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October 2011

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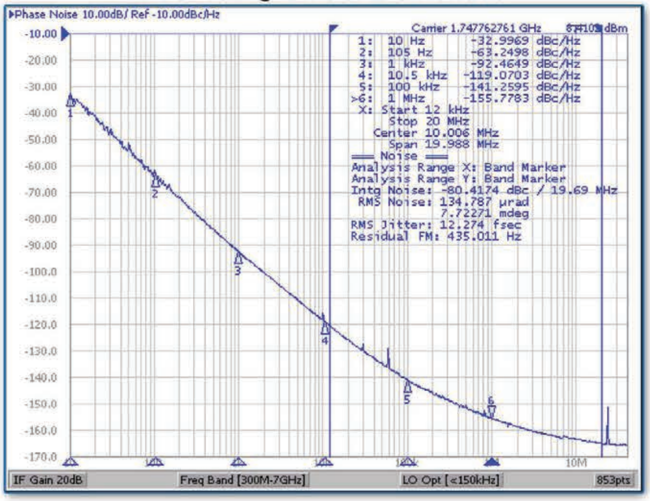

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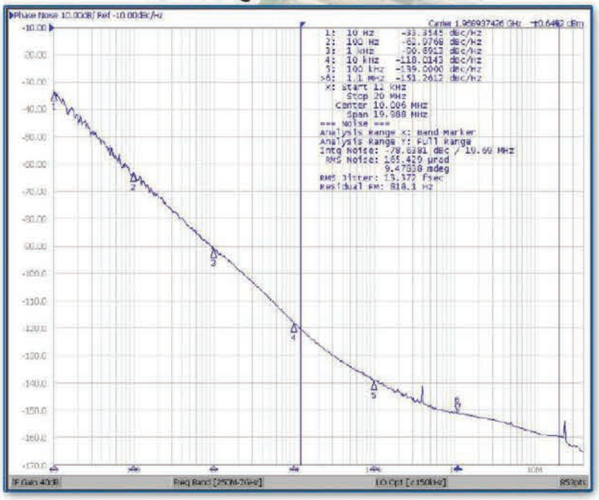

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FEATURES

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The Quest for a Rugged Transistor
White Paper, Freescale and Richardson

Executive Interviews

Jason Breitbarth, President, CTO and Founder of **Holzworth Instrumentation**, discusses the company's history, high performance products and outlook on the instrumentation market.

David Moore, Director of Business Development for the Defense/Aerospace Business Unit at **Avnet Electronics Marketing,** talks about the company's global distribution operation, its design and supply chain services, and shifts in the defense market.

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6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	1	2	3

November 2–4: IME 2011 November 2-4 China — **China Microwave and Antenna Conference & Exhibition** Shanghai, China

November 7–9: **COMCAS 2011 International IEEE Conference on Microwaves, Communications, Antennas and Electronic Systems** Tel Aviv, Israel

November 7–10: MILCOM 2011 Networks... Attaining the Value — Baltimore, MD

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OCTOBER

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FEBRUARY

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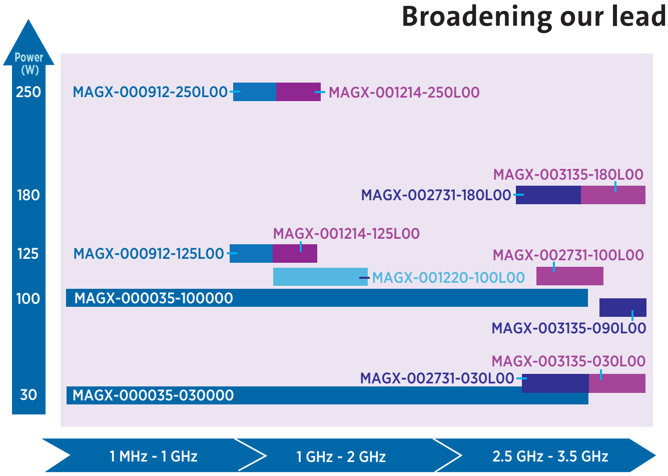

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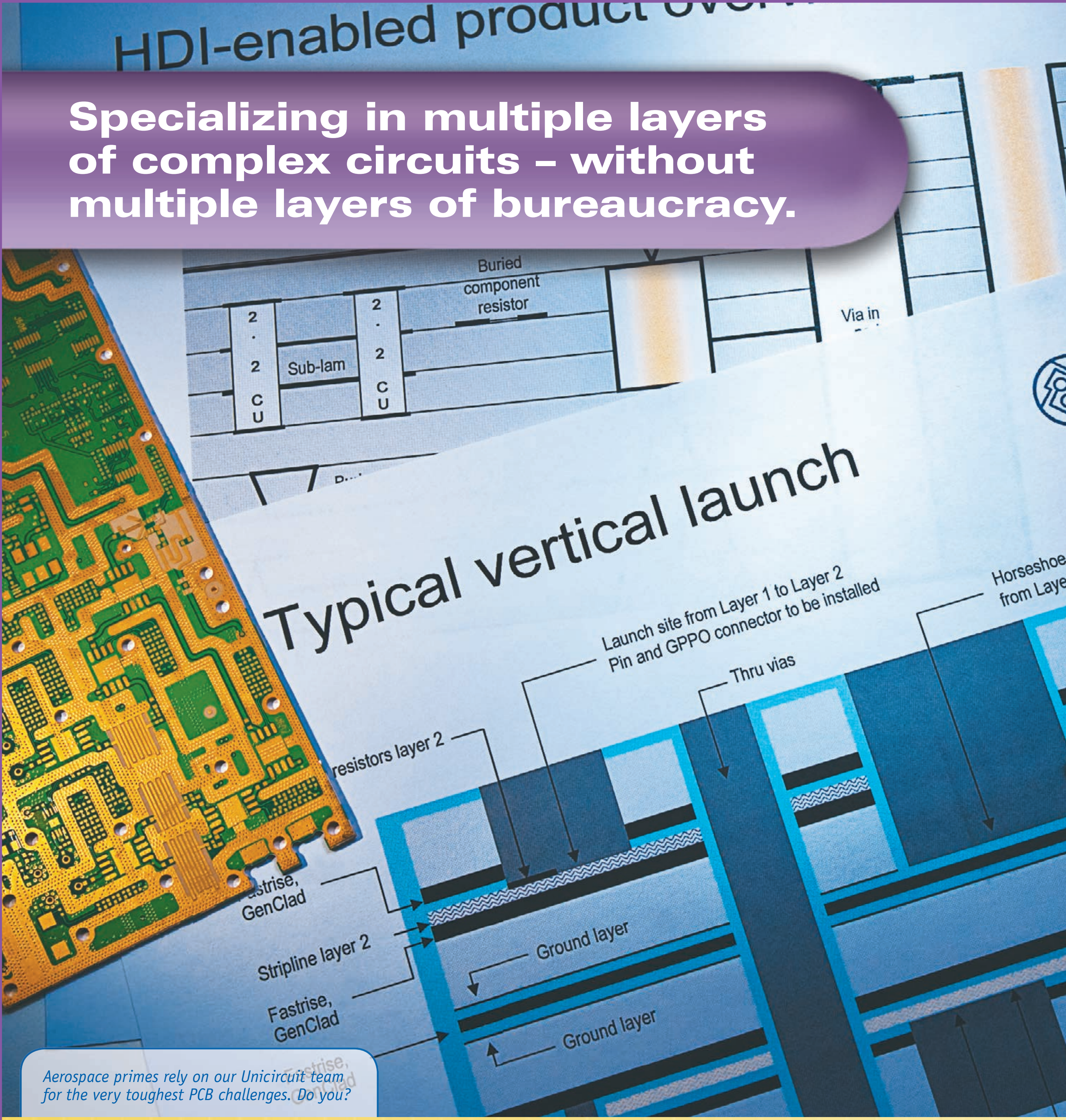

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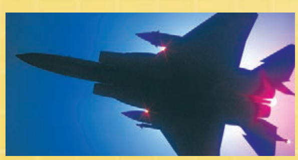

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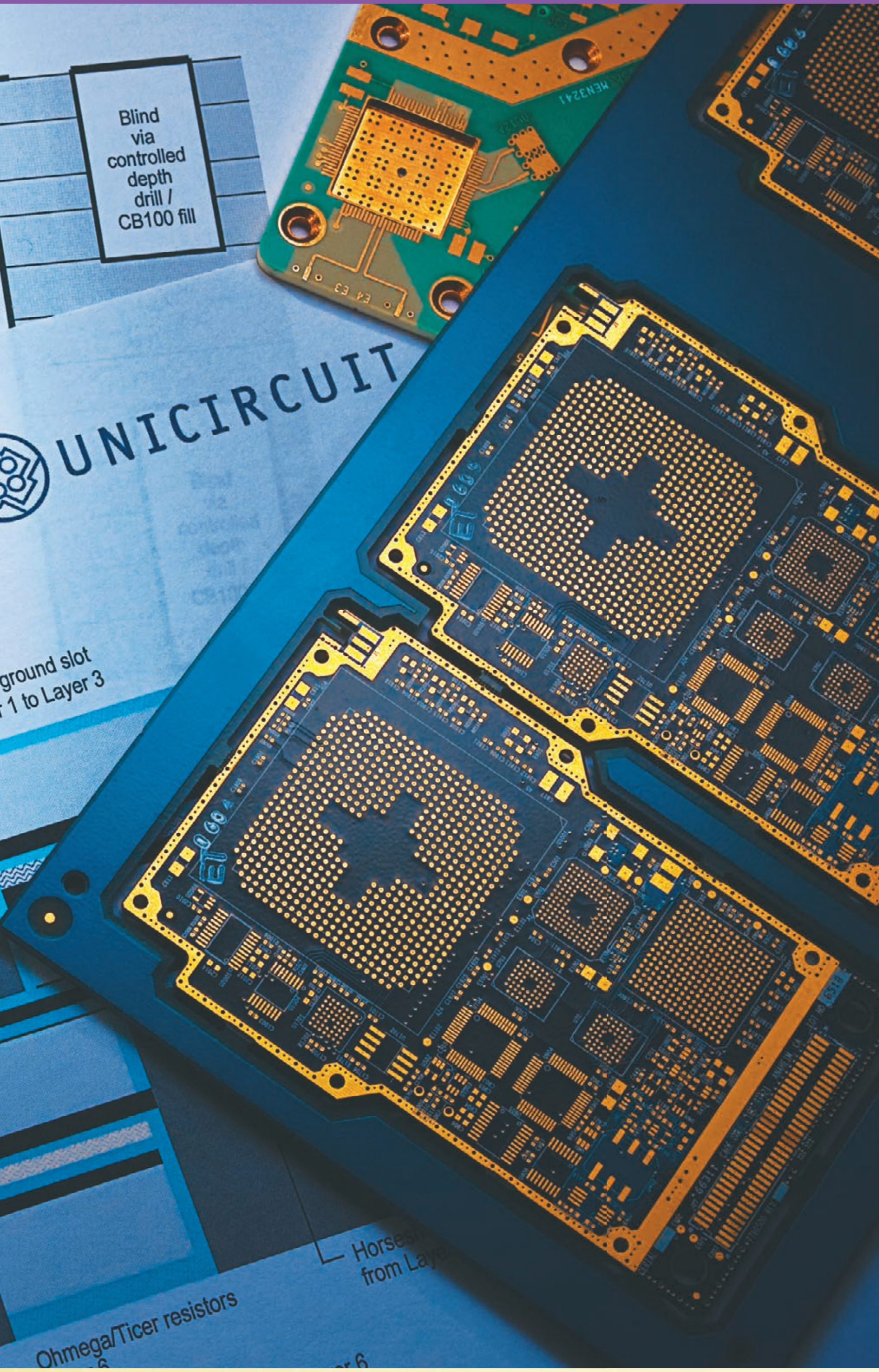

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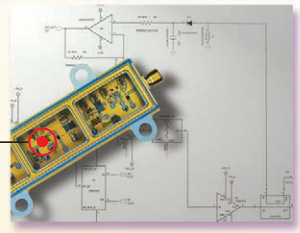

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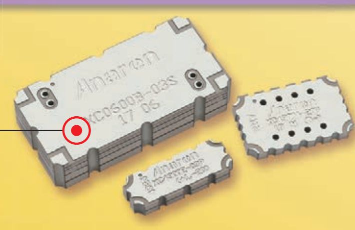

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The Defense/Security Sector Is Developing Products James Bond Would be Proud to Use

"BOND, JAMES BOND."

Ever since Ian Fleming's famous agent 007 uttered those words in 1962's "Dr. No," moviegoers have admired this uber-cool member of Her Majesty's Secret Service for his steely approach to villains, beautiful women and high tech gadgets, all while enjoying a martini – shaken not stirred, of course.

Central to the success of any Bond mission is Q and his team at Q Branch (the fictional R&D division of the British Secret Service), responsible for the latest covert devices and weaponry. While the devices not yet ready for the field sometimes provided comic relief with their disastrous performance during Q's lab demo, those that made it into action were likely to be responsible for saving 007's life, helping him successfully complete the mission and ensure that Bond gets the girl. Since "Dr. No," five decades ago, much of what was science fiction has now become science fact.

BOND-ISSUED COTS

A pertinent question is: Did Q's gadgets inspire engineers developing real products for military and intelligence agencies or were the movie gadgets inspired by real life? The members of Q's team were certainly early adopters of COTS components for the spy trade – the Aston Martin DB5, the Walther PPK handgun, the Omega Seamaster or Rolex watch (depending on the highest bidder for product placement).

In "Tomorrow Never Dies," Ericsson designed a concept phone with a variety of unique features, including a 20,000 V stun gun for disabling foes, a fingerprint scanner/analyzer/transmitter for opening fingerprint-ID locks, a detachable antenna lock pick, which when inserted into a keyhole could open the lock by hitting a key on the phone. And who could forget Bond's flip-open remote control for operating his BMW 750iL? The car had a directional steering pad, LCD monitor for the front and rear view and controls to fire a rocket. Much of the phone's style, including its flip-open design, was incorporated into Ericsson's R380 smartphone a few years later. The R380 combined a fully functional mobile phone, PDA-like tools and WAP services.

