Model

Figure 10 shows the full parasitic design; the ideal design can be seen in Figure 2. The dimensions of the TL elements were obtained from the CAD design of the "best" LPF.

Plots of the "best" LPF measured data vs modeled performance can be seen in Figure 11; once again, compare this to the ideal model performance seen in Figure 5. For the "best" approach, the agreement between the full parasitic LPF model performance and the measured data has

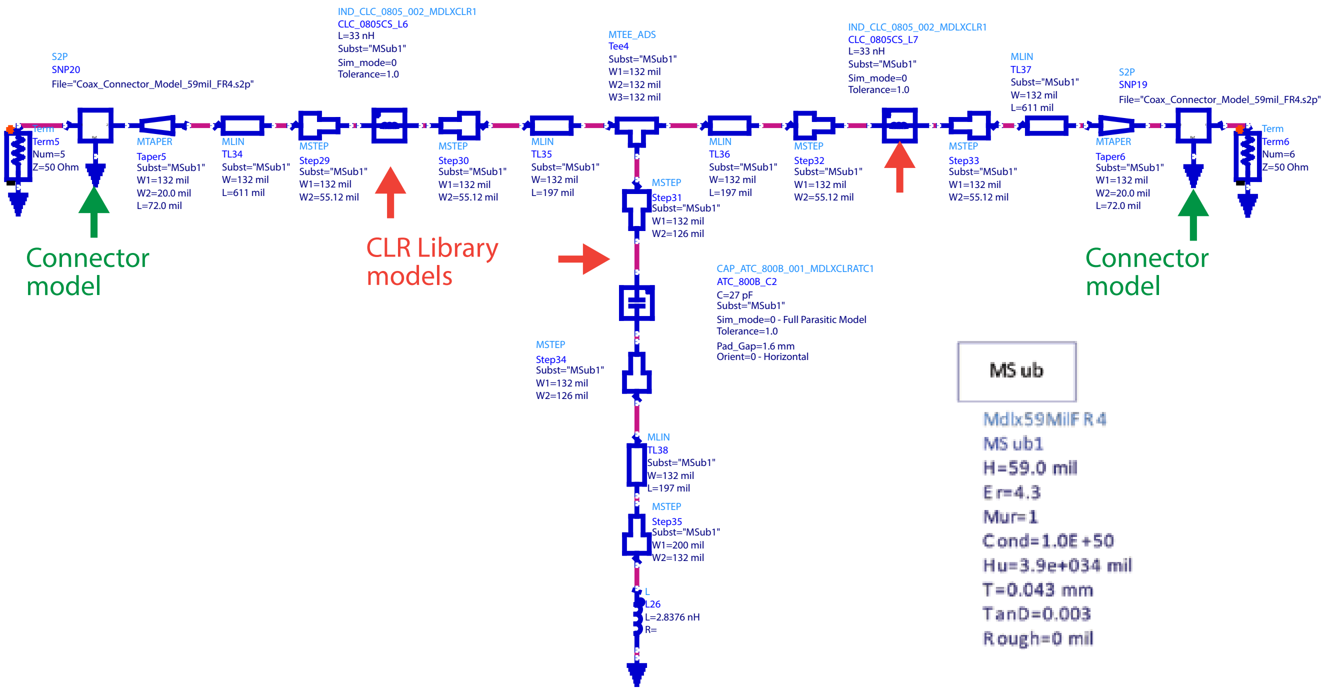


Figure 4 • Full parasitic "good" LPF containing TL and ground models as well as Modelithics CLR models for the passive lumped elements (CLR models indicated by the red arrows) and connector models (connector models indicated by the green arrows).

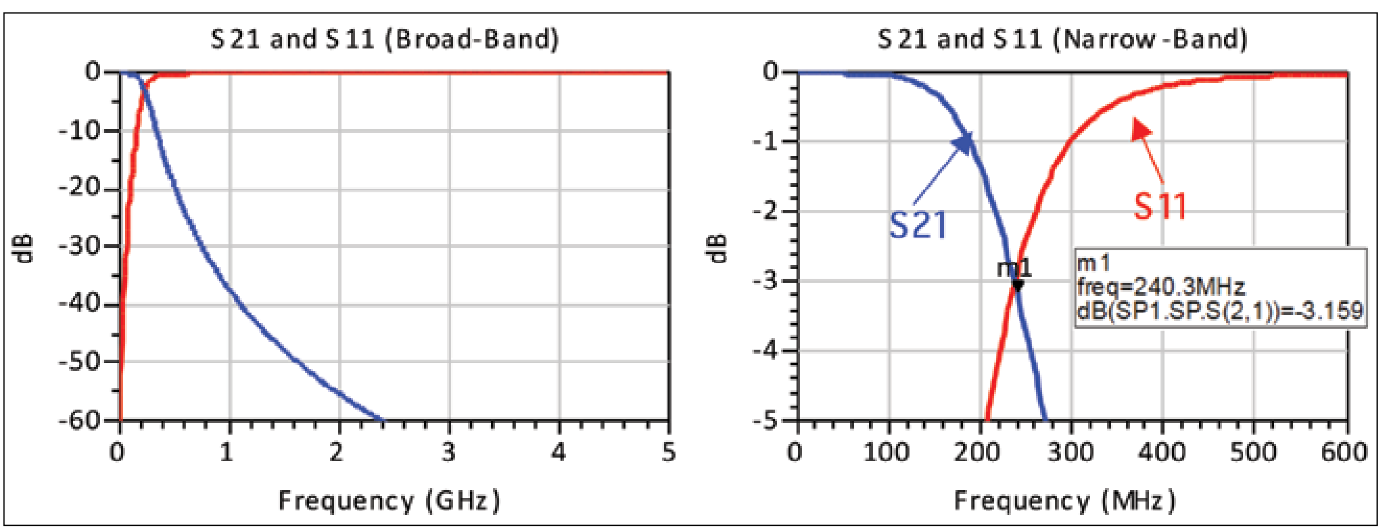


Figure 5 • Ideal LPF model performance; S21 (blue line) and S11 (red line). Broad-band (left) and narrow-band (right).

improved over the "better" approach and is much higher than the "good" approach.

Closing Remarks and Conclusions

In this document, a comparison was performed of three fabrication techniques used to generate a simple three element 250 MHz low pass filter (LPF) design. It was shown that using less than ideal calibration methods and fabrication techniques can lead to major discrepancies between model performance and measured data. This document also provided insight into how parasitic effects will cause the measured data to differ from the ideal model performance, especially when viewed at high frequencies. To obtain improved measured to model agreement, proper modeling of the parasitic effects in subsequent design iterations is required.

Once a full parasitic model has been obtained, it is possible to tune the design in order to achieve the ideal LPF performance in the desired band.

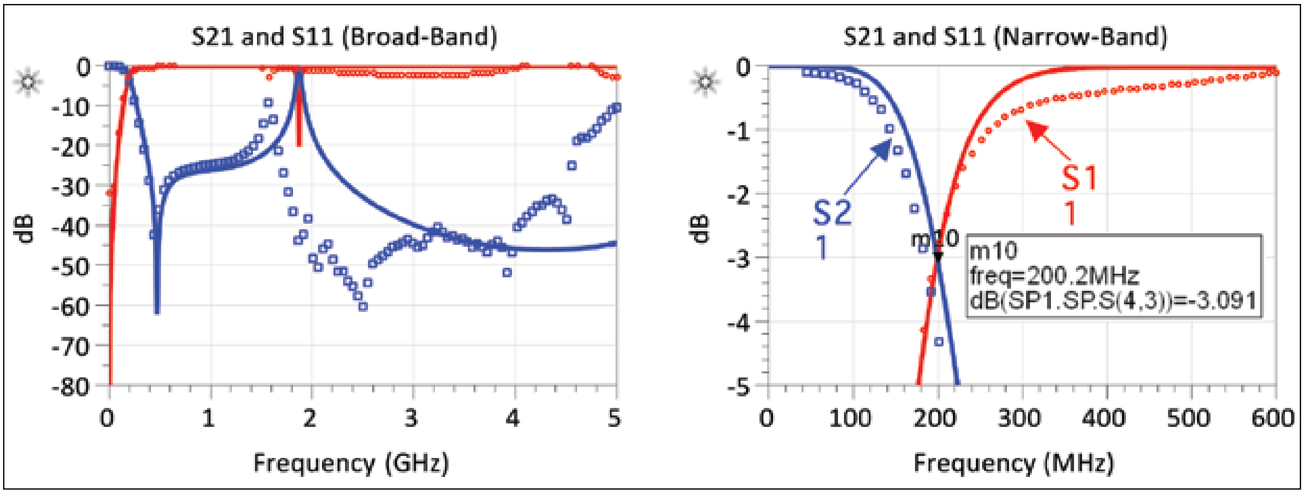


Figure 6 • Ideal "good" LPF with TL elements; measured data (symbols) vs model performance (solid line). S21 (blue) and S11 (red); broad-band (left) and narrow-band (right).