007's celluloid image may have glamorized the role of secret agents and the gadgets they employ, but in the 21st century there are real threats to be faced and vital intelligence to be gathered, and state-of-the-art RF and microwave technology is making a significant contri-

DAVID VYE, RICHARD MUMFORD AND PATRICK HINDLE
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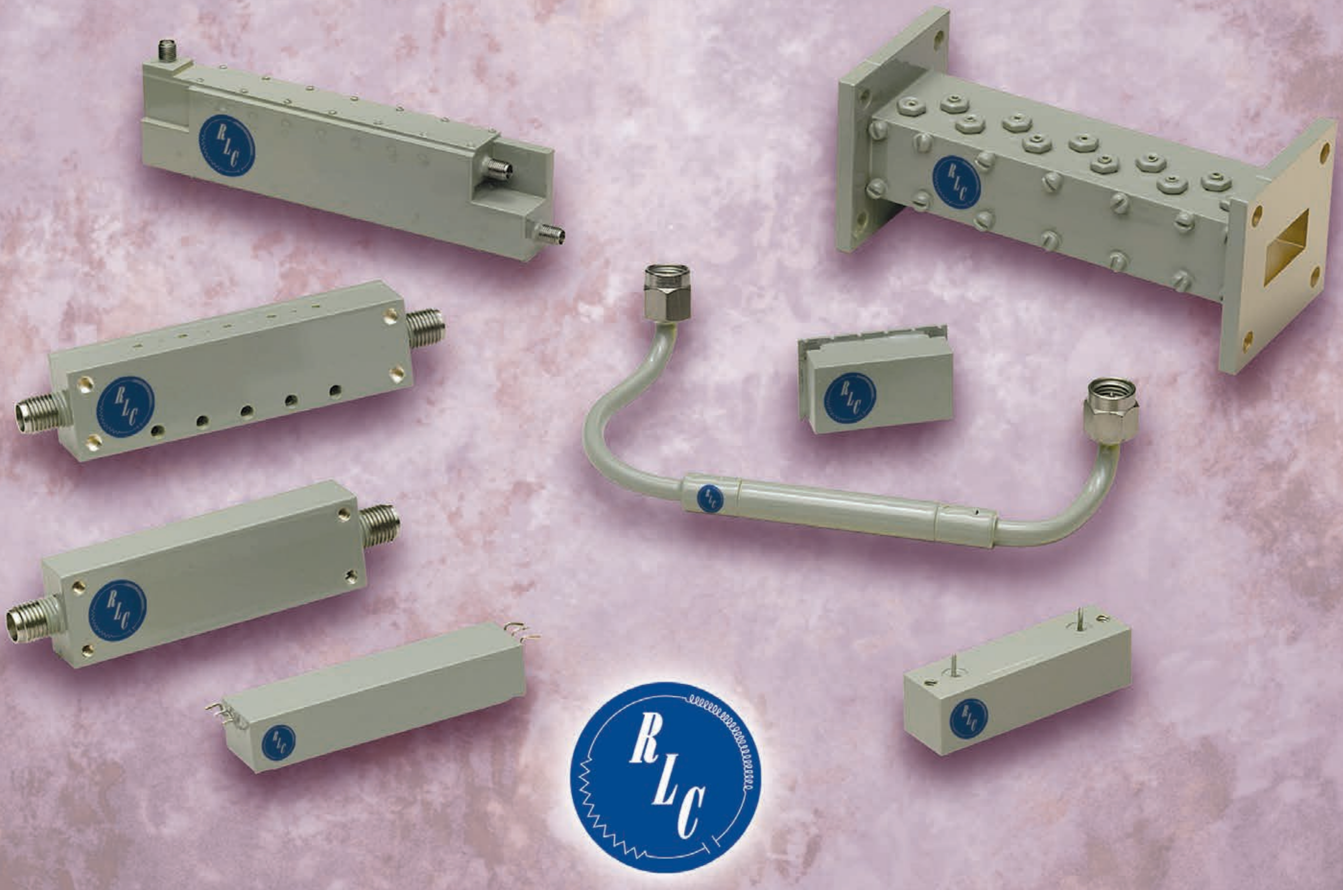

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bution to the cause. So what is the real world producing that is suitable for the next Bond adventure?

LIVE AND LET DRIVE

What is James Bond without his signature, gadget laden Aston Martin or BMW? Several car makers, such as Audi and Ford, have announced plans to incorporate WiFi into their vehicles. This opens up a number of possibilities, such as access to mission information, secret databases, hacking into the enemy's computers and utilizing special apps. Now Bond can access overlay maps to Google Earth and see hidden facilities or other land features while driving during a shoot-out and utilizing the local geography to his advantage.

With today's remote sensing technologies, the flip-open remote control for operating his BMW 750iL is no longer needed as the car can operate autonomously. It can drive right up to James Bond and safely take him wherever he wants as he evades enemy gunfire. Over recent years, the Defense Advanced Research Projects Agency (DARPA) Challenge has shown that a vehicle can operate and navigate around roads using various radar and video sensors. The car can sense and detect objects, their speed and direction, all while keeping the vehicle safely on the road (see ***Figure 1***). These sensors can be used for range finding and can activate offensive or defensive weapons as needed. The latest DARPA Challenge includes ideas such as a removable door that doubles as a defensible fighting position when away from the vehicle, a tortoise shell-inspired rollover recovery frame, or a modular exoframe enabling multiple configurations and additional storage (for other gadgets, of course).

As well as employing radar sensors to navigate the vehicle, how about using them to defend against missiles and Rocket Propelled Grenade (RPG) attacks? As such weaponry has become popular with terrorists for attacking ground vehicles, several defense companies have developed RPG defeat or missile defense systems. The first fielded system – known as Trophy – was developed by Rafael Advanced Defense Systems and Israel Aircraft Industries' Elta Group. Trophy is an active system that intercepts and destroys incoming missiles and rockets with a shotgun-like blast using radar sensors to track the incoming missiles.

The Trophy system includes the Elta EL/M-2133 F/G-Band fire-control radar with four flat-panel antennas mounted on the vehicle and has a 360° field of view. A computer uses the signal from the incoming weapon and calculates an approach vector. The system then calculates the optimal time and angle to fire the neutralizers. The launchers fire the neutralizing agents, which are usually small metal pellets (like buckshot).

Another system that is a non-lethal RPG defeat design is the RPGNet from QinetiQ US that uses a net shaped trap made of super-high strength ballistic fiber, developed under a joint Office of Naval Research (ONR)/DARPA program. The net intercepts the flight trajectory at a safe distance from the vehicle and defeats the RPG by crushing its nose, rendering the fuse inoperable. This action stops the high order blast effect by preventing the formation of the shaped charge plasma jet. The system is in development by Foster Miller under an ONR program.

▲ *Fig. 1 North Carolina State DARPA Challenge 2007 autonomous vehicle (courtesy of NC State University).*

A third option is the ShotScreen™ RPG Defeat System from General Dynamics, which is an active protection system that can be mounted on a variety of new or retrofitted vehicles, including helicopters. The system releases a wave of small diameter, low velocity non-lethal pellets from several non-slewing locations to defeat multiple anti-tank type RPGs. It provides 360° horizontal protection with variable inclination coverage and an option for full hemispherical coverage. Raytheon is also working on active protection systems.

A VIEW TO A KILL

With today's world of asymmetric warfare and the need for effective counter-insurgent strategies, the roles of the warfighter and the intelligence officer are becoming interchangeable. It is conceivable that Bond and the British armed services would be working from the same bag of tricks. The US Army plans to provide troops in Afghanistan with hand-held sensors that can peer through walls, detect buried explosives and spot hiding enemy fighters.

These devices use low power ultra-wideband RF to produce images of concealed objects. The Army's Expeditionary Warrior Experiments program will also use these small RF imagers to help find buried roadside bombs, like IEDs. The devices can produce clear images of objects by penetrating any non-metallic structure, including culverst, walls, glass, floors, concrete and the earth up to 10 feet deep.

TiaLinx of Newport Beach, CA, offers the sensors in three different models. The Eagle5 scanners – an M model and a P model – operate at 5 GHz, giving them substantial penetrating capability, even at extremely low power. The M model is designed to detect motion, even a heartbeat or breathing. The company says the device can detect people or animals farther than 20 feet behind an eight-inch thick concrete slab.[1]

The P model is designed to penetrate the ground and can find tunnels, people in tunnels and buried objects at depths greater than 10 feet, according to the company. Both of the Eagle5 models can also be used as motion sensors for stand-off surveillance of

buildings, trails and other areas. The Eagle60 operates in the V-Band to produce sharper images. But the atmospheric attenuation at 60 GHz means this model cannot penetrate as deeply.

Because these devices transmit ultrawideband (UWB) signals, the developers lay claim to being able to obtain a more complete view of hidden objects. Whereas, most ground-penetrating radars that use a narrow band of signals offer a more limited view and are more prone to producing false readings. UWB signals are also less affected by environmental factors such as rain, snow and fog that degrade the performance of many radars. Also, these sensors consume much less power, a fraction of what is used by a cell phone.

About twelve inches long, 8 inches wide and 3 inches thick and weighing three and a half pounds, the scanners look like a cross between a video game controller and an oversized cell phone. The higher frequency version is roughly the same size but weighs about 6 pounds. The devices run on batteries and can operate for about four hours between recharges.

▲ *Fig. 2 TiaLinx mini UAV, including radar sensors for-through-the-wall imaging (photo courtesy of TiaLinx).*

In each case, the sensors have an antenna that sends radio frequency pulses toward a target and a receiver that detects the pulses that bounce back. A signal processor built into the device analyzes the returned pulses, and a complex algorithm turns them into an image of the reflecting object, which is displayed on a small screen. The images can also be transmitted wirelessly from devices that have been mounted on ground-crawling robots or small unmanned aerial vehicles.

And, when it comes to UAVs, TiaLinx offers a mini-UAV that is suited for long standoff surveillance missions. The Phoenix40-ATM is a lightweight and agile mini-UAV with programmability to fly to or land at multiple waypoints and has been integrated with the company's fine beam UWB, multi-GHz RF sensor array (see ***Figure 2***). The entire system is able to detect motion, as well as breathing, inside a compound in order to detect motionless live objects. Perhaps a remote lie detector could be coming next, utilizing heartbeat monitoring.

FOR YOUR EYES ONLY

At the Satellite 2011 Conference and Exposition in Washington, DC, Norsat International partnered with ConcealFab Corp. of Colorado Springs, CO, to unveil a 1.8 m transportable satellite technology that is capable of hiding in plain sight thanks to an RF-transparent shelter designed to help sensitive military communication equipment escape detection.

This radio frequency transparent antenna enclosure is designed to protect and conceal sensitive communications equipment from detection. Multiple rugged, transportable satellite terminals are concealed within a UV-protected, maintenance-free enclosure. The entire facility is designed to be up and running in minutes with simple setup and alignment features for broadband connectivity on prolonged missions.

BOND TIDBITS

Homing devices make frequent appearances in Bond movies, including two homing beacons in "Goldfinger" in 1964. The larger one is used by Bond to track the villain, Auric Goldfinger, to his base. The second is small enough to be hidden in a secret compartment in the heel of Bond's shoe, allowing MI6 to track 007. In 1965's "Thunderball," homing devices get even smaller, this time taking the form

of a pill that emits a signal detected only by a certain receiver.

In the category of related technologies: High-powered electromagnetics of questionable functionality are a common Bond theme. In "Diamonds are Forever" in 1971, Q creates a ring with an electromagnetic RPM controller that, when used, ensures a jackpot at the slot machines every time. In 1973's "Live and Let Die," Q conjures up an electromagnetic watch that creates a magnetic field strong enough to deflect a bullet.

Prior to mobile phones, Bond utilized various odd communication devices. In "Live and Let Die," the communicator is a radio hidden inside a clothing brush with a key that allows it to transmit messages in Morse code. In the same movie, Baron Samedi used a Flute Communicator as a direct radio transmission communicator to Dr. Kanaga.

THE MAN WITH THE GOLDEN PHONE

As the cell phone is now a computer equipped with GPS, gyroscopes, Bluetooth, Internet access and more – using augmented reality apps can take Bond to the next level. New smartphone apps allow range-finding and location functions to track objects or subjects, identify them and overlay additional layers of information. Spyglass provides a detailed heads-up-display over anything you are seeing through your phone.[2] The app allows a person to assign a primary target, constantly updating its proximity. It also enables tracking of the sun, moon and some star positions. The app can also be used as a rangefinder and an inclinometer, perfect for when a gang of machine-gun toting thugs on skis are chasing you down a mountain in the Alps.

With the right app, Q could provide Bond with a distinctly 007 advantage. Imagine Bond pointing his phone at a building for an overlay of the room layout with which to plan his covert break-in and escape. Another smart app could use facial recognition to get immediate identification of suspected spies or use eavesdropping capabilities for voice recognition. As UWB radar units become small enough, Q will no doubt embed them into the phone for seeing through walls, scanning people for weapons and monitoring their vital signs for lie detection. Augmented reality apps also will identify the nearest subway or safe house to assist Bond in his getaway.

THE WEB IS NOT ENOUGH

What self-respecting secret agent does not love a suitcase filled with enough equipment to set up an autonomous, metropolitan WiFi network. Such technology is under development by The New America Foundation, a nonpartisan research group. This portable, WiFi-based network can be carried into contested regions and will allow our hero (or other dissident groups) to set up networks independent of a government-controlled network.

According to reports, The Obama administration is leading a global effort to deploy these Internet and mobile phone systems that dissidents can use to undermine repressive governments that seek to silence them by censoring or shutting down telecommunications networks.[3] The group's Network Suitcase project will rely on a version of mesh network technology, which can enable devices like cell phones or personal computers to create a wireless web without a centralized hub. Data can hop directly between the modified wireless devices with each device acting as a mini cell tower and phone to bypass the official network.

The suitcase includes small wireless antennas, which could increase the area of coverage; a laptop to administer the system; thumb drives and CDs to spread the software to more devices and encrypt the communications; and other components like Ethernet cables. With this WiFi network in a suitcase, James Bond can complete his missions to overthrow governments on the brink.

THE LIVING DAYWEAR

James Bond is always smartly dressed, attracting the ladies with his charm and immaculate attire. Sporting a tuxedo, 007 is no stranger to the elaborate


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dinner party, where he can keep an eye on his quarry while scouting the security systems of the facility he will break into after the canapés have been devoured. Sean Connery wore outfits by Anthony Sinclair in the early Bond years in movies, such as "Dr. No" and "You Only Live Twice." During the Moore years, the suits designed by Cyril Castle were intended to update Bond's look with contemporary 1970's styles. More recently, Pierce Brosnan and Daniel Craig have worn Brioni suits. Nice threads, but today's high tech suit is also a personal area network ready for the latest in miniaturized electronics interwoven into the fabric.

Wearable Antenna Technologies makes the Tactical Vest Antenna System (TVAS), a concealable antenna designed for military and covert applications.[4] The radiating elements slide smoothly over the SAPI plates inside the plate carrier, consequently placing the antenna out of the enemy's sight, and out of the radio operator's way. The antenna system consists of two antenna inserts, two interconnecting cables, and a cable for radio connection.

The TVAS also contains a quick-release mechanism, which allows the operator to disconnect the system in emergency situations. The TVAS has frequency coverage of 30 to 512 MHz in order to be compatible with Tactical Handheld Radios (THHR) as well as other radios with a 50 Ω impedance and maximum power output of 10 W. This includes Motorola radios and other amateur radios. However, the TVAS was designed to fit inside tactical vests by conforming to the ESAPI, and XSAPI inserts. Perhaps they can add some Kevlar and make it bullet proof too.

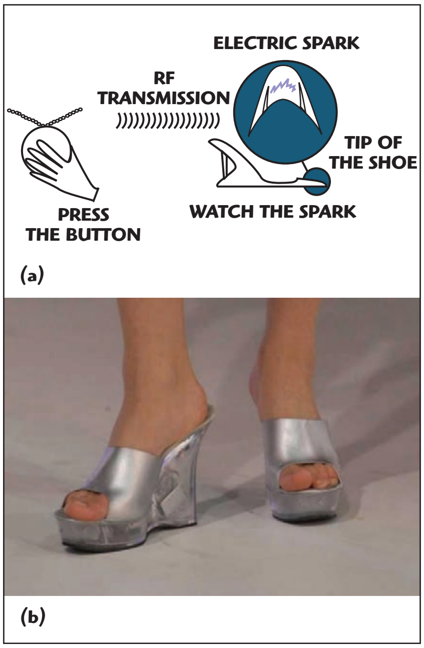
Pharad also manufactures wearable/worn antennas that are antenna solutions for soldiers engaged in urban and combat missions in addition to security/intelligence personnel operating covertly.[5] The body wearable antennas are fabricated using a thin flexible material that conforms to the exterior of the body and outer garments. Communications link performance is maintained without hindering the user's vision or movement.

Different mounting configurations and spatially diverse wearable antenna systems that further enhance link performance are available. Standard connector options allow these wearable antennas to easily connect to most radios. The applications include HF/VHF/UHF communications, GPS, military radio systems, UWB, WLAN, TETRA/Hydra and more.

SOMETHING FOR THE LADY SPIES – TASER PUMPS

As a ladies' man, Bond frequently hooks up with female spies as allies or adversaries, who often employ their own feminine gadgetry. However, times have moved on since Rosa Klebb utilized a venom-laced blade hidden in her shoe to attack Bond in "From Russia with Love" in 1963. Today's self-respecting female secret agent will be sporting the Electric Cinderella Shoe, which is ideal for neutralizing any human threat. The innocent-looking taser pump is capable of delivering 100,000 V jolt when activated by a wireless necklace (see ***Figure 3***).[6]

The stun gun has a one-time use as the wearer has to smash the glass tip to enable it. The stun gun is activated by a switch in the matching earring or necklace, which wirelessly activates the stun gun. The crystal tip of the shoe glows, warning the attacker to back off. Once the crystal



▲ *Fig. 3 Electric Cinderella Shoe System diagram (a) and photo (b) (photo courtesy of gizmag.com).*

tip is smashed (against the shin of the attacker for instance) 100,000 V of electricity leaves him/her helplessly immobile. The weapon is powered by a 9 V battery hidden in the heel. It was invented by Simona Brusa, who views them as an empowering device that transforms the wearer into a semi-lethal weapon.

GOLDENEYE

Another of Bond's female adversaries, May Day, played by Grace Jones in "A View to a Kill," would no doubt be tempted by the stylish camera-equipped Eyez glasses that enable users to share point-of-view video with a stealth camera and allow easy sharing of video without complicated file transfer. The Ray-Ban-style shades capture an extra-wide 130° field of vision through a half-inch fisheye-like lens, which is masked as a grommet on the right side of the frame.[7] A 0.2 inch HD sensor captures images, and then a low power 1 GHz processor compresses the video. The footage is either saved into an onboard flash memory or transmitted from a 2.4 GHz WiFi/Bluetooth radio to a smartphone.

An app controls the camera remotely and acts as a host through which footage streams to Facebook, YouTube or the Eyez homepage. The setup gets power from a molded lithium-polymer battery in the frame's left arm and the glasses are only slightly heavier than regular glasses at 4 ounces. The resolution is 720p video with one-megapixel stills. It holds 16 GB (up to four hours of video) with up to three hours of battery life. As cellular radios continue to shrink and become more efficient over the coming years, Eyez will be able to connect, stream and share from anywhere without relying on a cell phone.

BACKPACKER

Somewhere in-between the electronics embedded suit and the suitcase is the trusty backpack – the perfect accessory for a spy on the go, especially one with X-ray vision. Cambridge Consultants, a UK product design and development firm that presented at this month's Defense and Security Forum at EuMW 2011, has introduced a see-through-wall radar sensing device, called the Prism 200c. By providing added mobility and covertness to surveillance, the Prism 200c can gain intelligence on the location and movement of any people that might be inside a particular room. It is a lightweight and inconspicuous device that fits covertly inside a backpack (see ***Figure 4***).[8]

This technology is already used by the military, security agencies and Special Forces throughout the world and employs sophisticated software to evaluate the position and movement of people in rooms and buildings, from

▲ *Fig. 4 Cambridge Consultants' through-the-wall radar sensor unit (photo courtesy of Cambridge Consultants).*

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Freq Range (Min) (MHz)	*Freq Range (Max) (MHz)*	*P_{OUT} (dBm)*	*EVM (%)*	*Gain (dB)*	*V_{CC} (V)*	*I_{CC} (mA)*	*Package*	*Part Number*
2400	2500	27.0	2.5	35.0	5.0	900	Laminate Module	RF5605
2400	2500	25.0	2.5	33.0	5.0	420	Laminate Module	RFFM4200
2400	2500	25.0	2.5	33.0	5.0	420	Laminate Module	RFFM4201
2400	2500	27.0	2.5	35.0	5.0	900	Laminate Module	RFFM4202

Note: Rated power measured at antenna port at front end module

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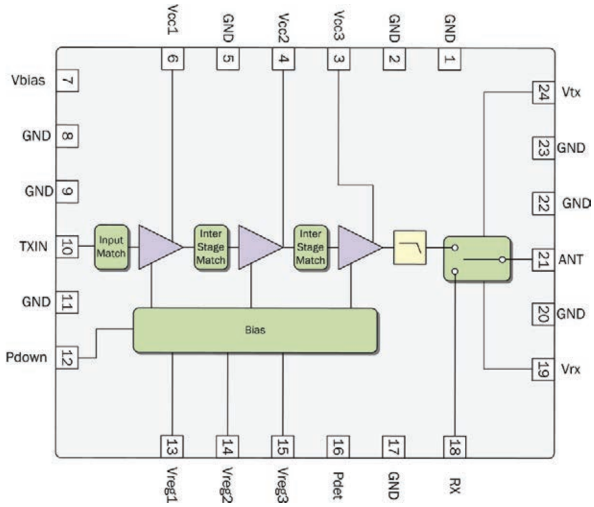
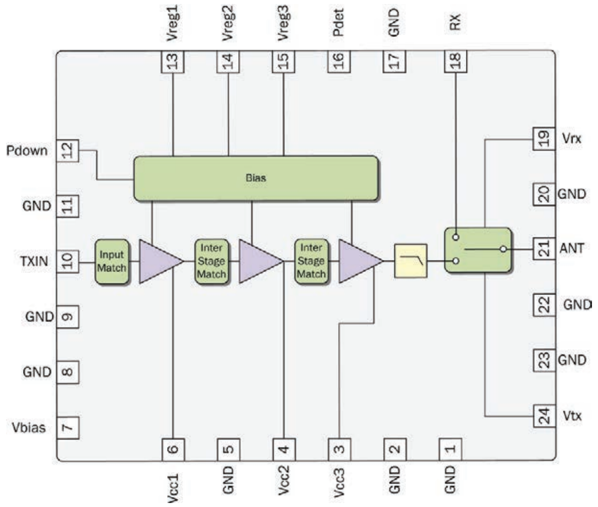
RF5605/RFFM4200 Diagram



RFFM4201/RFFM4202 Diagram



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the other side of the wall. The Prism 200c improves upon this capability, reducing the setup process. The operator can simply lean against a wall to either monitor or record the activity within a building, maintaining cover by operating it via a handheld laptop computer or similar personal device on site.

The Prism 200c is a battery-powered and highly portable radar device that employs smart radar signal processing to sense human movement and position – even in environments with a number of radar reflecting surfaces. It also provides meaningful data presentation, both on-device and remotely, including front, side and overhead, and 3D views.

FROM ROBOTS WITH LOVE

For other surveillance tasks, the iRobot 110 FirstLook is a small, light, throwable robot that provides quick situational awareness, persistent observation and investigates confined spaces without risk to the spy. FirstLook is for a range of infantry missions and special operations, including building clearing, raids and other close-in scenarios with enemies.

Four built-in cameras with configurable video compression provide high situational awareness, allowing observation points in front of, behind and on both sides of the robot. The robot also includes two-way audio communication using 2.4 or 5.8 GHz public frequencies or can use military radio bands. It provides two-way video and audio communications, if needed. Digital mesh networking capabilities allow multiple FirstLook robots to relay messages over greater distances, increasing Line of Sight and Non-Line of Sight capabilities. It uses a wrist-mounted, touchscreen Operator Control Unit (OCU). The battery-powered OCU includes a built-in radio.[9]

TOMORROW NEVER DIES

James Bond and his gadgets are fictional, but as this article demonstrates, the RF and microwave industry is at the forefront of technological development that offers the capability to address real threats, carry out covert surveillance and gather essential intelligence. Some devices may seem off-the-wall, literally in some cases. And others may seem spectacular. But sometimes fact can be stranger than fiction. What is true is that the defense/security sector will continue to be a source of innovation for our industry, which will continue to develop products that James Bond would be proud to have in his arsenal of advanced electronics. ■

Comment online – Use the new article comment feature on www.mwjournal.com to let us know gadgets you know of that we have may have missed in this review.

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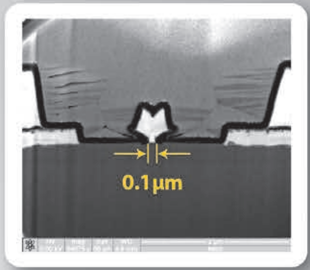
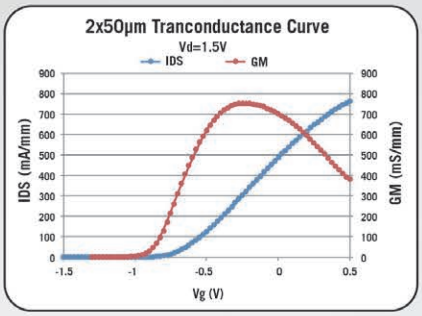
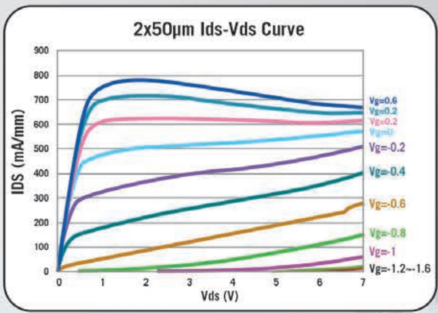


PP10-10, 11 Tranconductance Curve



PP10-10, 11 I-V Curves



Comparison of WIN's millimeter wave pHEMT technologies

	PP25-21	PP15-50/51	PP10-10/11
Gate length	0.25μm	0.15μm	0.1μm
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Max Drain Bias	8V	6V	4V
Max Id (Vg=0.5V)	490 mA/mm	630 mA/mm	760 mA/mm
IDSS (Vg=0V)	340 mA/mm	470 mA/mm	520 mA/mm
Max Gm	410 mS/mm	460 mS/mm	725 mS/mm
Vto	-1.15 V	-1.35 V	-0.95 V
Von (Diode turn on)	0.8 V	0.8 V	0.9 V
BVGD	20V (18V min)	16V (14V min)	9V (8V min)
f_T	65 GHz	90 GHz	130 GHz
f_{max}	190 GHz	185 GHz	180 GHz
Power Density (2x75μm)	1100 mW/mm @ 8V, 10GHz	870 mW/mm @ 6V, 29GHz	860 mW/mm @4V, 29GHz (2x50μm)

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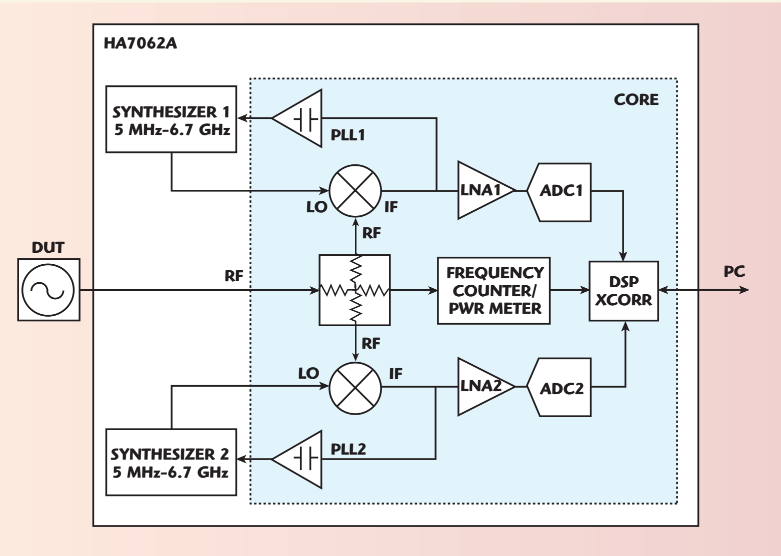
INTUITIVE PHASE NOISE ANALYZER

Holzworth Instrumentation has developed a fully automated phase noise analyzer with an integrated, cross correlation engine that responds to the most common issues of modern phase noise test systems. The HA7062A provides ease of use, fast measurement speeds, high reliability, high stability and pricing that makes an easy decision of implementation into the manufacturing environment.



▲ *Fig. 1 Simplified system block diagram.*

HARDWARE BASICS

The HA7062A design follows a basic Holzworth philosophy of creating unique, high performance products. The core engine of the HA7062A combines the best of traditional analog phase noise measurement front-ends (being virtually spur free) with the latest technology in cross correlation analysis. The digital analysis system leverages a proprietary DSP with a powerful cross correlation engine that achieves sub -165 $dBc/Hz^{1/2}$ measurements in less than 20 seconds.

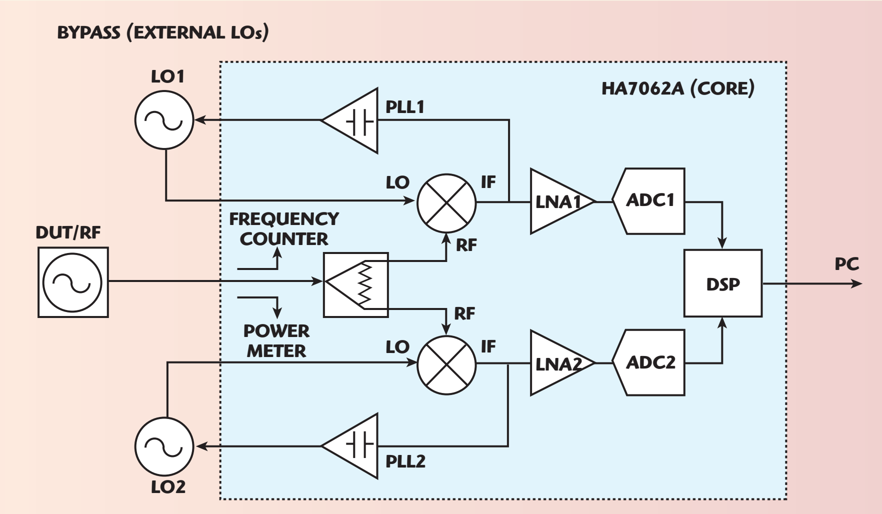
The unparalleled stability of the HA7062A is credited to a pair of Holzworth RF synthesizer modules. Holzworth RF synthesizers are known for industry-leading stability due to proprietary non-PLL designs. These high performing RF sources complement the core engine to provide an advanced (yet simple) phase noise analyzer (see ***Figure 1***). For high speed measurements that require lower noise floors, the synthesizers can be bypassed for direct access to the core cross correlation engine with user-supplied LOs (see ***Figure 2***).