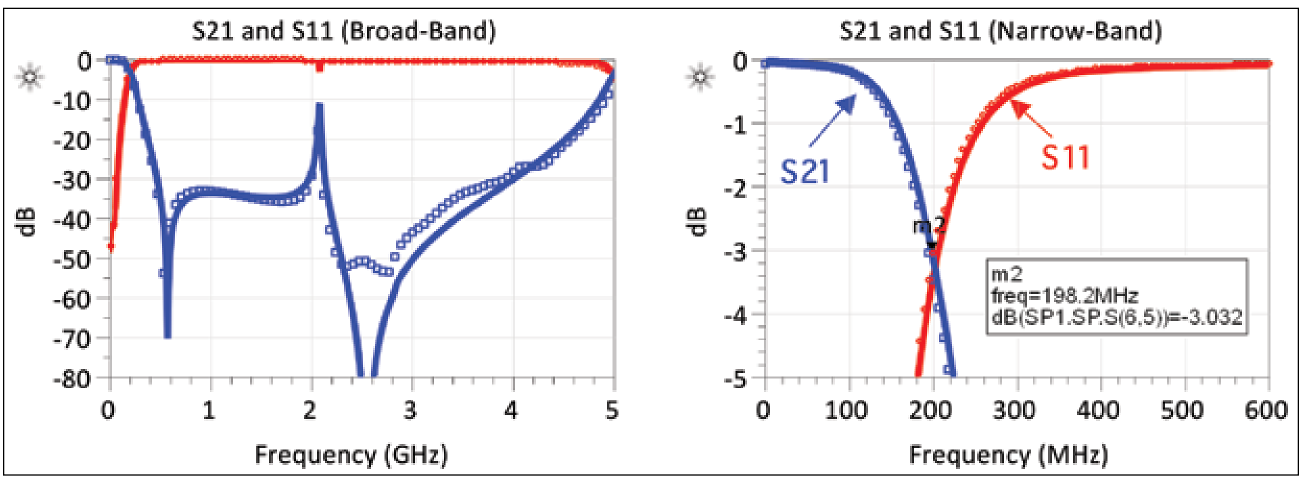


Figure 7 • Full parasitic "good" LPF; measured data (symbols) vs model performance (solid line). S21 (blue) and S11 (red); broad-band (left) and narrow-band (right).

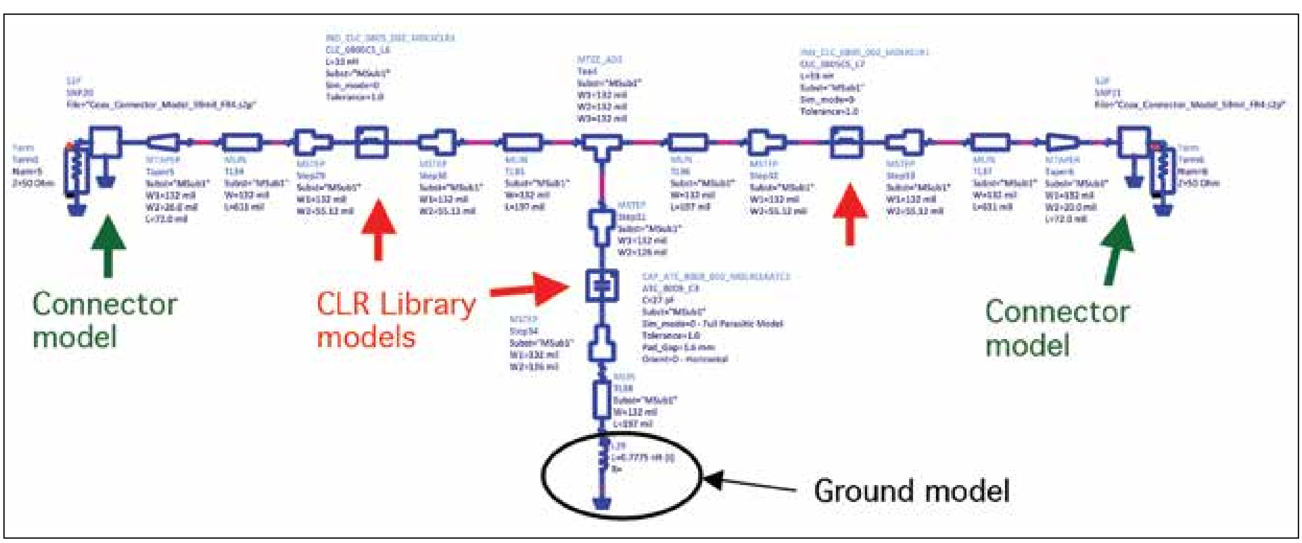


Figure 8 • Full parasitic "better" LPF containing TL and ground models as well as Modelithics CLR models for the passive lumped elements (CLR models indicated by the red arrows) and connector models (connector models indicated by the green arrows).

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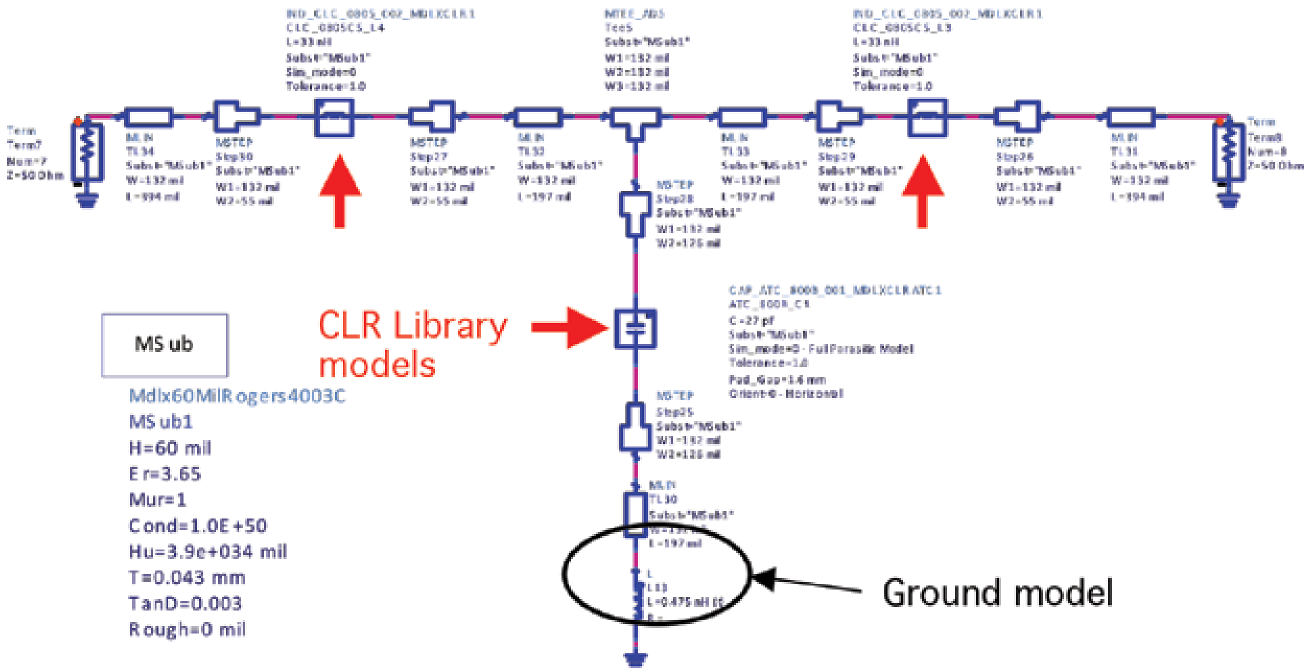

Figure 10 • Full parasitic "best" LPF containing TL and grounding effects as well as Modelithics CLR models for the passive lumped elements (CLR models indicated by the red arrows).

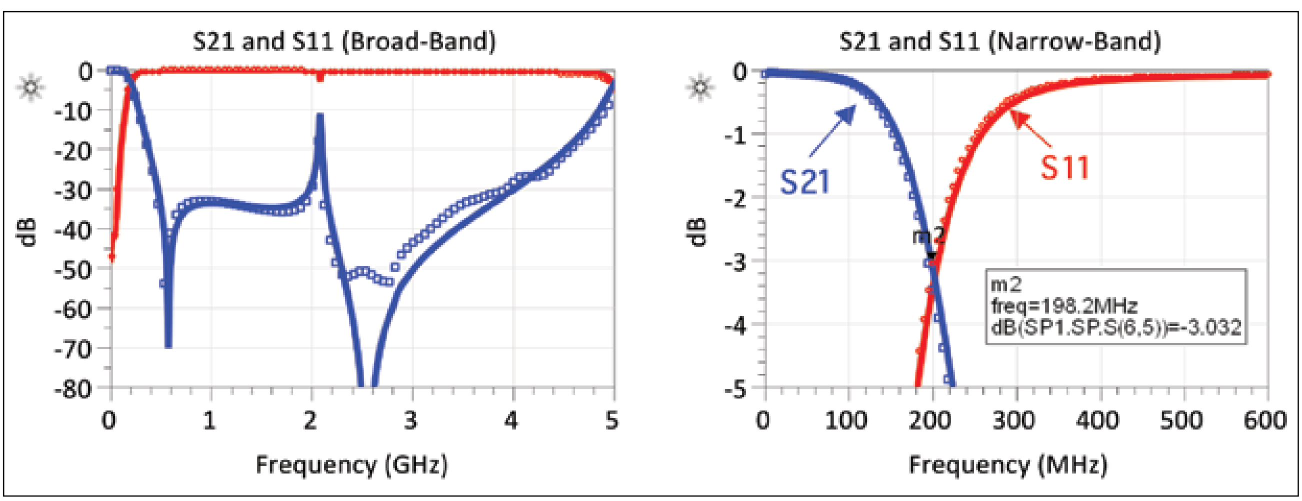

Figure 11 • Full parasitic "best" LPF; measured data (symbols) vs model performance (solid line). S21 (blue) and S11 (red); broad-band (left) and narrow-band (right).