The entire test system is enclosed in a 1U high, fan-less chassis. Developing the product on a fully integrated, low power platform has

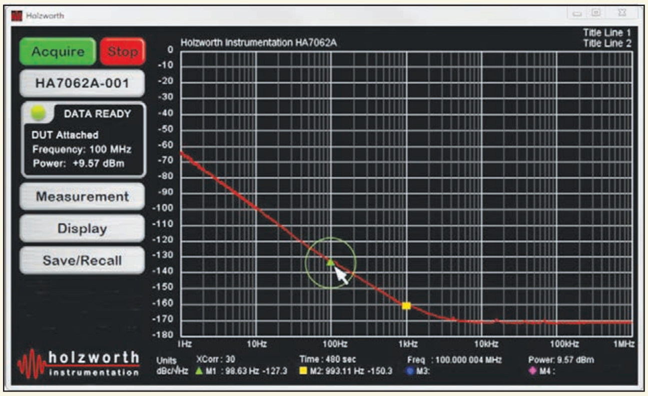
HOLZWORTH INSTRUMENTATION
Boulder, CO

eliminated fan-cooling requirements, which also eliminates non-valid measurement spurs caused by microphonics. The integrated chassis further eliminates test system noise ground loops. The 20 lb (9 kg) chassis is fully sealed, rugged and portable for field applications. It provides consistent results from location to location without the worry of recalibration support or repair.

The HA7062A is a virtual instrument from a command/control perspective. Holzworth eliminates proprietary motherboards, displays, etc. from all test instrument products as a means to reduce product costs while increasing reliability. The USB controlled, non-driver, Human Interface Device (HID) installation is "plug-and-play" with any standard PC that runs JAVA™.



▲ *Fig. 2 Internal LO bypass when using fixed LOs.*



▲ *Fig. 3 HA7062A virtual front panel.*

▲ *Fig. 4 HA7062A display settings window.*

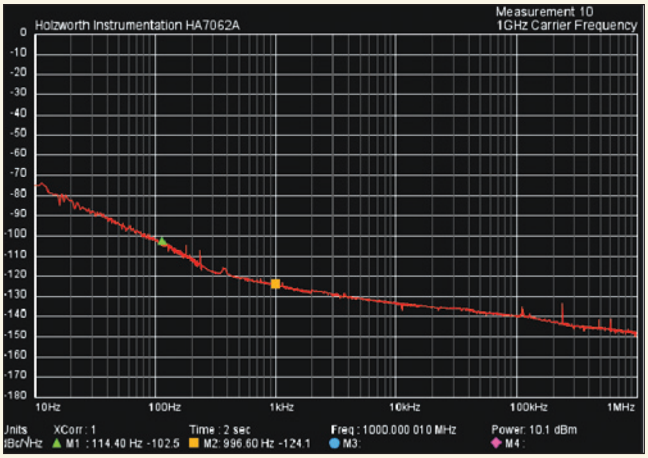
INTERFACE BASICS

Holzworth Instrumentation has been measuring the phase noise of 100 percent of its shipped products since the company was founded in 2004. We understand that the quality of the user interface is as important as the capabilities of the hardware. The interface GUI to the HA7062A was developed to be highly intuitive based on Holzworth's own lessons learned as well as feedback from industry users who regularly measure phase noise. The result is an application GUI that is easy to navigate and operate (see ***Figure 3***). There are simple indicators for DUT lock status and that the test results are valid.

Embedded diagnostic hardware provides the information the software needs to auto-detect, lock, calibrate, acquire data, and even warn if the data is "out of character" or if more correlations are required to achieve a valid measurement. Interface highlights include:

- DUT lock status indicator, power level & frequency
- Frequency offset control
- Drag and drop markers
- Overlay imported ASCII data
- Auto-scale graph, quick cursor zoom or manual set
- Data saves in both CSV (delimited) and PDF image file
- Touch-screen optimized GUI
- User-defined test limits with pass/fail flagging (see ***Figure 4***)

If the need for support were to arise, the HA7062A GUI maintains a detailed system log file that can be used for remote diagnostics. The user simply exports the file (ASCII format) and emails it to the factory. Real time trouble-shooting eliminates questions relative to the analyzer so that the user can be up and running as quickly as possible.



▲ *Fig. 5 Saved PDF image from HA7062A measurement.*

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TABLE I

PERFORMANCE PARAMETERS (TUNABLE LOs VS. EXTERNAL FIXED LOs)

Parameter	LO Configuration	
	Internal (Tunable Sources)[1]	Bypass (Fixed LO Inputs)[2]
DUT Tuning Range	5 MHz to 6.7 GHz	
Measurement Floor	< -165 dBc/Hz$^{1/2}$	<-175 dBc/Hz$^{1/2}$
Signal Acquisition Time	~100 ms	
Measurement Speed	1.4 s (1 kHz to 1 MHz) 18 s (1 Hz to 1 MHz)	
Measurement Offset	0.1 Hz to 1 MHz	

[1] Measurement Floor and Signal Acquisition Time are carrier frequency dependent.
[2] Measurement Floor and Signal Acquisition Time are dependent on performance of external LO. Example values based on 100 MHz OXCO pair (-175 dBc/Hz$^{1/2}$ at 100 kHz OS).

TABLE II

HA7062A SENSITIVITY LEVELS (dBc/Hz$^{1/2}$)

RF Input Frequency	Offset Frequency						
	1 Hz	10 Hz	100 Hz	1 kHz	10 kHz	100 kHz	1 MHz
10 MHz	-94	-125	-156	-160	-164	-165	-165
100 MHz	-74	-105	-136	-154	-164	-165	-165
1 GHz	-54	-85	-116	-133	-144	-149	-150
3 GHz	-44	-75	-106	-127	-135	-140	-141
6.7 GHz	-37	-68	-99	-121	-129	-134	-135

Sensitivity levels based on use of internal synthesizers. Improved levels are possible with use of external LOs.

PERFORMANCE BASICS

The HA7062A is a phase noise measurement workhorse that was designed to consistently provide clean, accurate absolute phase noise data. The standard unit has an operating range of 5 MHz to 6.7 GHz. The user can achieve improved phase noise floors with decreased measurement times by bypassing the internal synthesizers and directly accessing the cross correlation core with a matched pair of user supplied fixed LOs (see ***Table 1***).

The phase noise data shown in ***Figure 5*** is data collected from a Holzworth HSM6001A synthesizer set to a 1 GHz carrier frequency. The sensitivity of the system is dependent on both the carrier frequency of the DUT and the desired measurement offset (i.e. measurement time). ***Table 2*** demonstrates the typical sensitivity when using the internal (tunable) LO sources to make a measurement assuming an approximate 18 second measurement with an offset from 1 Hz to 1 MHz.

The HA7062A is designed to quickly and reliably measure absolute phase noise. There are other phase noise test systems available that offer some additional functionality, not to mention offering many more buttons, menus and sub-menus. The HA7062A gives users a highly reliable, dedicated phase noise analyzer at a very reasonable price. List price starting at $35,500 (US), Holzworth's HA7062A is a cost-effective phase noise analyzer that is an excellent fit for dedicated manufacturing phase noise test as well as advanced product development.

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359 rev S

PALLET PERSUASION

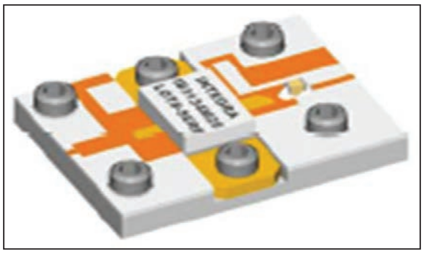
BRIAN D. BATTAGLIA *Integra Technologies, El Segundo, CA*

10 years ago…RF discrete transistors integrated into pallets

Integration: Traditional designs in the military defense sector often utilized bipolar technology in a pallet form for radar and avionics applications. A pallet or module is a 50 Ω matched design. Most pallets that were requested were single transistor pallets with the input and output matching stages incorporated on a PCB substrate as in ***Figure 1***. A pallet design offers an ease of manufacturability. The pallet manufacturer actually performs the physical mounting of the RF device to the metallic heatsink. This process assures a sufficient thermal transfer path with an adequate connection to RF ground. A sound thermal path to the heatsink eliminates overheating of the semiconductor material and ensures a long lifetime and reliable design. The pallet manufacturer also is responsible for the physical positioning of the device affecting RF performance with the x-axis determining phase performance and the y-axis affecting the impedance match and ultimately the RF performance parameters. With the RF design 100 percent RF tested before being shipped, all that is left to do at the customer end is to physically mount the pallet onto a heatsink with some metal screws and the design is complete. This shortens the design cycle, freeing up the end-user to concentrate on designing higher system level functionality.

A few years ago…several RF discrete transistors integrated into pallets

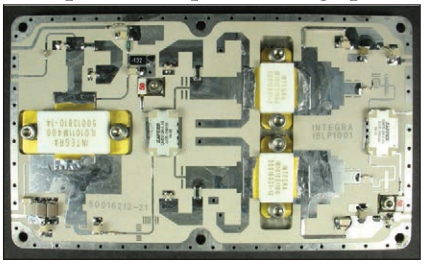
More integration: In 1997, Integra began its operations, introducing a single bipolar discrete transistor designed for S-Band Air Traffic Control Radars using patented technology. Market demand has led the company to double its pallet portfolio in the last two years. Pallets offer several key advantages over discrete devices. These pallets have higher levels of integration – multiple device stages for higher gain and/or multiple devices in parallel at the output for higher levels of power. Pallets allow the use of different semiconductor technologies with specific advantages to be integrated for overall performance optimization. Thus, companies knowledgeable in multiple technologies can offer high gain LDMOS and high power bipolar technologies for the best of both worlds. An example is shown in ***Figure 2***. Additional integration of functionality is added for bias control, bias compensation or flattening the gain and/or output power across the operating frequency band.



▲ *Fig. 1 Picture of a 25 W discrete transistor on a 50 Ω pallet.*

In the last year…RF pallets integrated into HPAs

Even higher integration: In 2011, the market has requested even more integration in the form of entire power amplifiers. Requests for high power



▲ *Fig. 2 Picture of a 2000 W avionics pallet with a LDMOS drive stage driving two high power bipolar devices in the output stage.*

amplifiers with at least 1 kW of output power are becoming more common. The request for amplifiers has come from sources with the same goal in mind – replacing TWT systems in the ISM and military radar industries. There will most likely be a place for TWTs as they produce very high power (MW) and very high gain. But more and more often, the driver stages are in the kW range, which can be handled with a solid-state solution. The ISM market, which includes industrial (frozen food heaters, laser cutters), scientific (linear particle accelerators) and medical (RF ablation), is heavily served with TWT solutions. Another market is military radar, traditionally served by tubes, which is now looking for solid-state systems for radars from L-, S-, C- and X-Band. A successful manufacturer needs the right portfolio with silicon solutions for the L/S bands and GaN for the higher frequency bands.

To meet this demand, senior engineers with design experience in this field are needed. A likely source for these engineers will be those who have worked for commercial cellular HPA developers. Already proficient with multiple stage pallets with additional functionality, migrating to HPA manufacturing is the next logical step. HPA design is not as trivial as placing a highly integrated pallet into an enclosure with a power supply and on/off switch. Instead, the complexity is another order of magnitude with mechanical concerns, environmental aspects and interference patterns all playing an important role in the final product. Also, the RF portion for HPAs have advanced circuitry in addition to the bias control and other circuitry – LEDs for on/off switch, over voltage protection, OVSWR alerts and other alarm functions.

Does this trend toward higher levels of integration speak to a lack of RF talent in the industry? Is the art of RF a dying breed of engineers as newer engineers focus more on digital/analog and only see RF PAs as a system block? Most new wireless designs focus on low power, such as cellular handsets and ZigBee, which surely sounds more exciting to the young professional. I prefer not to hazard a guess and leave this up to the reader to decide. ■

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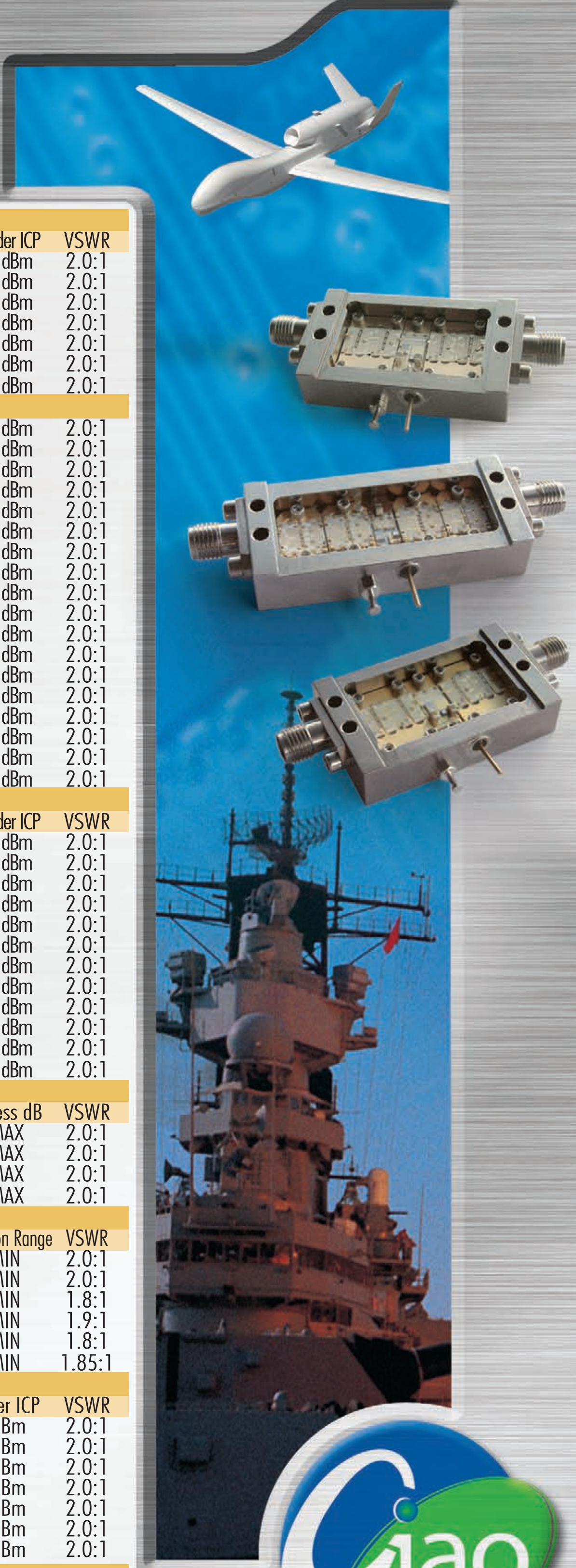

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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Dan Massé, Associate Technical Editor

US Air Force and Lockheed Martin Sign Tri-Mode Seeker Cooperative Agreement

The US Air Force Research Laboratory (AFRL) Munitions Directorate and Lockheed Martin have signed a five-year cooperative research and development agreement (CRADA) to assess the viability of its cooled tri-mode seeker for integration onto Air Force weapon platforms.