About the Authors

Scott Muir was previously with Modelithics, Inc. He is now with TriQuint Semiconductor in Apopka, Florida. Larry Dunleavy and Tom Weller are with Modelithics.

Acknowledgements

The milling of the "good" LPF was performed by Anand Kumar Santhanakrishna, a USF PhD student. The authors would like to thank Isabella Delgado and Alberto Rodriguez for their helpful editing comments.

The ADS and CAD files associated with the filters shown here are available upon request.

References

[1] David M. Pozar, "Microwave Engineering", Second Edition, pp. 433-450.

[2] T. Weller and L. Dunleavy, "Wireless and Microwave Education: From Circuits to Systems," Proceedings of the 1999 European Microwave Conference - Invited Paper, pp. 93-97.

[3] Keysight (formerly Agilent) Technologies, "Measuring Noninsertable Devices", A new technique for measuring components using the 8510C Network Analyzer – Product Note.

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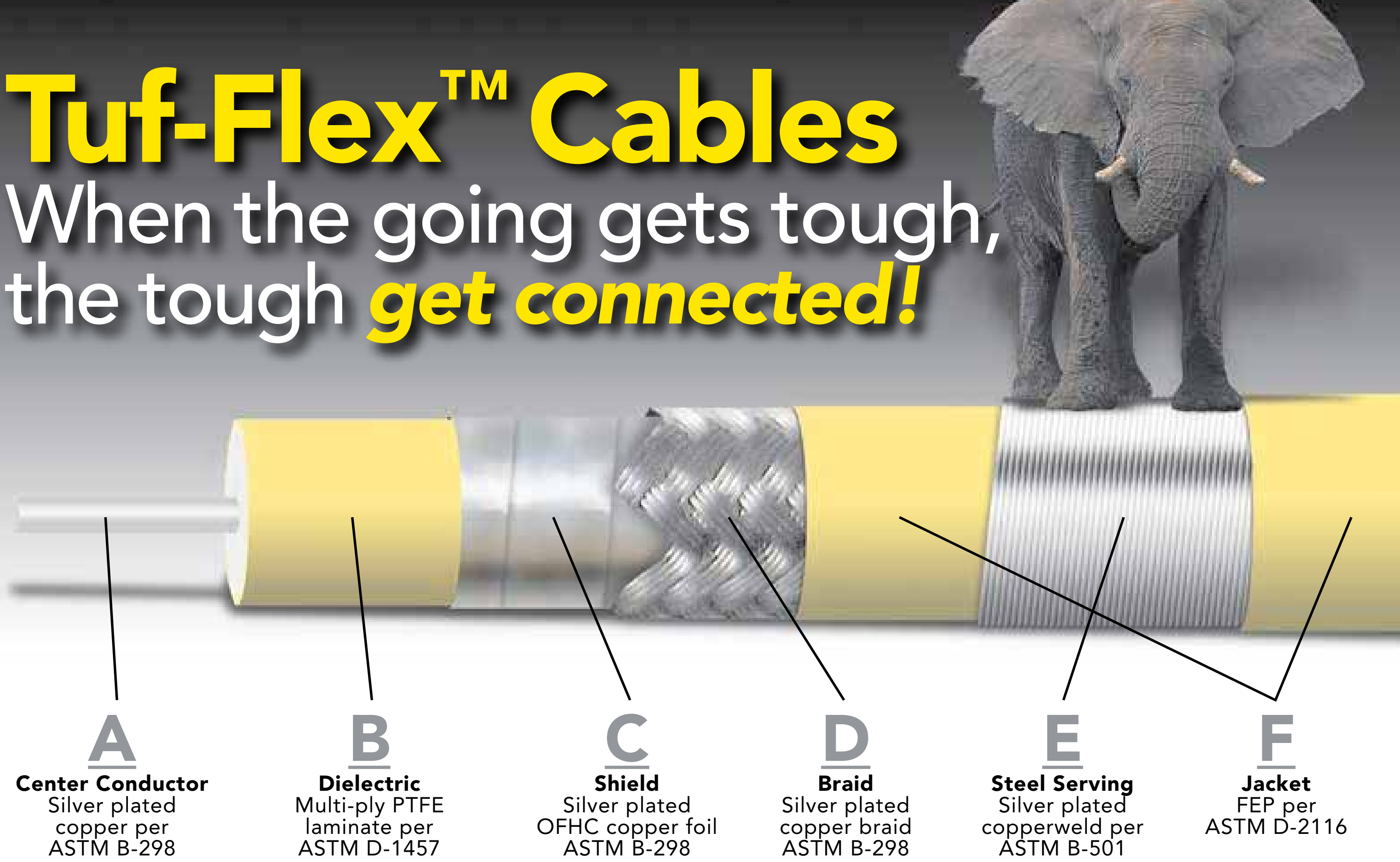

TUF-FLEX offers an internal layer of silver plated copperweld protection that is crush resistant & offers exceptional resistance to kinking in lieu of external armor.

TUF-FLEX Cable Performance vs. Crush Force

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90	1.20	1.3
160	1.20	1.3
200	1.22	1.3
225	1.28	1.3

Results of crush and bend tests on IW's TUF-FLEX cable assemblies, using 2 ft long samples of our 1803 cable. Results show max VSWR and insertion loss over a frequency range of .04 to 18 GHz.

For crush force testing, the cable was placed between two 1 inch diameter plates with force applied to the top plate. The same cable was then tested using successively smaller bend radii to a minimum bend radius of 1.5".

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New Products

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Passive Plus now provides customers with the option of specifying capacitor assemblies with SAC 305 solder, which is 100% lead free. Previous to this breakthrough, engineers were limited to specifying capacitor assemblies that typically utilized a high lead content solder to attach the leads to the capacitors.

Passive Plus
passiveplus.com

Filters

RBPF-485+ surface mount band pass filters provide a pass band of 435 to 535 MHz, supporting military aircraft and marine communication application bands. They provide sharp rejection at the lower and upper cut offs (30 dB rejection at 320 MHz and 700 MHz, respectively), 1.3 dB pass band insertion loss, and RF power handling up to 5W.

Mini-Circuits
minicircuits.com

Power Amp

Model SBP-5536533022-1515-E1 is a V band power amplifier covers the frequency range from 55 to 65 GHz. The amplifier exhibits 30 dB small signal gain with +/- 2 dB gain flatness. The P-1dB is +22 dBm typically and it draws 800 mA current from a +8 volts DC supplier. It is equipped with standard WR-15 waveguide and UG385/U flange as its RF connectors.

SAGE Millimeter
sagemillimeter.com

Oscilloscope

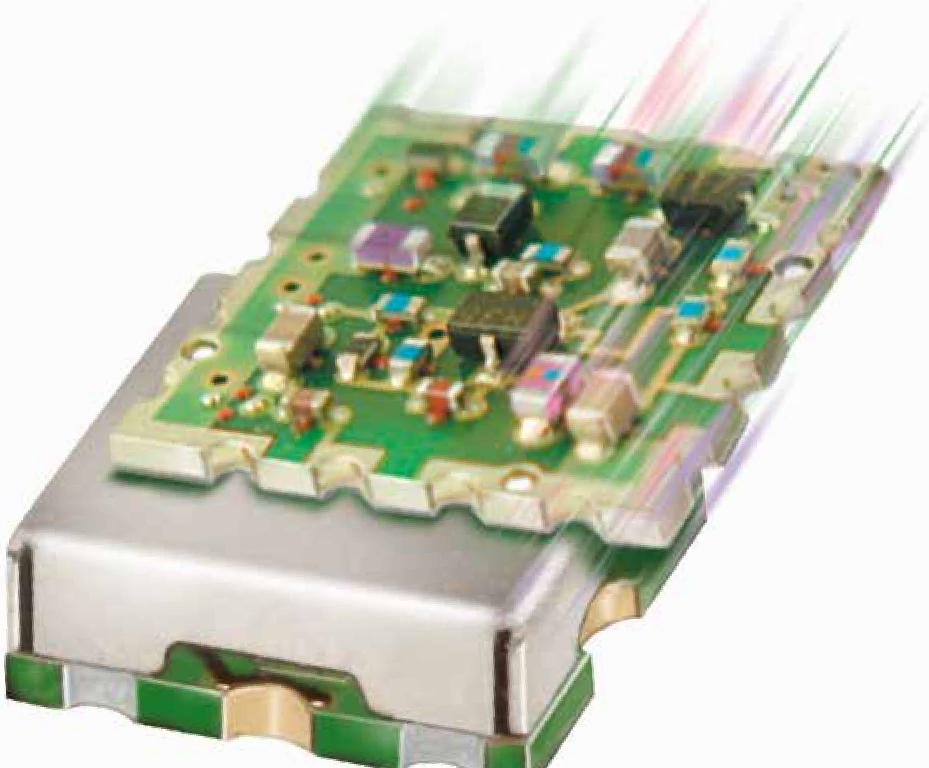
Rohde & Schwarz is expanding its R&S RTM bench oscilloscope family by adding a new model that is ideal for the education sector. The instrument features a 200 MHz bandwidth and an education mode that deactivates special measurement tools to help students quickly learn how to work with an oscilloscope.

Rohde & Schwarz
rohde-schwarz.com

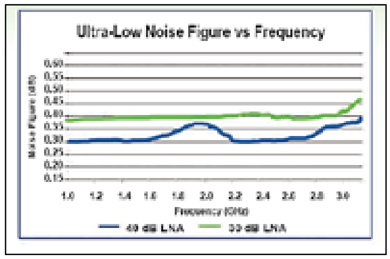
Mixers

OML can extend the frequency range of your existing spectrum analyzer to millimeter wave frequencies with its single diode unbalanced harmonic mixers. Harmonic mixers are available for the waveguide bands between 18 and 325 GHz. These frequency extension modules are compatible with most spectrum analyzers that offer optional external mixer access.