"We will work closely with Lockheed Martin to leverage their mature seeker technology with some of our novel in-house targeting concepts. Our scientists are excited to begin incorporating these proven tri-mode seekers into data collects, algorithm developments and subsystem evaluations," said Buddy Goldsmith, Chief of the US Air Force's Weapon Seeker Sciences Branch and Seeker Phenomenology Evaluation and Research (SPEAR) facility.

Lockheed Martin and AFRL will work together over the next five years to thoroughly assess tri-mode weapon capabilities, emerging targeting concepts and guidance techniques. Data and analysis from this effort will enable AFRL to develop a baseline for integrating seekers onto future US Air Force weapon platforms intended to engage stationary and mobile targets in day, night and adverse weather conditions.

"We are pleased the US Air Force is interested in further evaluating our tri-mode seeker and pushing it to its operational limits," said Frank St. John, Vice President of Tactical Missiles in Lockheed Martin's Missiles and Fire Control business. "We have continued developing and testing our seeker hardware and software for other customers and applications since the end of the Small Diameter Bomb II competition, and we look forward to demonstrating our mature seeker still offers superior effectiveness at the best value."

"We look forward to demonstrating our mature seeker still offers superior effectiveness at the best value."

Lockheed Martin's cooled tri-mode seeker is based on three combat-proven weapon systems: Javelin, LONGBOW and HELLFIRE. The first-generation tri-mode seeker was developed in 2001 for the Common Missile program; later generations were developed for the Small Diameter Bomb II and other weapon systems. The seeker, now in its fourth generation, has undergone thousands of hours of laboratory, tower and captive-carry tests and has been proven in dirty battlefield testing and in guided flight. The tri-mode seeker combines a semi-active laser sensor, an imaging infrared (I2R) sensor and a millimeter-wave radar into a single seeker with a common aperture. The cooled I2R sensor provides passive detection and lock-on-before-launch from substantial standoff ranges, significantly increasing warfighter survivability.

Raytheon Small Diameter Bomb II Seeker Exceeds Expectations

A series of laboratory tests on the Raytheon Co. Small Diameter Bomb (SDB)II tri-mode seeker demonstrated that it exceeds anticipated performance parameters. SDB II's seeker fuses millimeter-wave radar, uncooled imaging infrared (IIR) and semiactive laser sensors on a single gimbal. The result is a powerful, integrated seeker that seamlessly shares targeting information between modes, enabling the weapon to engage fixed or moving targets around-the-clock in adverse weather conditions.

"We kept SDB II affordable by designing it to meet – not exceed – government requirements. The fact that the uncooled IIR sensor surpasses design specifications is a win for the warfighter and the taxpayer," said Harry Schulte, Vice President of Air Warfare Systems for Raytheon Missile Systems. "These tests prove there's no need to increase the cost of a tri-mode seeker by adding a cooled IIR seeker when an uncooled IIR will work just as well."

World's First Soldier 'Smart Radio' has Mapping Tools, Video Transmission

Harris Corp. has introduced the RF-7800S-LR Leader Radio, the world's first soldier "smart radio" – with embedded GPS, encryption and a Personal Digital Assistant (PDA). The RF-7800S-LR provides unit leaders with combat-proven tactical communication and computing capabilities in a single, lightweight device for enhanced mission flexibility. The Harris RF-7800S-LR combines a tactical radio with a built-in computer to deliver voice, wideband data and networking and supporting applications, such as mapping tools, messaging and video transmission. These capabilities allow deployed warfighters and their leaders to send and receive information critical to situational awareness, including the collection and streaming of full-motion video. The Leader Radio offers a variety of input/output options to connect to external devices, and serves as the core of the Harris Falcon Fighter™ – a modular Soldier System that seamlessly integrates C4 devices, sensors, networking components and power modules.

"It is the smallest, lightest and most integrated soldier communication and computing device available on the market today."

"The Leader Radio provides commanders more capabilities in a smaller and lighter radio, while maintaining the impressive range offered by the RF-7800S team radio," said Andy Start, President, International Business, Harris RF Communications. "With the RF-7800S-LR, commanders are connected to every member of their team via secure,

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digitized voice and data communications. By combining various technologies into a single device, the RF-7800S-LR dramatically reduces the soldier's load. It is the smallest, lightest and most integrated soldier communication and computing device available on the market today."

Raytheon Awarded $32 M for US Navy's Positioning, Navigation and Timing Service

Raytheon Co. has been awarded a $32.2 M US Navy contract for the Global Positioning System-based Positioning, Navigation and Timing Service program for Navy surface and subsurface platforms. GPNTS, designed to replace the current Navigation Sensor System Interface, supports mission-critical real-time positioning, navigation, and timing (PNT) data services, including weapons, combat systems, and other command, control, communications and intelligence systems that require PNT information. Raytheon is providing an open architecture solution that allows hosting of data in a common computing environment and true "system of systems" architecture, enhancing the ship's operability with onboard systems.

"By leveraging our extensive ship systems and integration experience, we were able to offer an affordable, low-risk solution to our Navy customer," said Raytheon Integrated Defense Systems' (IDS) Kevin Peppe, Vice President of Seapower Capability Systems. "Our experience leading large, complex ship integration programs, including LPD 17, DDG 1000 and the open architecture Ship Self-Defense System, makes us uniquely qualified to deliver this critical capability to the fleet."

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Under the GPNTS contract, Raytheon IDS will be responsible for the design, development, testing and delivery of GPNTS. The company has partnered with Argon ST, an experienced provider of systems and sensors for the command, control, communications, computers, combat systems, intelligence, surveillance and reconnaissance markets.

Public Consultation Runs Until 30 November on European Research Area

The scientific community and other interested groups and individuals are being asked to help redefine the research landscape in Europe. The European Commission has launched a public consultation to find out how the European research environment can be radically improved. The goal is to achieve the European Research Area (ERA) by 2014, creating a genuine single market for knowledge, research and innovation. This will enable researchers, research institutions and businesses to circulate, compete and co-operate across borders, increasing growth potential.

European Commissioner for Research and Innovation, Máire Geoghegan-Quinn said, "The need to boost Europe's economy means that we have to get the very best out of our research. It is unacceptable that it is often more attractive and easier for our top scientists to cross the Atlantic than to move across the EU. We want the research community to tell us what they need, so we can work together to tear down barriers to growth and jobs."

The consultation runs until 30 November 2011 and some of the questions the European Commission wants to tackle include: are researchers looking for new opportunities, but finding themselves locked behind national borders, are scientists in need of new research infrastructures to perform and test ideas, and does the research community need more opportunities to share views, realise new projects and create new products and services?

The Commission will draw on input received on these and many other questions to finalise its proposal for an enhanced ERA Framework, to be published before the end of 2012. The Framework will optimise the coordination of research funding across Member State borders, improving the efficiency and the impact of European research.

ERA Update

Proposed in January 2000 by the European Commission in its communication Towards a European Research Area, the creation of a European Research Area was given new impetus in 2007 with the European Commission's Green Paper on ERA. The Treaty of Lisbon introduces a legal basis for the creation of a European Research Area. Such an area is intended to permit, in particular, the free movement of researchers, scientific knowledge and technologies. The European Commission will propose the ERA Framework in 2012 in line with the commitment made in its Communication on creating an Innovation Union. Those interested in participating in the consultation should visit: www.mwjournal.com/ERAOCT2011.

German Project to RELY on Developing New Chip Design Methodology for Self-test

Seven partners from the German business and research communities are teaming up in the three-year RELY research project to explore ways of enhancing the quality, reliability and resilience of modern microelectronic systems. The focus will be on applications in transportation, medical technology and automation – sectors where microelectronics is expected to play a far more prominent role in coming years.

The RELY project, which sets out to design new development processes for tomorrow's microelectronic systems and to integrate new reliability and safety criteria, is supported by the German Federal Ministry of Education and Research (BMBF) with €7.4 M under the Information and Communications Technology 2020 programme. The team members, alongside project leader Infineon Technologies AG, are EADS Deutschland GmbH, the Fraunhofer-Gesellschaft, MunEDA GmbH, X-FAB Semiconductor Foundries AG, the Technical University of Munich and the University of Bremen.

The focus will be on applications in transportation, medical technology and automation...

The RELY project, which is part of the European CATRENE project of the same name, aims to lay the foundations for establishing reliability as a new target parameter throughout the chip development process. So far, optimization has been levelled primarily at area, performance and energy consumption. In the course of the research, the partners will seek to develop novel chip architectures that will allow a chip to automatically determine its operating status, react to it and even enter into interaction with the electronic system. In the future, such a self-test function of the chip could permit a timely alert of possible signs of wear in electronic systems.

TNO and Huawei to Set Up LTE Test Network in the Netherlands

To explore LTE technology and its possibilities, the independent research organisation TNO, is launching a trial in cooperation with Huawei. A test network will be set up on the outskirts of Delft, the Netherlands, with a number of market players and user groups scheduled to take part in the study.

The LTE standard offers greater efficiency, network capacity and peak transmission in comparison to UMTS. LTE technology enables substantially faster data speeds at a lower price per delivered Megabit. In Europe, LTE will operate on several frequency bands: 800, 900 and 1800 MHz and 2.6 GHz and the expectation is that a number

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...the expectation is that a number of mobile operators in the Netherlands will roll out LTE in the coming years.

of mobile operators in the Netherlands will roll out LTE in the coming years.

A great deal of technical and theoretical knowledge is available on the possibilities of LTE and the Delft trial will test the performance of the new technology in the 800 and 1800 MHz bands, with Huawei supplying TNO with the necessary base station and core network equipment. The study will look at, for example, what performance can be achieved with different network options, and which performance is needed to offer services, such as broadband video. In addition, user groups will assess new application possibilities.

TNO aims to utilise the knowledge obtained in the LTE pilot study to provide support to the public and private sectors in realising an optimum roll-out and implementation of the LTE network in the Netherlands.

COST-TERRA Promotes More CR Trials

COST-TERRA, a forum spearheading a regulatory breakthrough for the European development of Cognitive Radio and Software Defined Radio (CR/SDR) technologies, is promoting more active trials of CR to identify its best feasible application, guide policy-makers to open a regulatory framework and facilitate development of the technology.

After assessing several projects and developments in this area, COST-TERRA will collaborate with its sister, COST Action IC0902, and FP7's CREW project in promoting the importance of real-life CR testing and building real-life CR deployment scenarios into the CR testing programmes. Additionally, COST-TERRA has begun to outline a proposal to regulators on dedicating a pilot frequency band for a set of most attractive CR deployment scenarios.

...a pilot band would provide regulatory certainty for the industry...

Such a pilot band would provide regulatory certainty for the industry to make the necessary investments in the trial of this novel, and yet unproven technology. In order to further develop this project, COST-TERRA will work on better defining this proposal for the pilot CR band with the aim of exploiting the established liaisons with the EU regulators, such as the European Conference of Postal and Telecommunications Administrations (CEPT) and the European Commission.

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Markets for Millimeter-wave Products Growing Rapidly, Engalco Reports

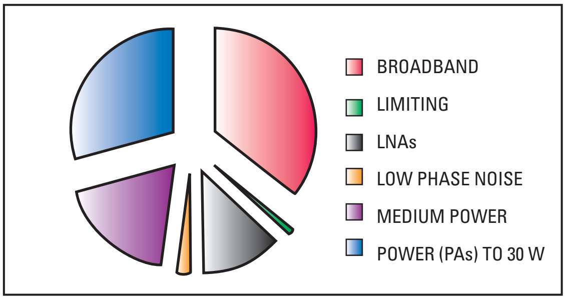
Engalco has released a new industry and markets report covering the following categories of connectorized microwave and millimeter-wave modules: broadband amplifiers, limiting amplifiers, low noise amplifiers, low phase-noise amplifiers, medium-power amplifiers, power amplifiers, CW-immune DLVAs, SDLVAs, "Other" DLVAs, frequency converters, frequency synthesizers and transceivers. "Amplifiers and Integrated Microwave Assemblies" (AIMA) provides comprehensive "free world" market forecast data for microwave electronic module products sold into in the electronic warfare (EW), radar, ground-based SATCOM and space-based SATCOM segments.

The report separates products and applications into microwave (0.5 to 18 GHz) and millimeter-wave (above 18 GHz). While microwave products always take the lion's share of all markets, those for millimeter-wave products are growing comparatively rapidly. This report indicates that the overall global total available market (TAM) amounted to just more than US $1.1 B in 2010 and will reach almost US $1.3 B in year 2016. The ground-based SATCOM segment leads both for microwave and millimeter-wave modules – the latter being strongly driven by the on-going K/Ka-Band developments requiring frequency converters and transceivers. Engalco's B-SAT1 report, released in summer 2011, covers these types of products in detail and includes highly granular geographic market data.

Major OEM players in this market include Elisra Electronic Systems, M/A-COM Technology Solutions, MITEQ and Tokyo Keiki.

The pie chart shown clearly indicates the importance of broadband, power, medium power and low noise amplifiers (LNA). In fact, according to AIMA, the three largest microwave markets are occupied by broadband amplifiers, sub-30-W power amplifiers and frequency synthesizers. Each of these market segments is valued in the low hundreds of US million dollars for the 2010 base year. Major OEM players in this market include Elisra Electronic Systems, M/A-COM Technology Solutions, MITEQ and Tokyo Keiki. In the AIMAs report, the top 10 suppliers are identified and analyzed in terms of their market shares.

Year 2010 Connectorized Linear Amplifiers in Microwave Segments (i.e. 0.5 to 18 GHz) TAMs in US $M



Source: Engalco

White Space Consumer Devices Expected to Enter the Market in Five Years

Cambridge Consultants has released a report discussing the foremost business opportunities in wireless technologies enabled by White Space frequencies, predicting the development of the first White Space consumer devices in the next five years. The report, entitled "White Space Radio: High Street Hit or Left In the Lab?" is the culmination of a White Space workshop hosted by Cambridge Consultants and brings together experts from across the wireless and broadcast industries, including representatives from Nokia, Samsung, BBC, BSkyB, Neul and CSR.