OML
omlinc.com



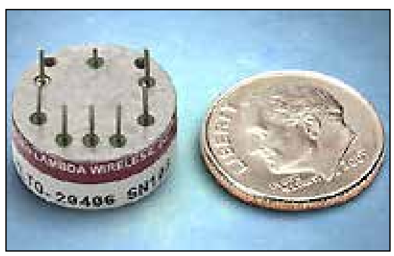
New Products



LNAs

Ciao Wireless's new line of ultra-low noise amplifiers with noise figures as low as 0.30 dB typical between 1.0 – 3.1 GHz with delivery in 1 – 2 weeks ARO. Ciao's designs feature multiple frequency and gain options while maintaining ultra-low noise figures between 0.3 dB to 0.4 dB.

Ciao Wireless
ciaowireless.com



YTOs

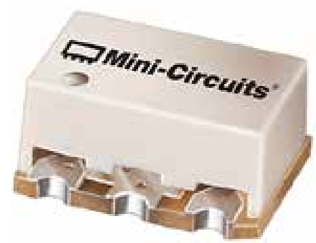
The MICRO LAMBDA MLTO-Series Permanent Magnet YIG-Tuned Oscillators cover any 2 GHz bandwidth over the frequency range of 2-8 GHz. They are available in customer selected tuning ranges and are fitted with a low power main coil, and FM coil for phase locking. All units operate from a +8 Volt and –5 Volt supply and operate over the 0° to + 65°C temperature range. Units do not require a heater.

Micro Lambda Wireless
microlambdawireless.com

Gate Driver

Richardson RFPD announced availability of a new 1.2kV, 80mΩ all-SiC six-pack (three-phase) module and associated six-channel gate driver from Cree, Inc. The CCS020M12CM2 includes C2M™ MOSFETs and Z-Rec™ diodes and features ultra-low loss, high-frequency operation, zero reverse recovery current from the diodes, zero turn-off tail current from the MOSFETs, fail-safe operation, and more.

Richardson RFPD
richardsonrfpd.com



Limiters

Mini-Circuits' RLM-63-2W+ surface mount limiters cover 30 to 6000 MHz with +12 to +32 dBm limiting range and 11.5 dBm typical output power, ideal for protecting LNAs and other sensitive devices from ESD or input power damage. Measuring just 0.25 x 0.31 x 0.16", this model provides 0.3 dB insertion loss and 1.2:1 VSWR when input power is less than +3 dBm.

Mini-Circuits
minicircuits.com

Socket

Ironwood Electronics' new stamped spring pin socket addressing high performance requirements for testing BGA243 - CBT-BGA-7020. The contactor is a stamped spring pin with 31 gram actuation force per ball and cycle life of 500,000 insertions. This socket can be used for quick device screening, device characterization at extreme tem-

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peratures as well as final production test.

Ironwood Electronics
ironwoodelectronics.com

TWTA

The Model 367 is a dual mode Pulse/CW TWT Amplifier which has been designed to operate TWT's in the 200-300 watt power range at frequencies up to 18 GHz. The RF output pulse is generated by the grid pulse without the use of RF switches. RF output pulse is controlled by the input video pulse.

Applied Systems Engineering
applsys.com

Circulator

Model F2823-0150-67 is an octave band SMA (or type N) connectorized circulator covering 100 MHz to 200 MHz frequency range. It features 1.0 dB insertion loss, 15 dB minimum reverse isolation, and 1.50:1 VSWR, and can handle 20 Watts of CW power. Higher power version up to 100 Watt is available with reduced bandwidth. Package size is 2.09 × 3.03 × 1.02".

Wenteq Microwave
wenteq.com

Directional Coupler

Model 20CH170 is a single directional coupler covering 700-2,700 MHz. Coupling is 20±1.25 dB throughout the band with 22 dB minimum directivity and 1.2:1 return loss. Rated at 100 watts. Designed for low-PIM appli-

cations. Standard with N-Female connectors. Measures 4.5 x 2.0 x 0.8 inches. Crafted in USA.

Werbel Microwave
werbelmicrowave.com

Switch

Model SKD-9031045030-1010-R1 is W band Single-Pole Double-Throw (SPDT) switch that operates from 90.0 to 100.0 GHz. It has better than 30 dB isolation and 5.0 dB typical insertion loss over the entire frequency range. The power handling and input P-1 dB is +23 dBm CW. This model has a build-in TTL driver with provides 2us switching speed. Required bias is +/- 5 Vdc/10 mA.

SAGE Millimeter
sagemillimeter.com

GaN Amp

Comtech PST introduced a Gallium Nitride (GaN) amplifier for applications in the X-Band radar market. The AB linear design operates over the 8.5-10 GHz frequency range intended for use in radar applications. Features include options for control of phase and amplitude to allow for integration into high power systems utilizing conventional binary or phased array combining approaches for power levels of up to 10kW.

Comtech PST
comtechpst.com

Module

Anaren's Wireless Group released its first AIR for WICED™ Smart Bluetooth module and Atmosphere on-line developer platform as part of a strategic engagement with Broadcom. This new relationship enables both companies to support designers, innovators, and end-equipment manufacturers with easy-to-use tools that will simplify the challenge of 'going wireless' and speed time to market.

Anaren
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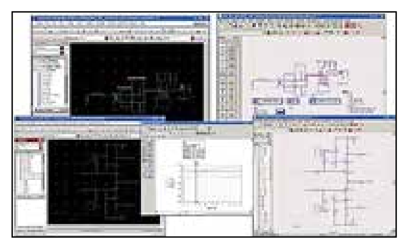

EDA Software

Keysight Technologies introduced the latest release of its Advanced Design System (ADS) software, ADS 2015. Featuring silicon RFIC interoperability with Cadence's Virtuoso, GoldenGate-in-ADS, and a host of capabilities intended to increase design efficiency, ADS 2015 is changing how silicon RFIC and multi-technology module design is performed.

Keysight Technologies
keysight.com

Design Kit

Cree introduced a MOSFET design kit that includes all of the components needed to evaluate Cree® MOSFET and Schottky diode performance in a configurable half bridge circuit. Quick and easy to assemble and use, the kit enables comparative testing between IG-


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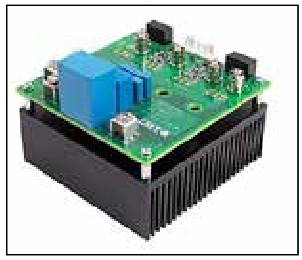
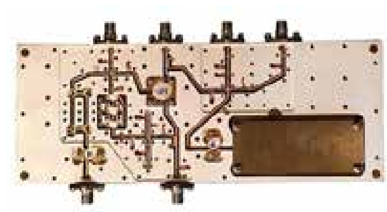
New Products



BTs and Cree MOSFETs, and provides an effective layout example for properly driving Cree MOSFETs with minimal ringing.

Cree
cree.com



Switching Assembly

Operating over Ku band, the AMC Model RFM-16M7 integrated switching assembly contains solid state switches, circulators, a digital controlled attenuator, a Ku band solid state source and a DLVA with digitized video output. It measures 6.5 x 2.5 x 1.48 in. Designed for flight line use in conjunction with an optical delay line to provide precise pulse delays for radar calibration.

American Microwave
americanmic.com

Filters

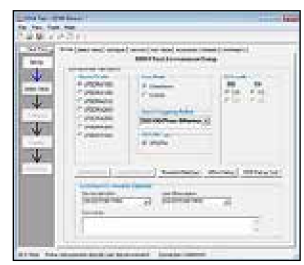
SXBP-72+ surface mount band pass filters provide a narrow pass band of 68 to 76 MHz, developed specially for harmonic rejection and IF signal processing in avionics and air traffic control applications. They provide 3.3 dB pass band insertion loss, 30 dB lower stop band rejection (DC to 60 MHz), and 27 dB upper stop band rejection (87 to 4000 MHz).

Mini-Circuits
minicircuits.com

Power Sensor

LadyBug Technologies' new LB5940A patented no-zero no-cal before use USB RF Power Sensor is for radar applications. The sensor's broad frequency range combined with exceptional sensitivity makes it ideal for weather radar as well as defense applications. Whether it's average power, statistical pulse data, or a time domain visual pulse profile, there is a LadyBug high-accuracy RF power sensor to fill your need.

LadyBug Technologies
ladybug-tech.com



Compliance Test

Keysight Technologies introduced the industry's most complete compliance test application for systems using low-power double-data-rate 4 memory. The application gives engineers an efficient and quick way to characterize LPDDR4 designs. The application also offers offline testing support for running signals from simulation tools like Keysight's Advanced Design System.

Keysight Technologies
keysight.com

Flexible Cables

FLC-series test cables support applications from DC to 26 GHz with low insertion loss and rugged, extra-flexible cable construction, ideal for tight system layouts. Available in a variety of lengths, they feature SMA(M) to SMA(M) connectors and provide excellent reliability, backed

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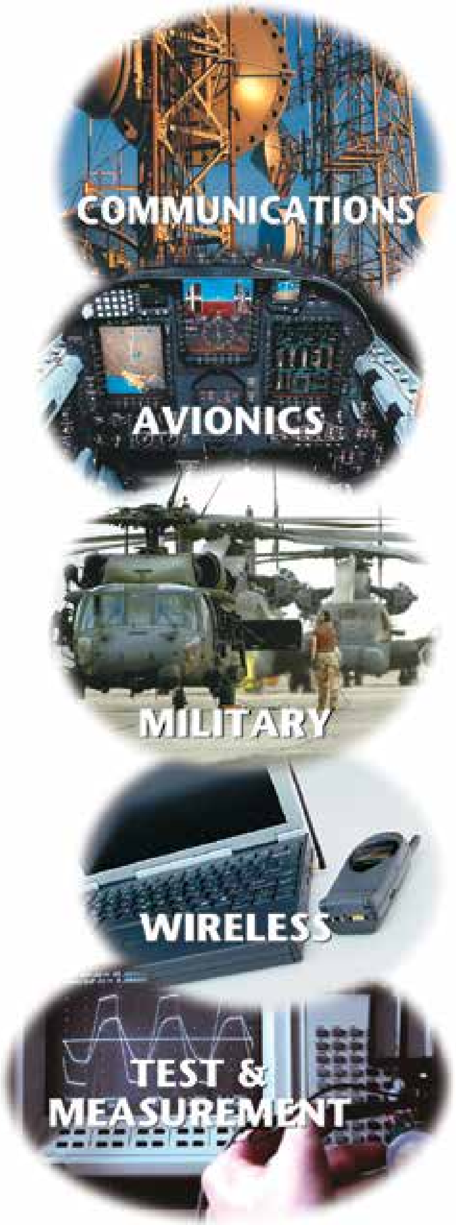

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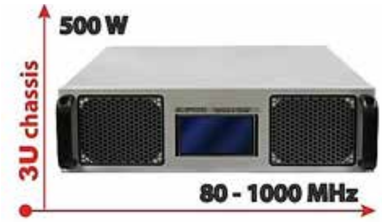
Power Amps

Empower released additional power amplifier models that complement the frequency coverage and power level "footprint" of its next generation, high power PA product family. Model 2175, covering 80 to 1000 MHz and delivering 500W of broadband output power in a 3U, air cooled chassis, is market released and available for immediate



purchase. Model 2175 provides excellent performance for end applications that include test and measurement, electronic warfare, and communications.

Empower RF Systems
empowerrf.com

Diode

RFMW announced design and sales support for the SMV1275-079LF hyperabrupt junction varactor diode from Skyworks. Specifically designed for battery operation. The specified high-capacitance ratio and low-series resistance make the SMV1275-079LF appropriate for low phase-noise Voltage-Controlled Oscillators (VCOs) used at frequencies in wireless systems up to and above 2.5 GHz.

RFMW
rfmw.com

Oscilloscope

The high definition mode increases the vertical resolution of the R&S RTO and R&S RTE digital oscilloscopes to up to 16 bits – a 256 fold improvement over the 8 bit resolution available in standard mode. To achieve this higher resolution, the signal is lowpass-filtered directly after the A/D converter.

Rohde & Schwarz
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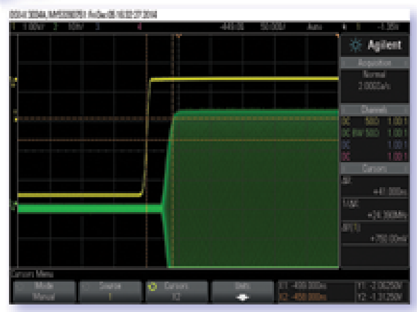
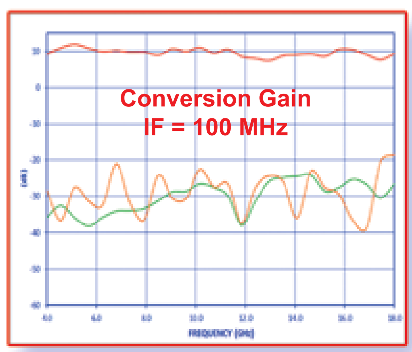
- 25dBc Typical Suppression

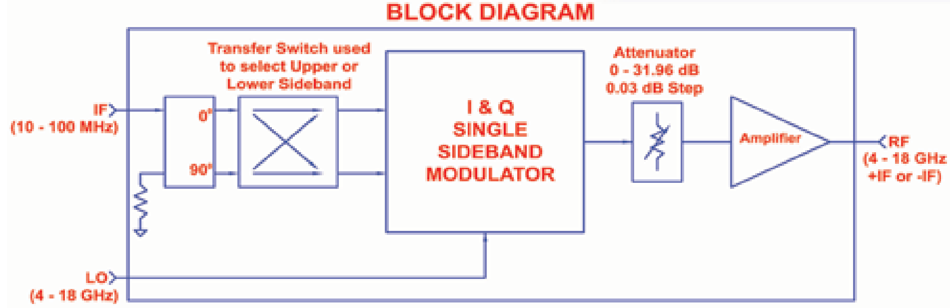
Frequency Range	4.0 to 18.0GHz
Conversion Gain	10dB, ±3dB max (RF+ 0dBm, IF Modulation = +14dBm)
Max Input Power	20dBm max
VSWR	2.0:1 max (RF - 0dBm, IF Modulation - +14dBm)
Carrier Suppression	20dBc min, 25dBc typ
Side Band Suppression	15dBc min, 20dBc typ
IF Frequency Range	10MHz to 100MHz
Power Supply	+15V @ 400mA max -15V @ 100mA max
RF Output 1dB Compression	12dBm typ (RF = 2dBm, IF Modulation = +14dBm)
RF Input 1dB Compression	5dBm typ (IF Modulation - +14dBm, >5dB Attenuation)
Sideband Switching Speed	150ns max
RF Connectors	SMA(F) Inputs and Outputs
Data Control Input	True Binary
Logic Levels	TTL & LVTTL Compatible
Latch	Logic "1" = Data Transparent Logic "0" = Data Locked
Size	6.5" x 2.5" x 0.5"
Finish	Painted Blue
Attenuator	
Attenuation Range	0 to 31.96dB
Number of Attenuation Bits	10-Bits (1024 Steps)
Max Attenuation Step Size	0.03dB
Switching Speed	500ns max



Sideband Switching Speed
45ns Measured



BLOCK DIAGRAM



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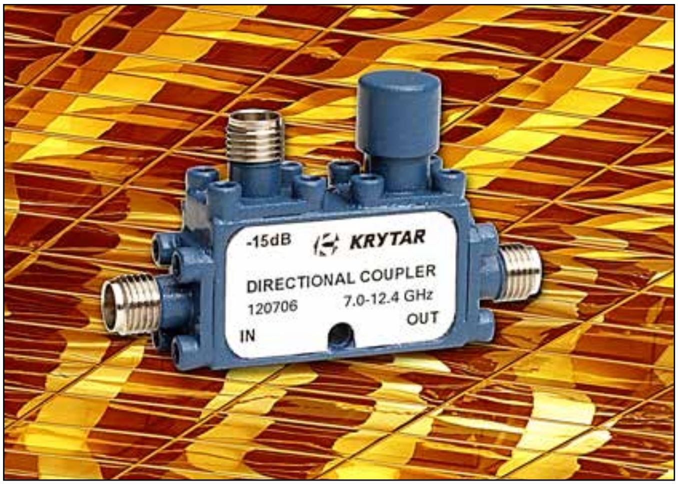


Coupler

KRYTAR announced the addition of a new model offering 6 dB of coupling over the frequency range of 7.0 to 12.4 GHz, in a single, compact and lightweight package. The directional coupler continues to expand the family of superior performance narrow-band products covering the frequency range of 0.3 to 50 GHz.

KRYTAR
krytar.com

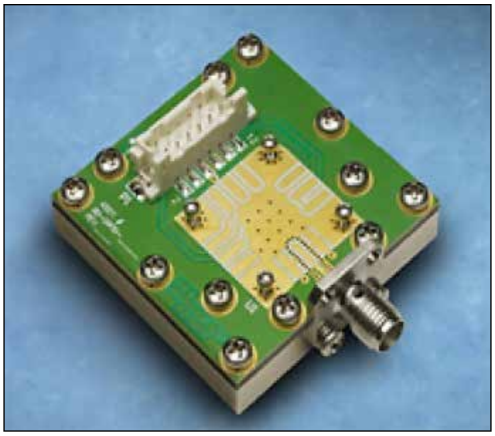
Power Amp

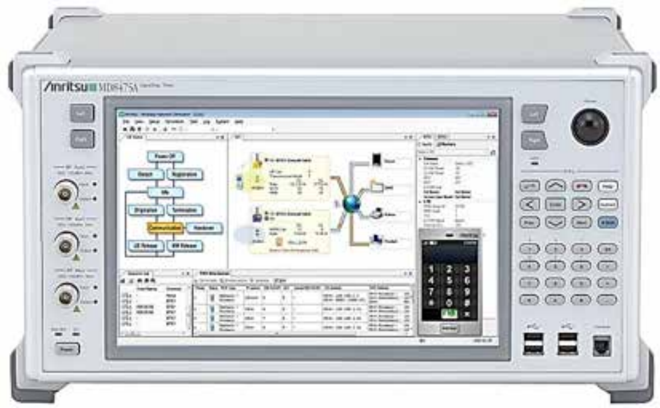
Model SBP-8138632018-1212-S1 is an E Band high power amplifier with small signal gain of 20 dB minimum and P-1 dB of + 18dBm in the frequency range of 81 GHz to 86 GHz. The DC power requirement for the amplifier is +8.0 Vdc/650 mA. The input and output port configurations are both WR-12 waveguides with UG387/U flanges.