Consensus views the use of White Space radio as an inevitability, addressing a critical need for redressing methods of spectrum usage and opening up new possibilities for wireless devices. Much discussion of White Space to date has focused on the potential for helping meet rapidly increasing demand for mobile data on smartphones. However, the report emphasizes that White Space technology has the potential to provide for a far broader range of applications and presents a solution for the "always on" society.

"A priority now should be establishing standards to allow for common platforms, economies of scale and large scale uptake."

Deemed the "White Space economy," new business opportunities for a range of industries suggests that initial market opportunities will emerge as a series of smaller, niche applications. They would minimize dependency on multiple parties and require lower investment. In terms of revenue generation, White Space technologies could see returns both through direct data delivery or indirect revenue streams, such as advertising. Data revenue may suit certain geographies for applications, such as rural broadband, whereas advertising could be more suitable for applications like local content broadcasting.

Areas of opportunity:

Micro or localized wireless Internet service providers (WISP)

There is great potential for businesses (from supermarkets to local government, for example) operating in more

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remote areas to supply Internet services and advertising to the local surrounding area. Delivery of personalized and location-based services to very local clientele, for a very modest investment by the supplier, is an attractive new business model and the report speculates that delivery could cost as little as one tenth of the cost of copper.

Delivery of personalized and location-based services to very local clientele, for a very modest investment by the supplier, is an attractive new business model...

Localized broadcasting

For broadcasters, there is now interest in using White Space for interactive "back-channel" applications and the delivery of highly localized content and advertising.

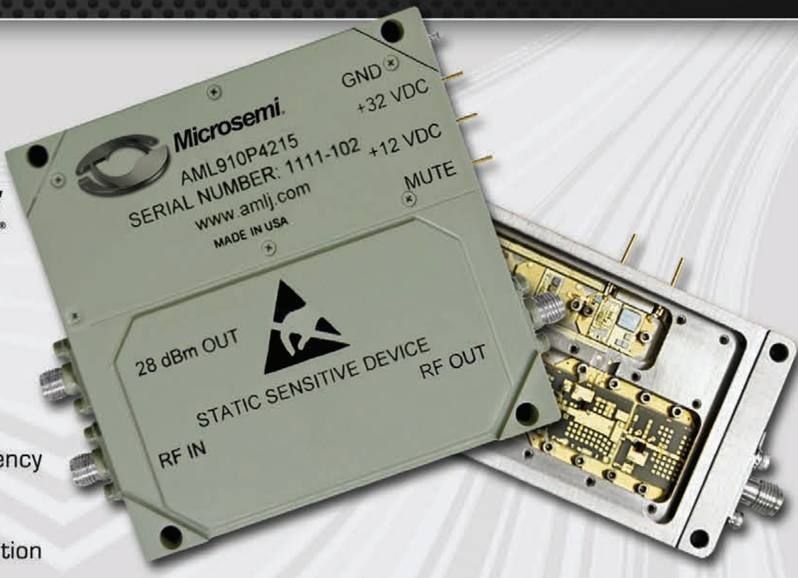
The "Internet of Things"

Encompassing areas, such as M2M, smart metering and applications that require connectivity over a long-range but low data rate, White Space stands out as an enabler of the "Internet of Things." White Space is especially appropriate, first because the method for connecting can be optimized to meet the need for longer range and lower bit rate. Second, the data transferred is low rate and, in some instances, very infrequent and, for some applications, the majority of data can be transferred at a time when it is less likely to cause interference.

Cambridge Consultants predicts that we will see enterprise White Space devices developed by the end of 2011, and consumer devices entering the market in five years. "It is important to view White Space as a platform that a multitude of technologies can use, presenting incredible potential for application far beyond simply supplementing traditional cellular networks. One of the main difficulties is identifying which vertical market will see significant headway first. Technology is being developed, but this is still largely hidden from public view and further demonstration of both the technology and specific market application is needed before significant investment is forthcoming," commented Fraser Edwards, Head of Radio Frequency Systems at Cambridge Consultants.

"A priority now should be establishing standards to allow for common platforms, economies of scale and large scale uptake. Without standards, White Space could be a footnote, but effectively marshalled White Space has the potential to deliver even greater innovation and new services that we have seen in previously unlicensed spectrum, such as WiFi and Bluetooth."

AML is now Microsemi



Our Gallium Nitride (GaN) amplifier products employ the latest semiconductor technologies and present the very best performance to our customers. Gallium Nitride (GaN) technology, coupled with our chip and wire die level expertise maximize power added efficiency and high power density characteristics of GaN in small convenient packages. Multi-octave amplifiers and application specific narrow band amplifiers cover frequencies to 18 GHz. GaN amplifiers operate with voltages between +28VDC to +50VDC (design dependent). Catalog designs offer power levels up to 100 Watts; custom designs to 200 Watts are available.

GaN Power Amplifiers

Model Number	Frequency (GHz)	Gain (dB min)	Psat (dBm min)	Psat (dBm typ)	Psat (Watts typ)	Voltage (V) Current (A)	PAE	ECCN
AML056P4013	0.5 - 6.0	40	35	36	4	28V, 0.75A	22%	EAR99
AML056P4014	0.5 - 6.0	40	37	38	6	28V, 1.0A	20%	EAR99
AML056P4511	0.5 - 6.0	45	39	40	10	28V, 1.3A	25%	EAR99
AML056P4512	0.5 - 6.0	45	43	44	25	40V, 2.7A	23%	EAR99
AML13P5013	1.0 - 3.0	50	46	47	50	28V, 4.8A	25%	EAR99
AML26P4011	2.0 - 6.0	40	40	41	12	28V, 1.5A	30%	EAR99
AML26P4012	2.0 - 6.0	45	43	44	25	28V, 3.0A	30%	EAR99
AML26P4013	2.0 - 6.0	50	46	47	50	28V, 6.0A	30%	EAR99
AML59P4512	5.5 - 9.0	45	45	46	40	28V, 4.0A	35%	3A001.b.4.b
AML59P4513	5.5 - 9.0	45	48	49	80	28V, 8.0A	35%	3A001.b.4.b
AML910P4213	9.9 - 10.7	43	37	38	6	32V, 0.5A	30%	EAR99
AML910P4214	9.9 - 10.7	43	39	40	10	32V, 0.8A	30%	EAR99
AML910P4215	9.9 - 10.7	46	41.5	42	15	32V, 1.3A	30%	EAR99
AML910P4216	9.9 - 10.7	46	42	43	20	32V, 1.3A	30%	3A001.b.4.b
AML811P5011	7.8 - 11.0	45	43	44	25	28V, 2.8A	30%	3A001.b.4.b
AML811P5012	7.8 - 11.0	50	46	47	50	28V, 5.5A	30%	3A001.b.4.b
AML811P5013	7.8 - 11.0	50	48	49	80	28V, 11.5A	25%	3A001.b.4.b
AML1416P4511	14.0 - 16.0	45	42	43	20	35V, 3.2A	18%	ITAR
AML1416P4512	14.0 - 16.0	45	45	46	40	35V, 6.2A	18%	ITAR
AML618P4014	6.0 - 18.0	40	39	40	10	32V, 2.8A	12%	ITAR
AML618P4015	6.0 - 18.0	40	42	43	20	32V, 4.9A	12%	ITAR
AML218P4012	2.0 - 18.0	35	37	38	6	32V, 1.5A	13%	ITAR
AML218P4011	2.0 - 18.0	40	39	40	10	32V, 2.8A	12%	ITAR
AML218P4013	2.0 - 18.0	38	42	43	20	32V, 4.9A	12%	ITAR

Features: Fast TTL On/Off (Rise/Fall < 100ns);
Wide operating temperature range: -54º to +85ºC (hermetically sealed)

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Around the Circuit

Kerri Germani, Staff Editor

INDUSTRY NEWS

TowerJazz announced the closing of the sale of all its holdings in **Hua Hong Semiconductor Ltd.** (HHSL), the parent company of **HHNEC**, one of Mainland China's leaders in the field of IC foundry service, in a HHSL share repurchase transaction for $32 M in cash. TowerJazz's holdings consisted of 10 percent of HHSL's shares, valued per GAAP in the amount of $17 M on TowerJazz's balance sheet. TowerJazz received the cash from this transaction and expects to record a gross gain in the third quarter of $15 M as a direct result of this sale, and approximately $8 M of net gain.

CommScope has completed its acquisition of **Argus Technologies**, a producer of innovative antenna solutions for wireless applications. Argus, headquartered near Sydney, Australia, provides a wide array of high performance, high technology antennas for base stations, stadiums and other wireless applications. The acquisition enables CommScope to broaden its antenna solutions portfolio, deepen its research and development capabilities, strengthen its global market presence and accelerate its growth in the wireless market.

The **Massachusetts Institute of Technology** has announced the creation of the **MIT/MTL Center for Graphene Devices and Systems** (MIT-CG). This interdepartmental center, part of the Microsystems Technology Laboratories (MTL), brings together MIT researchers and industrial partners to advance the science and engineering of graphene-based technologies. The Center coordinates the work of more than 15 MIT research groups and leverages several existing collaborative efforts in graphene science that exist on campus.

Analog Devices Inc. (ADI) has received the 2009-2010 **Bosch** Supplier Award. ADI received the award for superior service in the electronics category (ASIC and ASSP), in particular for supplying application-specific analog and mixed-signal products designed to meet the rigorous quality and reliability standards of the automotive industry.

OML Inc. is celebrating 20 years in business. Located in the Silicon Valley of CA, the company's solutions empower engineers in R&D and manufacturing to pursue opportunities in emerging applications spanning radio astronomy, communication, imaging, space research and homeland security.

International Manufacturing Services Inc. recently donated a generous quantity of thin film chip resistors to the Department of Computer and Electrical Engineering at Brigham Young University in Provo, UT.

CONTRACTS

Comtech Telecommunications Corp.'s MD-based subsidiary, **Comtech Mobile Datacom Corp.**, received an initial funded order totaling $4.6 M to support the US Army's Movement Tracking System Program. This order was placed under Comtech's existing $384 M BFT-1 contract and represents the first order released by the Blue Force Tracking Program Office to support the MTS program, which has now been consolidated under its direction. This order provides partial funding for the continued supply of satellite bandwidth, satellite network operations, engineering services and program management support.

API Technologies Corp. announced it has been awarded new contracts valued, in aggregate, at $2.7 M to produce circuit card assemblies for use in counter-explosive equipment under the Joint Counter Radio-Controlled Improvised Explosive Device Electronic Warfare (JCREW) program. API's Electronics Manufacturing Services (EMS)/SenDEC division was awarded the order by a major defense electronics systems integrator and will be used by the US Armed Forces at home and abroad.

ASC Signal Corp. has been awarded a multi-million dollar sub-contract by **L-3 Narda Satellite Networks**, to provide more than 100, 3.9-meter, quad-band, fly-away antenna components and systems. The antenna systems will support high frequency communications over commercial and government satellites. Under this contract, ASC will deliver the largest quantity of Earth station systems for one program since the company's inception.

Wireless Telecom Group Inc. announced that its wholly owned subsidiary, **Boonton Electronics**, has been awarded an increase of $1.5 M to its contract with the US Navy. The total contract is for approximately $3 M and a considerable portion of this contract will be fulfilled over the next 12 months. Boonton's 4500B RF Peak Power Meter will be utilized by the Department of Defense (DoD) Naval Sea Systems Office personnel in shipboard and shore-based laboratories and by other DoD personnel to calibrate Radio Detecting and Ranging test sets, Tactical Navigation test sets, Identification, Friend or Foe (IFF) test sets and Commercial-Off-The-Shelf equipment, such as RF and microwave signal generators.

Skyworks Solutions Inc. announced it is supporting **ZTE's** ramp of next generation tablets and laptops with EDGE and WCDMA/LTE front-end solutions. Skyworks' modules are powering data cards and USB modems to help deliver greater mobility for tablets that are equipped with cellular connectivity. With these wins, Skyworks is broadening its relationship with ZTE, one of the world's fastest-growing handset OEMs. ZTE already leverages several of Skyworks' TD-SCDMA and CDMA solutions for handsets and will soon utilize Skyworks' antenna switch modules in several forthcoming smart phone platforms.

Custom electronics design firm **Stilwell Baker Inc.** announced the successful completion of a legacy power sup-

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HIGH POWER PRODUCTS

POWER DIVIDERS

Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] ◊	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ./Max.]	Isolation (dB) [Typ./Min.]	VSWR (Typ)	Input Power (Watts) [Max.] ▫	Package
2-WAY								
DSK-729S	800 - 2200	0.5 / 0.8	0.05 / 0.4	1 / 2	25 / 20	1.3:1	10	215
DSK-H3N	800 - 2400	0.5 / 0.8	0.25 / 0.5	1 / 4	23 / 18	1.5:1	30	220
P2D100800	1000 - 8000	0.6 / 1.1	0.05 / 0.2	1 / 2	28 / 22	1.2:1	5	329
DSK100800	1000 - 8000	0.6 / 1.1	0.05 / 0.2	1 / 2	28 / 22	1.2:1	20	330
DHK-H1N	1700 - 2200	0.3 / 0.4	0.1 / 0.3	1 / 3	20 / 18	1.3:1	100	220
P2D180900L	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1 / 2	27 / 23	1.2:1	5	331
DSK180900	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1 / 2	27 / 23	1.2:1	20	330
3-WAY								
S3D1723	1700 - 2300	0.2 / 0.35	0.3 / 0.6	2 / 3	22 / 16	1.3:1	5	316

◊ In excess of theoretical split loss of 3.0 dB
▫ With matched operating conditions

HYBRIDS

Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] ◊	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ./Max.]	Isolation (dB) [Typ./Min.]	VSWR (Typ)	Input Power (Watts) [Max.]	Package
90°								
DQS-30-90	30 - 90	0.3 / 0.6	0.8 / 1.2	1 / 3	23 / 18	1.35:1	25	102SLF
DQS-3-11-10	30 - 110	0.5 / 0.8	0.6 / 0.9	1 / 3	30 / 20	1.30:1	10	102SLF
DQS-30-450	30 - 450	1.2 / 1.7	1 / 1.5	4 / 6	23 / 18	1.40:1	5	102SLF
DQS-118-174	118 - 174	0.3 / 0.6	0.4 / 1	1 / 3	23 / 18	1.35:1	25	102SLF
DQK80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2 / 5	20 / 18	1.30:1	40	113LF
MSQ80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2 / 5	20 / 18	1.30:1	40	325
DQK100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1 / 4	22 / 20	1.20:1	40	326
MSQ100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1 / 4	22 / 20	1.20:1	40	346
MSQ-8012	800 - 1200	0.2 / 0.3	0.2 / 0.4	2 / 3	22 / 18	1.20:1	50	226
180° (4-PORTS)								
DJS-345	30 - 450	0.75 / 1.2	0.3 / 0.8	2.5 / 4	23 / 18	1.25:1	5	301LF-1

◊ In excess of theoretical coupling loss of 3.0 dB

COUPLERS

Model #	Frequency (MHz)	Coupling (dB) [Nom]	Coupling Flatness (dB)	Mainline Loss (dB) [Typ./Max.]	Directivity (dB) [Typ./Min.]	Input Power (Watts) [Max.] ▫	Package
KDS-30-30	30 - 512	27.5 ±0.8	±0.75	0.2 / 0.28	23 / 15	50	255 *
KBS-10-225	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	255 *
KDS-20-225	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	255 *
KBK-10-225N	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	110N *
KDK-20-225N	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	110N *
KEK-704H	850 - 960	30 ±0.75	±0.25	0.08 / 0.2	38 / 30	500	207
SCS100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	361
KBK100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	322
SCS100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1	14 / 5	25	321
KDK100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1	14 / 5	25	322
SCS100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	12 / 5	25	321
KDK100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	14 / 5	25	322

* Add suffix - LF to the part number for RoHS compliant version.
▫ With matched operating conditions

Unless noted, products are RoHS compliant.