SAGE Millimeter
sagemillimeter.com

Product Showcase

Product Highlights





Test Fixture

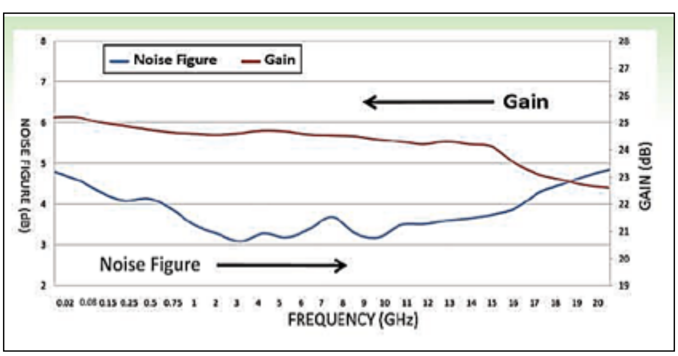
The MICRO LAMBDA MLOTF-Series Oscillator Test Fixture has been specifically designed to accommodate all of the MLSMO model types. A compatible DC connector is provided to generate the necessary DC wire harness. DC wire harness instructions are included.

Micro Lambda Wireless
microlambdawireless.com

Signaling Tester

The MD8475A signaling tester with SmartStudio Manager Windows-based control software now provides multi-operator support for Commercial Mobile Alert System (CMAS) Carrier Acceptance Test (CAT) packages. It is the comprehensive solution for analyzing CMAS, providing users the ability to verify that their wireless devices are correctly receiving emergency cell broadcast messages and properly alerting users.

Anritsu
anritsu.com



Broadband Amps

The Ultra-Broadband Amplifier Series includes designs that cover frequency ranges as wide as 20 MHz to 20 GHz of instantaneous bandwidth. They feature flat gain response over ultra-broadband widths with typical gain flatness of better than +/- 2.0 dB over the full frequency bands. Featuring noise figures of 3.2 dB TYPICAL over much of their bands with very good input and output matches of better than 2.0:1.

Ciao Wireless
ciaowireless.com

Product Highlights

PIM Tester

The PIM 21 is a microprocessor controlled, portable test set allowing detection of distortion components and assemblies in radio base station, in-building DAS installations and other systems transmitting radio frequencies.

Boonton
boonton.com

Terminations

MECA offers low power, 4.1/9.5 (Mini-DIN) Male & Female 50 ohm loads efficiently designed for high performance, cost effective solutions. Rated for 1 & 10 watts average power (2 kW peak). Available from stock to 3 wks. Made is USA - 36 month warranty.

MECA Electronics
e-MECA.com

Signal Analyzer

It is now easy to extend the frequency range of existing PXA, MXA, and EXA X-Series signal analyzers. Through return-to-Keysight upgrades, you can select frequency options up to 50 GHz, depending upon the model. Your analyzer will maintain its full compatibility, retain its complement of options and applications, and keep the same serial number.

Keysight Technologies
keysight.com

Product Highlights

Filters

Anatech Electronics offers the industry's largest portfolio of high-performance standard and custom RF filters and microwave filters, as well as related passive and active products. Their goal is to help RF design engineers and anyone involved with transmitting or receiving RF signals find the RF filters and products they need to accomplish their design or interference solution task.

Anatech Electronics
anatechelectronics.com

Low PIM Adapters

Fairview offers dozens of low PIM adapters with operation up to 7.5 GHz. Ideal for portable PIM testing, cellular/PCS, DAS, OEM in-rack RF routing, in-building systems and land mobile radio applications.

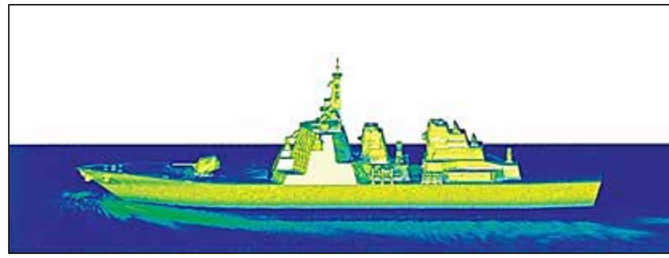
Fairview Microwave
fairviewmicrowave.com

Switch

RLC Electronics announced the addition of a high power 18 GHz SPDT switch with N connectors to its product capabilities. The switch can handle 1000 Watts at 100 MHz, 200 Watts at 4 GHz and 125W at 18 GHz, and provides high reliability, long life and excellent electrical performance characteristics over the frequency range (including high isolation).

RLC Electronics
rlcelectronics.com

Product Highlights



Power Meter

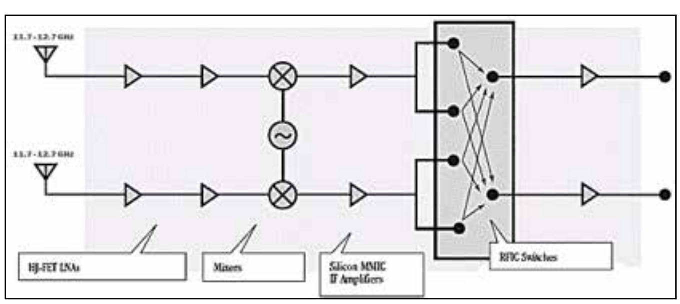
Boonton's versatile 4541 (1 Ch) and 4542 (2 Ch) combined Peak/Average Power and Voltage meters are leading-edge instruments for most accurate RF measurements. Features like high dynamic range, rise time of less than 7ns and an effective time resolution of 200 ps provide the greatest detail in signal waveform analysis. These are the instruments of choice for capturing, displaying, and analyzing RF power in both the time and statistical domains.

Boonton
boonton.com

3D EM Simulation

CST MICROWAVE STUDIO® (CST MWS) offers customers the choice of multiple powerful solver modules. In addition to its time domain solver featuring the PERFECT BOUNDARY APPROXIMATION (PBA)®, CST MWS also included modules based on methods including finite element method (FEM), method of moments (MoM), multilevel fast multipole method (MLFMM) and shooting boundary ray (SBR).

CST
cst.com



Transistors, Amps

Renesas High Performance, Low Noise HJ-FETS, High Gain SiGe Transistors, Si IC IF Amplifiers, and Industry-Leading Low-Loss GaAs Switches provide a complete solution for DBS LNB manufacturers. Available NOW, through California Eastern Laboratories.

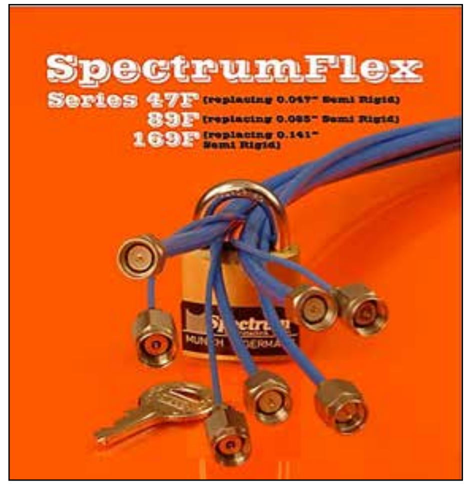
CEL
cel.com

Product Highlights

Signal Analyzer

The SR785 Two-Channel Dynamic Signal Analyzer is a precision, full-featured signal analyzer that offers state-of-the-art performance at a price that's less than half that of competitive analyzers. Building on its predecessor, the SR780, the SR785 incorporates new firmware and hardware that make it the ideal instrument for analyzing both mechanical and electrical systems.

Stanford Research Systems
thinksrs.com



Flexible Cable

SpectrumFlex is a flexible cable that can be terminated with any standard semi-rigid cable connector, saving you costs. Add to that its durable construction, which translates to consistent performance, every time. Series 47F: replaces 0.047" semi-rigid. Series 89F: replaces 0.085" semi-rigid. Series 169F: replaces 0.141" semi-rigid.

Spectrum Electrotechnik
Spectrum-et.org

Precision Connectors

SGMC Microwave is a registered ISO 9001:2008 manufacturer of precision coaxial connectors including cable connectors, adapters, and receptacles. SGMC Microwave was founded to provide the microwave and millimeter-wave industry with high quality products that are precision grade and readily available. We are committed to quality and performance and consider our connectors "precision components."

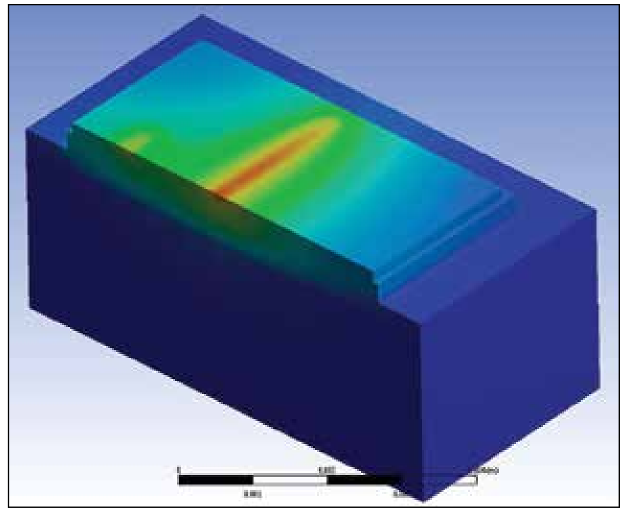
SGMC Microwave
sgmcmicrowave.com

Product Highlights

Module, Gate Driver

Richardson RFPD announced availability and design support for a new 1.2kV, 80mΩ all-SiC six-pack (three-phase) module and associated six-channel gate driver from Cree. The CCS020M12CM2 includes C2M™ MOSFETs and Z-Rec™ diodes and features ultra-low loss, high-frequency operation, zero reverse recovery current from the diodes, zero turn-off tail current from the MOSFETs, fail-safe operation, and more.

Richardson RFPD
richardsonrfpd.com



Thermal Analysis

RFMW announced availability of a new white paper from TriQuint (Qorvo) titled GaN Thermal Analysis for High-Performance Systems. This paper addresses the TriQuint (Qorvo) integrated approach to thermal design that leverages modeling, empirical measurements (including micro-Raman thermography), and finite element analysis (FEA) for high performance microwave GaN HEMT devices and MMICs.

RFMW
rfmw.com

Receiver

Analog Devices announced an integrated direct conversion receiver development platform for radar systems where reduced size, weight and power (SWaP) implementation is critical. The new AD-FMCOMMS6-EBZ platform is a 400-MHz to 4.4-GHz receiver (1350 MHz to 1650 MHz with installed filters) supporting the key L- and S-band frequency radar bands. The platform's VITA57-compliant form factor ensures seamless connectivity to FMC (FPGA mezzanine card) platforms.

Analog Devices
analog.com

Product Highlights

Online Connector Catalog

Improve your component and system performance with connectors, adapters and cables that feature exceptionally low insertion loss, low VSWR and low RF leakage. View the Southwest Microwave product catalog online, and then click on the product links for product details. You can also download the entire catalog, or individual catalog sections as PDFs, as needed.

Southwest Microwave
southwestmicrowave.com

Power Sensor Drivers

LadyBug Technologies announced six new LabVIEW instrument drivers for its power sensors. The new drivers make it easy for users of 32 bit LabVIEW to run multiple sensors on upgraded 64 bit computers. They are available as individual downloads for 2009 to 2014 versions of LabVIEW, and are designed to make building compiled test software quick and easy. Visit the downloads section of LadyBug's website.

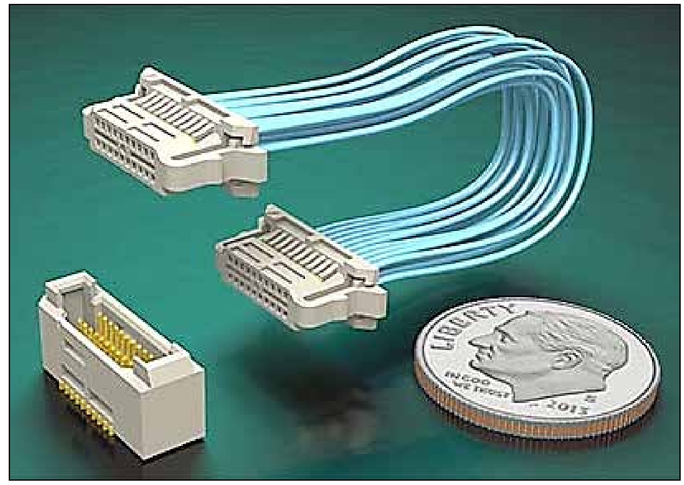
LadyBug Technologies
ladybug-tech.com

Diplexer

The DPL Series offers compatibility with OML's MxxHWD harmonic mixer series for external mixer applications. In this popular spectrum analysis scenario, the DPL Series provides external diplexer functionality when integrated capabilities are not available in the destination spectrum analyzer (e.g., Keysight's PSA E4440A).

OML
omlinc.com

Product Highlights



Capacitors

Passive Plus offers a line of Hi-Q/Low ESR Capacitors available in 4 case sizes. These multilayer capacitors are ultra-reliable and can be used in demanding high RF current and voltage applications. Products available in surface mount or leaded configurations that are 100% RoHS compliant. These products are also available in a Non-magnetic termination.

Passive Plus
passiveplus.com

Wire System

Samtec recently expanded its line of Tiger Eye™ products with a .0315” pitch discrete wire system ideal for rugged applications where a highly reliable connection must be maintained. The micro pitch system increases contact density for greater space savings and features Samtec’s Tiger Eye™ contacts, which are designed for high reliability and high mating cycles.

Samtec
samtec.com

EMI Receiver

Keysight Technologies announced that its N9038A MXE EMI receiver is now available with a frequency range of 20 Hz to 3.6 GHz. The affordable pricing of this new option addresses the needs of commercial manufacturers that perform compliance testing in their own facilities and do not require measurements at higher frequencies.

Keysight Technologies
keysight.com

Product Highlights

LNAs

MITEQ's TTA Series of high performance Broadband Low Noise Amplifiers were specifically developed for Electromagnetic [EMC] compliance testing. Our latest addition to the TTA series is our new battery operated version which allows for up 10 hours of continuous use on a single charge. This battery option can be purchased as a separate add on [TTABP] if you already own a TTA or supplied internal in a single enclosure at the time of the order as a TTAB.

Miteq
miteq.com

Book Review

White Space Communication Technologies

Edited By: Nuno Borges Carvalho, Alessandro Cidronali, Roberto Gómez-Garcia

© Cambridge University Press 2015

ISBN 978-1-107-05591-9 (Hardback)

Want to learn more about Software Defined Radio? What about Doherty amplifiers? Cognitive Radio? White space technologies open the possibility of cooperating radios in sparsely populated frequency bands. *White Space Communication Technologies* clearly illustrates the paradigm shift taking place in future radio technologies development. The book starts by addressing regulatory issues in light of an interesting 100-year history that is presented from a multi-continent perspective. One of the principal premises is the opportunity offered by freeing up spectrum as a result of the migration of digital TV to UHF channels, freeing up VHF and lower UHF spectrum.

The book has a comprehensive and frankly fascinating chapter on *Reconfigurable RF front-ends for cognitive and software-defined radio.* Many emerging techniques are discussed, which includes packaging such as low temperature co-fired ceramics (LTCC). MIMO antenna systems, tunable filters and power amplifiers, MEMS and many other innovations are discussed.

Sampling theory and FPGA-based all-digital transmitters are also explained in a way that can be relatively easy to comprehend. Adaptable transceivers are discussed. Unique means to minimize interference are described.

The concepts presented in this book may appear to be constrained to a timeline. However, looking back, I'm sure there were many who thought TV broadcast as we knew it would last much longer than it actually did—about 70 years. Other "white space" spectrums will likely become available as new techniques emerge.

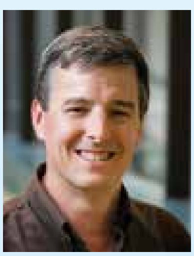
Many of the principles and techniques described in this book can and will be applied not only to "white space," but also to other portions of the spectrum: amateur, commercial, and military. The concept of white space does allow for innovative and clear thinking, much like starting with a blank sheet of paper! If you have access to this book, you will likely return to it on multiple occasions.

—Tom Perkins
Senior Technical Editor

2015 PLENARY SPEAKER

SOFT ASSEMBLIES OF RADIOS, SENSORS AND CIRCUITS FOR THE SKIN

- Dr. John Rogers
Swanlund Chair, Professor of Materials Science and Engineering, Professor of Chemistry
University of Illinois, Urbana-Champaign



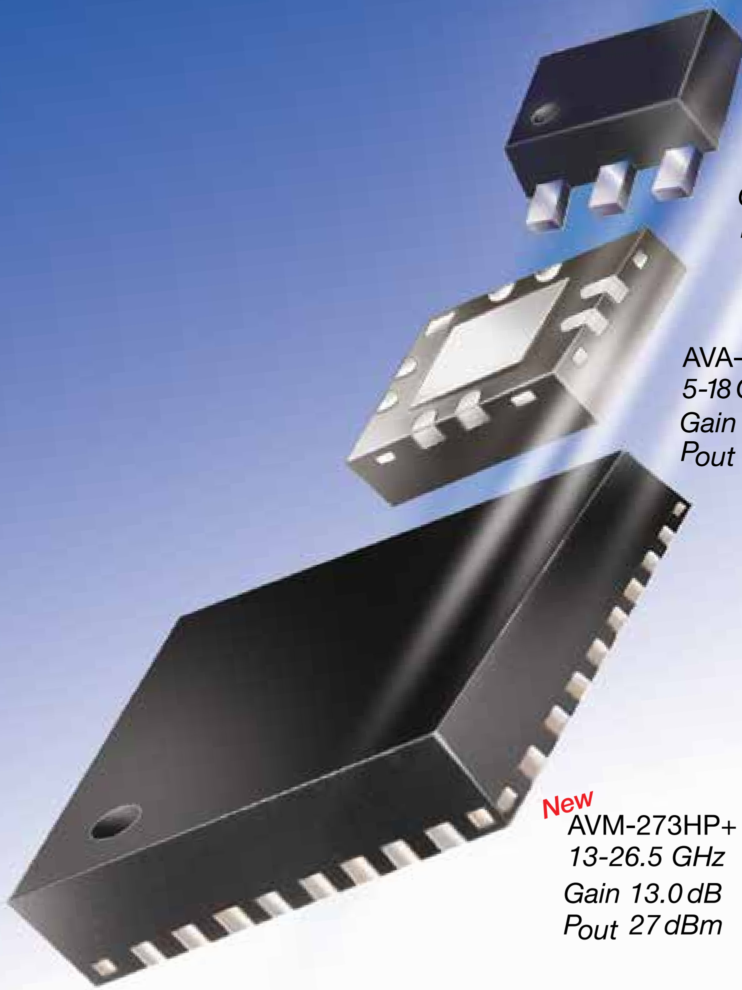
Professor John A. Rogers obtained BA and BS degrees in chemistry and in physics from the University of Texas, Austin, in 1989. From MIT, he received SM degrees in physics and in chemistry in 1992 and the PhD degree in physical chemistry in 1995. From 1995 to 1997, Rogers was a Junior Fellow in the Harvard University Society of Fellows. He joined Bell Laboratories as a Member of Technical Staff in the Condensed Matter Physics Research Department in 1997, and served as Director of this department from the end of 2000 to 2002.