SYNERGY® MICROWAVE CORPORATION

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ply re-design for **Superior Technical Services**. The company needed a solution for failing discrete power supplies on Scanning Electron Microscopes (SEM). Stilwell Baker engineers went onsite to characterize the power supply requirements in the various models of SEMs supported by Superior Technical. The team then wrote a detailed specification, designed and built the new power supply.

ORBIT Communication Systems Ltd., a subsidiary of Orbit Technologies Ltd., announced a contract with an Asian Navy for multiple OrBand™ (AL-7107) maritime C-Band VSAT systems. OrBand leverages breakthrough technology to deliver RF performance equivalent to industry-standard systems, in a much smaller footprint. Industry-standard systems feature a 3.8 m (150") radome, while OrBand features a compact 2.7 m (106") radome, requiring substantially less deck space.

NEW MARKET ENTRIES

Agilent Technologies Inc. announced that it has increased the company's capability to provide on-site Z540.3 calibration services at locations from Canada to Brazil. In March 2010, the Roseville, CA, service center became the first commercial calibration lab to be accredited by A2LA to ANSI/NSCL Z540.3-2006. Since then, 14 Agilent service centers, many with mobile calibration teams, have all been accredited to Z540.3 by A2LA. These centers now offer Z540.3 calibration service for more than 500 models, up from 230.

Raytheon Co.'s Network Centric Systems has combined its existing security solutions and civil communications businesses as part of a new product line to increase its focus on opportunities in public safety markets. The new product line, Security and Transportation Systems (STS), includes two major public safety focus areas. The first is security solutions, with an emphasis on critical infrastructure protection, including ports and airports, border protection and other needs served by the ClearView™ family of security management systems. The second area is interoperable communications networks and the equipment that allow first responders to communicate with one another in an emergency. The air traffic management business will also be part of STS.

Siklu is now offering its low cost millimeter-wave radio systems in the North American market. Siklu delivers carrier-grade millimetric-wave Gigabit Ethernet radio solutions with unparalleled price-performance value. Offering the industry's lowest total cost of ownership and incorporating on-board networking capabilities, solutions from Siklu are ideally suited for mobile backhaul, Carrier Ethernet business services, enterprise and vertical applications.

PERSONNEL

▲ *Dean Handrinos*

Anatech Electronics appointed **Dean Handrinos** as Director of US Sales, with the responsibilities of developing new business and managing of the company's sales activities throughout the country. Handrinos comes to Anatech from Stealth Microwave (a division of Micronetics), where he was Vice President. Handrinos received his bachelor's degree in engineering from Stevens Institute of Technology and is working toward his MBA degree from Lehigh University.

Giga-tronics Inc. announced that **Mark Elo** has joined the company as Vice President of Marketing. Elo comes to Giga-tronics with more than 20 years of test and measurement experience in RF and microwave instrumentation. He has held various positions at Hewlett-Packard, Agilent Technologies and Keithley Instruments – including Product Marketing Manager, Marketing Director and Business Development Director – as well as a number of R&D management roles. Giga-tronics also announced that **Malcolm Levy** will retain his responsibilities for managing the company's worldwide sales and business development activities

and will continue as an Officer of the company. He will assume the position of Executive Vice President of Sales.

IEE has appointed **Thomas Whinfrey** as President and CEO. Whinfrey brings more than 25 years of experience in managing operations and strategies for a number of large companies throughout the military and aerospace industries. This experience, coupled with his track record of visionary leadership, lays the foundation for successful partnerships with IEE's growing customer base.


▲ Vincent Pellicia

M/A-COM Technology Solutions recently announced two promotions. **Vincent Pellicia** was named Senior Director of Asia Pacific Sales. Pelliccia most recently served as M/A-COM Tech's Director of Sales Operations and Business Development. Prior to that, he served as Vice President of Sales at Mimix Broadband Inc., which was acquired by M/A-COM Tech in May 2010. Pelliccia worked at M/A-COM Inc. for 11 years as a Product Group Manager prior to joining Mimix Broadband. Pelliccia received a B.S. and M.S. in electrical engineering from the University of South Florida. **James Dempsey** has been promoted to the position of Director of Global Distribution. He most recently served as Deputy Director of Distribution at M/A-COM, and previously held leadership roles at Skyworks Solutions Inc., Alpha Industries and Herley Micro-Dynamics. Dempsey received a B.S. in electrical engineering from Wentworth Institute of Technology, while also earning a certificate from the MIT Sloan School of Management in the Greater Boston Executive Business Program.


▲ James Dempsey


▲ John Fisher

Modelithics Inc. announced the addition of **John Fisher**, as member of the Modelithics management team, as Vice President of Operations. Fisher has more than 29 years of engineering and management experience, including previous roles as Director of Engineering and VP of Sales and Marketing. Fisher earned a bachelor's degree in electrical engineering from the University of Central Florida, along with a master's degree in electrical engineering and a MBA from the University of South Florida.


▲ Patrick McNamee

Nujira has appointed **Patrick McNamee** to the newly created post of VP of Silicon Operations with overall responsibility for taking its Envelope Tracking ICs from design completion to volume production. He has more than 25 years experience in the semiconductor industry, including 15 years senior management experience with fabless semiconductor companies, such as Powervation,

Cambridge Silicon Radio (CSR) and Dialog Semiconductor. He joins the company from EoSemi, a UK based start-up with novel intellectual property in the field of silicon timers. Earlier in his career, he held test and product development positions at the senior engineer level with National Semiconductor and GEC Plessey.

REP APPOINTMENTS

MITEQ Inc. announced the appointment of **Omarim Technologies Ltd.** as the company's exclusive sales representative in Israel and **EMCO Elektronik GmbH** as the company's exclusive sales representative in Austria, Germany and Switzerland. Omarim and EMCO will represent MITEQ's component division of products, which includes amplifiers, mixers, frequency multipliers, passive power components, switches, attenuators, limiters, phase shifters, IF signal processing components, oscillators, synthesizers, integrated multi-function assemblies and fiber optic products. Omarim Technologies Ltd. can be contacted at 011-972-9-763-1000. EMCO Elektronik GmbH can be contacted at 011-49-89-895-5650.

SV Microwave announced the signing of **Mouser Electronics** as its newest authorized distributor. Mouser Electronics is one of the industry's fastest-growing global catalog and online semiconductor and electronic component distributors.

Valpey Fisher Corp. and **Precise Time and Frequency Inc.** (PTF) jointly announced an agreement in which PTF products will be sold and distributed worldwide by Valpey Fisher – expanding its line of high performance integrated products for timing and frequency control. A privately held company, Precise Time and Frequency Inc. will continue to be active in the design, engineering and manufacture of its frequency, time, GPS and switch products. New products will continue to be developed with input from new and existing customers. Through this agreement, Valpey Fisher will productize the line of PTF products and market them under the Valpey Fisher brand. Products will be sold and distributed through the direct and indirect global sales channels of Valpey Fisher.

WEBSITE

Versatile Power Inc. a technology leader in the design and manufacture of custom electronic subsystems, announced its new, expanded website: www.versatilepower.com. The new website provides ease of use for visitors wanting to learn about the company's broad offerings of custom design and manufacturing services for medical, semiconductor, ultrasonic, lighting, government lab, aerospace, military and industrial applications.

HI-REL LIMITERS

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Need to protect a low-noise receiver that will be operating in a hostile environment? These limiters offer excellent protection against ESD, power surges and unwanted high-level signals--without the tradeoff of high insertion loss. And these limiters react nearly instantaneously (2 ns response time, 10 ns recovery time) and work over a very broad band.

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U.S. Patents 7739260, 7761442

IF/RF MICROWAVE COMPONENTS

US ARMY SBIR PROGRAMS SPUR MICROWAVE INNOVATION

Congress established the Small Business Innovation Research (SBIR) program to provide an opportunity for small businesses and academia – through Small Business Technology Transfer (STTR) – to participate in government-funded research and development. The US Army SBIR program is the nation's largest source of early stage technology financing. This million dollar program enables hundreds of small companies to develop new products and technologies and progress from prototype to production. The program encourages small companies to research and develop new technologies and products in response to critical Army needs.

TABLE I

US ARMY SBIR PROGRAM PHASES[1]

Phase I	6 months $100,000 max.
Phase I (Option)	4-month option (Government's discretion) $50,000 max., to fund Interim Phase II efforts
Phase II	2 years $1,000,000 max.
Phase III	Unlimited time; non-SBIR funding

Table 1 shows the different phases these programs use in regard to the funding level and duration of each step. Phase I is a feasibility study that determines program viability, Phase II is a R&D effort resulting in a prototype and Phase III expects the small business to obtain non-governmental funding to progress from prototype to a viable product. Looking through the recent 2011 success stories publication from the Army that lists the best in Phase III commercialization efforts, we found many interesting RF and microwave-related technologies in addition to others we have seen in the news.[1]

EY Technologies (Fall River, MA) has developed conductive fiber technology in response to the military's needs for Electro textiles that will enable the next generation of military garments with integrated devices. Some examples

PATRICK HINDLE
Technical Editor, Microwave Journal

are body antennas that that identify a soldier's location, components for Electro Magnetic Interference (EMI) shielding, wearable computers, data/power conduits, body mapping for health/fatigue/wound monitoring systems and electrically heated garments. They have developed metal alloys that meet the Army's performance needs and the metal is incorporated into a polymer matrix, which maintains its properties when drawn into micro wires. Now antenna designers can develop new designs that are integrated into clothing. The product has already generated income from outside sources and the company is testing the product for other applications, such as GPS-enabled clothing for the blind, bio-threat sensors, advanced medical devices, artificial muscles, strain gauges for military parachutes, electro luminescent systems, iPhone/iPod compatible shirts, pressure monitoring hospital mattresses and for many other smart garments.

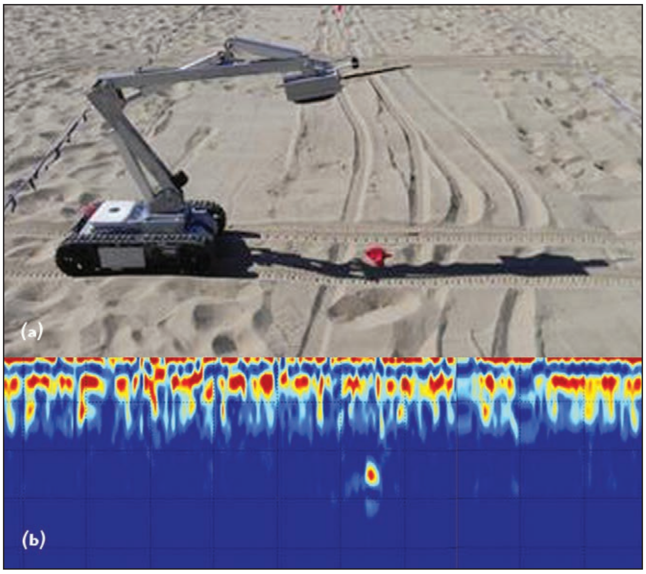

Fig. 1 UGV with IED detection radar sensor (a) imaging a buried object (b).

The Army has expressed a need for power conditioning elements that enable advanced RF warheads and multi-pulse RF systems that can be used for IED detection, vehicle/vessel disablement and impulse radar. Radiance Technologies (Huntsville, AL) has developed compact power conditioning elements that function in the megavolt and gigawatt range when integrated into RF impulse sources. These elements enable a pulse generator technology that scales from single pulses at gigawatt power levels to high rep-rate multi-pulse systems operating with peak power of gigawatts and with average power levels in the several kW range. This product has been used to demonstrate vehicle/vessel disablement, a direct strike undercarriage vehicle disabler, a broadband impulse UHF radar, a pre-ionizer for advanced space propulsion, a highly ionized plasma source that can be used for chemical processing, and a high power UHF transmitter that has been shown to disrupt the electronics associated with IEDs. A laboratory demonstration of an explosive-driven pulse generator is being evaluated for Electro Magnetic Pulse (EMP)-like warheads, and as a general laboratory pulse generator.

TiaLinx (Newport Beach, CA) has developed UWB RF systems that provide improved IED detection for better situational awareness. The Cougar mini-unmanned ground vehicle (UGV or robot) with tractable arm or Phoenix mini-unmanned aerial vehicle (UAV) with programmable waypoints, can carry a variety of sensors for extended standoff surveillance as well as detection of buried objects. Through software controlled interfaces, the company's UGVs and UAVs can be remotely guided at extended ranges. Multiple integrated cameras allow day and night visibility and operation for enhanced situational awareness. TiaLinx's UGVs and UAVs are able to perform through-the-wall imaging, IED detection, RF mapping and detection of IEDs on people. ***Figure 1a*** shows a Cougar10-B UGV using a radar sensor to detect IEDs buried underground. The sensor display in ***Figure 1b*** shows the object being detected underground.

Agile Digital Effects Processor (ADEP™) Digital RF Memory

Fig. 2 Agile Digital Effects Processor Digital RF memory unit.

(DRFM) from Systems and Process Engineering (Austin, TX) provides revolutionary improvements to EW capabilities that effectively support countermeasure techniques to combat current and future planned wide bandwidth radar with increasingly sophisticated modulation schemes based on an architecture that can effectively and rapidly evolve with the threat. It has the ability to generate sophisticated digital effects as accurately represented multiple crossing targets and extended range in comparison to other current DRFM products. The technology can generate accurate RF signals, waveforms and images without introducing artifacts. ***Figure 2*** shows a picture of the ADEP 800 unit.