He is currently Swanlund Chair Professor at the University of Illinois at Urbana/Champaign, with a primary appointment in the Department of Materials Science and Engineering, and joint appointments in several other departments, including Chemistry. He is Director of the Seitz Materials Research Laboratory.

Rogers' research includes fundamental and applied aspects of materials for unusual electronic and photonic devices, with an emphasis on bio-integrated and bio-inspired systems. He has published more than 450 papers and is inventor on over 80 patents, more than 50 of which are licensed or in active use. Rogers is a Fellow of the IEEE, APS, MRS and the AAAS, and he is a member of the National Academy of Engineering and the American Academy of Arts and Sciences. His research has been recognized with many awards, including a MacArthur Fellowship in 2009, the Lemelson-MIT Prize in 2011, the MRS Mid-Career Researcher Award and the Robert Henry Thurston Award (American Society of Mechanical Engineers) in 2013, and the 2013 Smithsonian Award for Ingenuity in the Physical Sciences.

50 MHz to 26.5 GHz

THREE AMPLIFIERS COVER IT ALL!



Mini-Circuits' New AVM-273HP+ wideband, 13 dB gain, unconditionally stable microwave amplifier supports applications from 13 to 26.5 GHz with 0.5W power handling! Gain flatness of ±1.0 dB and 58 dB isolation make this tiny unit an outstanding buffer amplifier in P2P radios, military EW and radar, DBS, VSAT, and more! Its integrated application circuit provides reverse voltage protection, voltage sequencing, and current stabilization, all in one tiny package!

The AVA-183A+ delivers 14 dB Gain with excellent gain flatness (±1.0 dB) from 5 to 18 GHz, 38 dB isolation, and 19 dBm power handling. It is unconditionally stable and an ideal LO driver amplifier. Internal DC blocks, bias tee, and microwave coupling capacitor simplify external circuits, minimizing your design time.

The PHA-1+ + uses E-PHEMT technology to offer ultra-high dynamic range, low noise, and excellent IP3 performance, making it ideal for LTE and TD-SCDMA. Good input and output return loss across almost 7 octaves extend its use to CATV, wireless LANs, and base station infrastructure.

We've got you covered! Visit minicircuits.com for full specs, performance curves, and free data! These models are in stock and ready to ship today!

RoHS compliant

FREE X-Parameters-Based
Non-Linear Simulation Models for ADS

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http://www.modelithics.com/mvp/Mini-Circuits.asp

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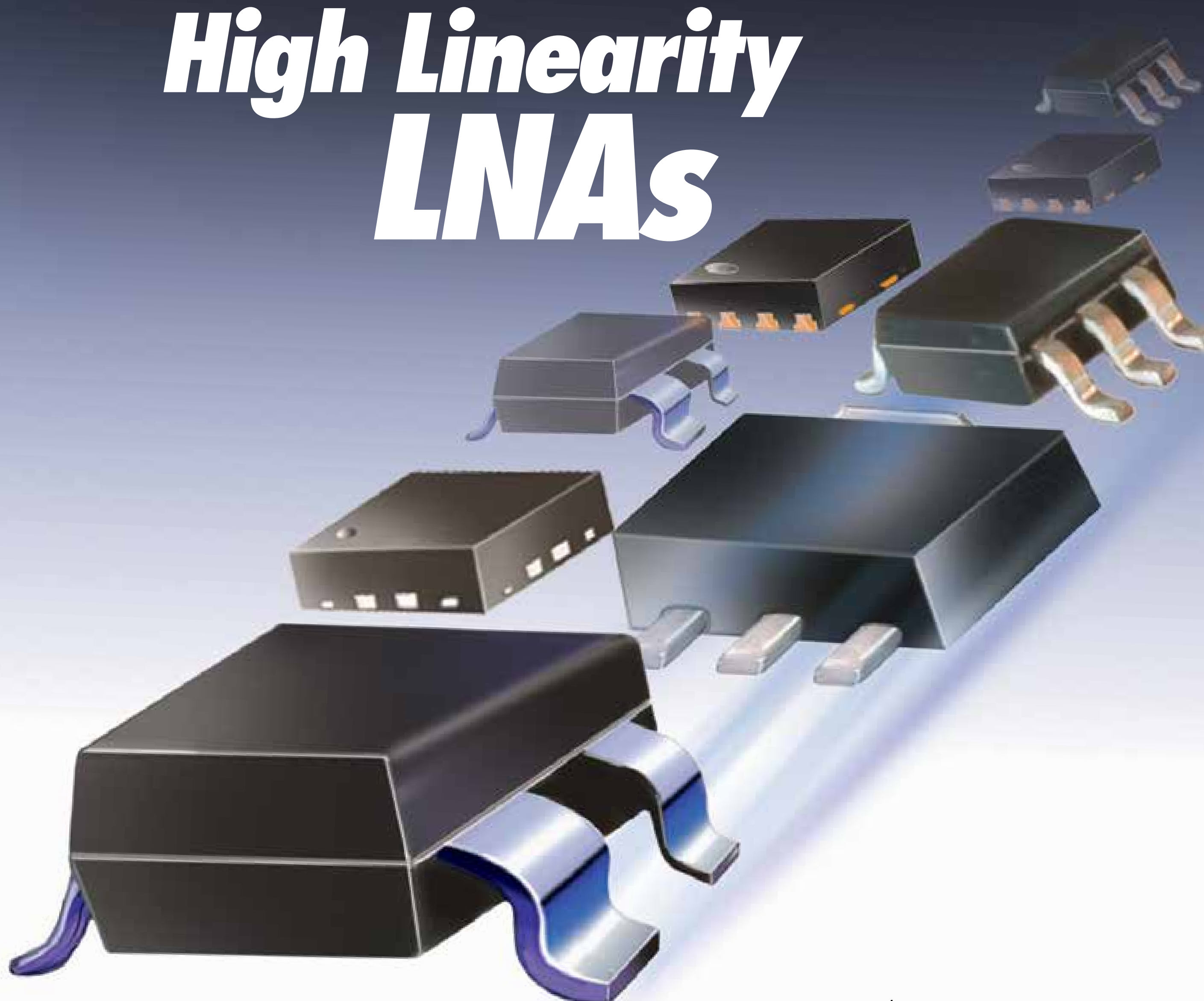
High Linearity LNAs



NF as low as 0.5 dB • IP3 up to 43 dBm • DC current 20 mA and up

from $1.49 ea. (qty. 20)

Pick your parameters, and meet your needs at Mini-Circuits! With over 20 low noise/high linearity amplifier models to choose from, you'll likely find the output power, gain, DC current, and broad bandwidths required to upgrade almost any 3-to-5V circuit—from cellular, ISM, and PMR to wireless LANs, military communications, instrumentation, satellite links, and P2P—and all at prices that preserve your bottom line!

Our catalog models are in stock and ready to ship, so why wait? Go to minicircuits.com for all the details, from data sheets, performance curves, and S-parameters to material declarations, technical notes, and small-quantity reels—as few as 20 pieces, with full leaders and trailers. Place an order today, and see what these tiny, high-performance amplifiers can do for your application, as soon as tomorrow!

RoHS compliant

Model	Freq. (MHz)	Gain (dB)	NF (dB)	IP3 (dBm)	P_{out} (dBm)	Current (mA)	Price $ (qty. 20)
PMA2-162LN+	700-1600	22.7	**0.5**	**30**	20	55	2.87
PMA-5452+	50-6000	14.0	**0.7**	**34**	18	40	1.49
PSA4-5043+	50-4000	18.4	**0.75**	**34**	19	33 (3V) 58 (5V)	2.50
PMA-5455+	50-6000	14.0	**0.8**	**33**	19	40	1.49
PMA-5451+	50-6000	13.7	**0.8**	**31**	17	30	1.49
PMA2-252LN+	1500-2500	15-19	**0.8**	**30**	18	25-55 (3V) 37-80 (4V)	2.87
PMA-545G3+	700-1000	31.3	**0.9**	**33**	22	158	4.95
PMA-5454+	50-6000	13.5	**0.9**	**28**	15	20	1.49

Model	Freq. (MHz)	Gain (dB)	NF (dB)	IP3 (dBm)	P_{out} (dBm)	Current (mA)	Price $ (qty. 20)
PGA-103+	50-4000	11.0	**0.9**	**43**	22	60 (3V) 97 (5V)	1.99
PMA-5453+	50-6000	14.3	**0.7**	**37**	20	60	1.49
PSA-5453+	50-4000	14.7	**1.0**	**37**	19	60	1.49
PMA-5456+	50-6000	14.4	**0.8**	**36**	22	60	1.49
PMA-545+	50-6000	14.2	**0.8**	**36**	20	80	1.49
PSA-545+	50-4000	14.9	**1.0**	**36**	20	80	1.49
PMA-545G1+	400-2200	31.3	**1.0**	**34**	22	158	4.95
PMA-545G2+	1100-1600	30.4	**1.0**	**34**	22	158	4.95
PSA-5455+	50-4000	14.4	**1.0**	**32**	19	40	1.49

Mini-Circuits®

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