Custom MMIC Design Services (Westford, MA) has developed a family of ultra low noise and ultra low power dissipation amplifiers at 10 and 20 GHz for use in Active Electronically Scanned Array (AESA) radars. The company has combined state-of-the-art semiconductor processing with its design techniques to reduce the power dissipation of each LNA down to 30 mW and lower the noise figure (NF) by 1 dB. The 10 GHz LNA has 20 dB gain with a NF of 0.8 dB and the 20 GHz LNA has 25 dB gain with a NF of 1.2 dB. The products have been qualified over the full commercial and military temperature ranges and are shipping in volume.

Digital Receiver Technology (Germantown, MD) has developed a portable Threat Warning Receiver (TWR) that gives soldiers immediate access to signal exploitation, electronic attack, force protection and wireless networking functions. It uses new software-defined radio (SDR) technology to analyze the incoming signals. The SDR technology enables high speed, wideband scanning with direction finding and can be easily upgraded.

Auriga Microwave (Lowell, MA) is involved in several SBIR programs from the US Navy, Air Force and Army.[2] The Army program addresses the demand for high power RF switches for the Joint Tactical Radio System (JTRS), which includes software-controlled reconfigurable RF hardware. Due to its reconfigurable nature, the JTRS requires a large number of RF switches in different configurations. In such multi-component switching blocks, use of traditional PIN-diodes has significant limitations on overall system performance due to high bias current consumption, relatively slow modulation speeds, vertical layout integration complications and low temperature stability. RF switches based on GaAs technology suffer from low power handling. Therefore, Auriga is pursuing another technical tract. To make a high power switch without the limitations of PIN or GaAs technologies, insulated gate Group III-nitride HFETs will be used. These devices are advantageous due to their higher power handling capability, temperature stability and high reliability for switches and monolithically integrated switch arrays. Auriga's goal is to design and deliver a family of MPMT switches that operate across two decades of bandwidth (2 to 2000 MHz), have less than 0.25 dB insertion loss and are capable of handling RF power up to 46 dBm.

The SBIR program provides millions of dollars in funding to small businesses to quickly provide solutions to the Army's critical needs as is also done with the other branches of the military. These funds provide an important impetus for small companies to invest in practical research and development and bring new, innovative products to the market. ■

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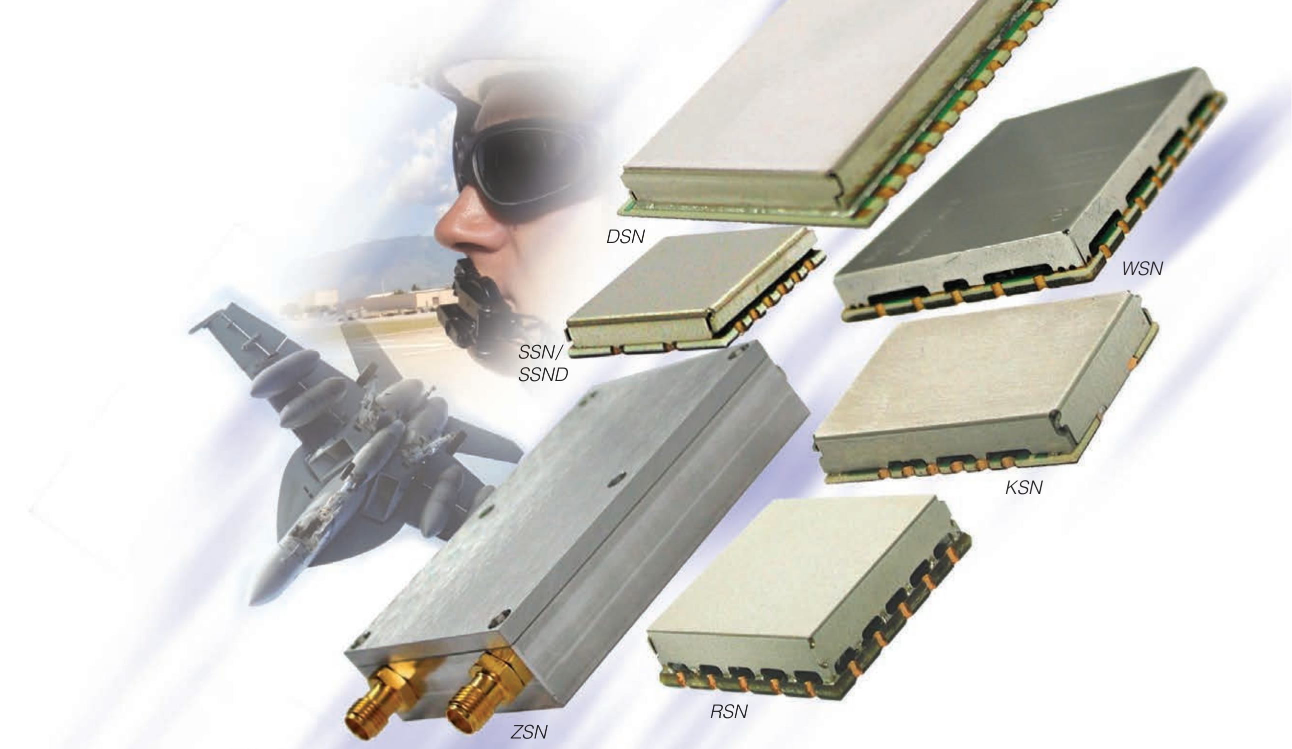

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IF/RF MICROWAVE COMPONENTS

PIM TESTING GROWING IN IMPORTANCE AS 4G ROLLS OUT IN EUROPE

European cellular system performance requirements are at an all-time high. System performance is an extremely important part of the day-to-day operation of a modern telecommunications network and is a direct reflection on the overall perceived quality levels experienced by each individual subscriber. Dropped calls, poor quality connections and other frustrating performance problems directly contribute to subscriber churn. This has a massive impact for the service provider, as it is a key indicator of customer sentiment.

The modern communications system is required to perform at a very efficient level. This quality standard has changed greatly during the past few years and will continue to change as current 3G and 4G systems compete for market share and increase infrastructure and coverage. Line sweep testing is more important than ever and emerging passive intermodulation (PIM) testing requirements have lifted the bar even higher. Ultimately, this means contractors, cell technicians and performance engineers must work closely together to achieve the required quality of service.

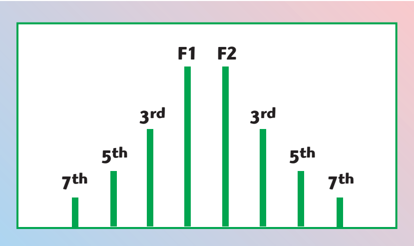

Fig. 1 Carriers F1 and F2 with 3rd through 7th order products.

PIM BASICS

PIM, often referred to as the diode effect or the rusty bolt effect, is a form of passive intermodulation distortion that occurs in components normally thought of as linear, such as cables, connectors and antennas. However, when subjected to the high power RF signals found in cellular systems, these devices can generate spurious signals. An on-site PIM test is a comprehensive measure of linearity and construction quality. PIM appears as a set of unwanted signals created by the mixing of two or more strong RF signals in a nonlinear device, such as in a loose or corroded connector.

The following pair of formulas can predict PIM frequencies for two carriers:

nF1 – mF2

nF2 – mF1

F1 and F2 are carrier frequencies and the constants n and m are positive integers. When referring to PIM products, the sum of n + m is called the product order, so if m is 2 and n is 1, the result (2+1=3) is referred to as a 3rd order product. Typically, the 3rd order product is the strongest, causing the most harm, followed by the 5th and 7th order products, which also cause significant harm. An example is shown in ***Figure 1***.

Because PIM amplitude becomes lower as the order increases, higher order products typically are not strong enough to cause direct frequency problems, but they usually assist in raising the adjacent noise floor. Once this raised noise floor crosses into the Rx band, it then has an open door into the base station (BTS). A standard PIM test will usually test for the 3rd order, because it is always the most powerful. The actual problem that exists within a site, however, may be 5th or 7th order PIM products that are causing the degradation in site perfor-

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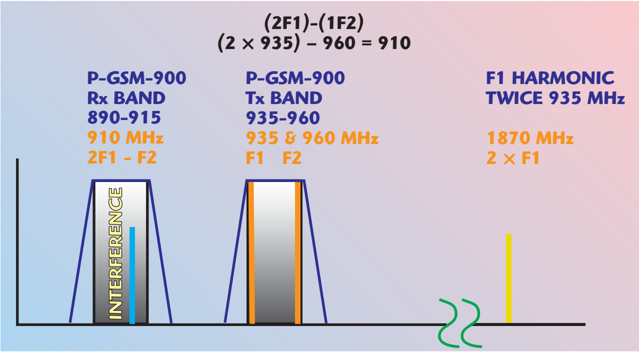

▲ *Fig. 2 PIM causing receiver interference at 910 MHz.*

mance. PIM products can be very wideband, covering wide swaths of frequencies.

PIM Calculation Examples

As shown in ***Figure 2***, a PIM example for the widely used 900 MHz band assumes two GSM carriers, one at 935 MHz and the other at 960 MHz. In this case, the 910 MHz 3rd order product is in the uplink band and the frequency of the F1 harmonic falls in the DCS 1800 band.

Three or More Carriers

All the calculations outlined have assumed that only two carriers are present. That is not the case in the real world. At the base station, one needs to consider the increase in susceptibility to multi-carrier-specific issues. When three or more carriers are involved, the calculations quickly become complex. The intermodulations created within a multi-carrier system often appear as a raised wideband noise floor. This is often referred to as a "shark's fin," as the BTS Rx filtering gives this noise a characteristic shape when monitored on the Rx path coupling ports.

IMPORTANCE OF LINE SWEEP TESTS AND PIM

Line sweep testing and PIM are very different tests. Both are extremely important and accurately measure a cell site's ability to provide service and perform optimally. Line sweeping measures the signal losses and reflections of the transmission system. PIM testing is a measure of construction quality and poor quality will result in self-interference.

PIM testing performance measurements are not relevant, unless accompanied by comprehensive line sweep tests. It is important to recognize that PIM test measurements performed on a transmission system that has poor microwave performance are irrelevant indicators of the transmission system performance. Unfortunately, not understanding how these tests relate to performance has not only resulted in compromised test data, it also has caused the need to re-test the systems repeatedly. In turn, connections and components are becoming increasingly overworked and greatly contribute to line sweep and PIM problems.

PIM requires both low system loss and good return loss (VSWR) to perform to an acceptable standard. If PIM testing is performed prior to line sweep testing, the operator may not be aware of the impedance characteristics of the transmission line. High insertion loss attenuates the PIM test signals, preventing the high power


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characteristics from reaching the very components that require this stringent testing. Poor return loss reflects a percentage of the PIM test signals back into the test set, causing some signal cancellation that can report a false positive. It is becoming increasingly common for poor line sweep performance to create a false "pass" of a PIM test.

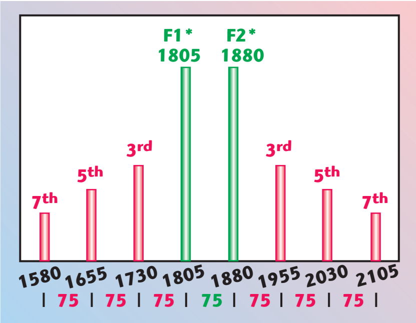
By performing the line sweep test prior to PIM testing, the operator can be confident the insertion loss and return loss data are at acceptable levels. This data ensures that the PIM test signals actually reach the components at the highest possible signal level, offering the most accurate indicator of true PIM performance. By constructing a system using modern low PIM practices, the need to break the transmission system back open will be minimized. If the lines are disassembled again to replace or clean a connector, the line sweep data will need to be repeated. One point that should be conveyed is that poor PIM may affect the site performance by lowering capacity, but poor return loss is a catastrophic failure and will take the site off air.

DCS1800 PIM ISSUES

Throughout Europe, the 900, 1800 and 2100 MHz communications bands are commonly used and are being upgraded for LTE deployment. With real estate at a premium, most cellular networks will share sites and infrastructure. The European frequency plans present some issues. DTV banding is very close to the cellular systems and several countries are expecting major interference challenges. Another common issue is that any faulty cable TV distribution amplifiers or lines that may be un-terminated can cause interference with a BTS receiver.

Another major problem is illustrated in ***Figure 3***. The 1800 MHz band produces 3rd order PIM in its own receive band. This is a very common occurrence for most cellular bands. It is also possible to create PIM that falls into the 2100 MHz receive band when a 3rd order PIM on the high side of the 1800 MHz band is present. In a distributed antenna system (DAS), any PIM generated by the DCS1800 band is certain to affect both receive bands, resulting in poor system performance. Where spread spectrum technologies are utilized, the PIM will be broadband in nature. These multi-banded systems will need to be constructed very well in order to perform under heavy subscriber traffic conditions.

Airports, sports venues and major tunnels may use a DAS where all operators' BTS signals are combined and share a common antenna and distribution system. The PIM performance of



▲ *Fig. 3 Carriers F1 and F2 with 3rd to 7th order products.*

these systems is critical, as any isolation enjoyed between carriers in the outside network will be lost. Also worth noting is that even high performance filtering will not fix linearity problems, as the PIM is generated on the common areas of the distribution system. When a PIM signal crosses into the Rx band, any filtering simply allows these signals to pass through to the receivers. The good news is that PIM testing can control these construction issues.

COMMON PERFORMANCE INDICATORS

BTS alarm conditions are designed to provide insight into performance issues. Many network operators are assuming that unfixable performance faults are due to poor PIM levels. It needs to be carefully considered if PIM can actually be a possible problem within the cell site. Unless the site has two or more transmitters on one feed line, self-generated PIM is unlikely. The BTS will offer indications of PIM performance, which is usually reported as an "Rx/Main diversity noise imbalance" alarm. This data indicates that the noise floor between the main line and the diversity line are different in level. All major BTS system manufacturers offer these alarm conditions, but different terms are used. If the feed line that carries the transmit signals has the raised noise floor, then PIM is highly suspected. External interference will be present on both the main and diversity feed lines. This interference, or raised noise floor, could be externally generated PIM and can be quickly isolated and identified by wilting (shutting down) one or more transmitters on the affected sector.

A cellular site that reports elevated Rx noise floor on both Rx lines (Duplex/Simplex) would indicate that the source is external. This is often a cable TV amplifier that is leaking RF power. The BTS receiver is very sensitive and can easily suffer from external noise that happens to cross into the receive band of the site. Another good example of this type of fault is problems caused by cellular jammers. Often this technology is employed without realizing the possible problems it can cause, especially if emergency calls are restricted.

SUMMARY

As subscribers utilize more high speed mobile devices, the performance issues of the cell system will grow at an even greater rate. This degradation in capacity and overall performance needs to be considered as network upgrades are made. PIM testing is fast becoming a commonly accepted test, much like impedance measurements. As technology advances, these performance measurements are becoming more critical. As new technologies are deployed and old technologies are phased out, the unique opportunity exists to ensure that critical areas of the infrastructure are capable of the performance required by these advanced communication formats. The performance engineering team will be responsible for multiple spread spectrum technologies. Having the right resources will be paramount to maximizing site and system efficiency as subscriber traffic increases. ■

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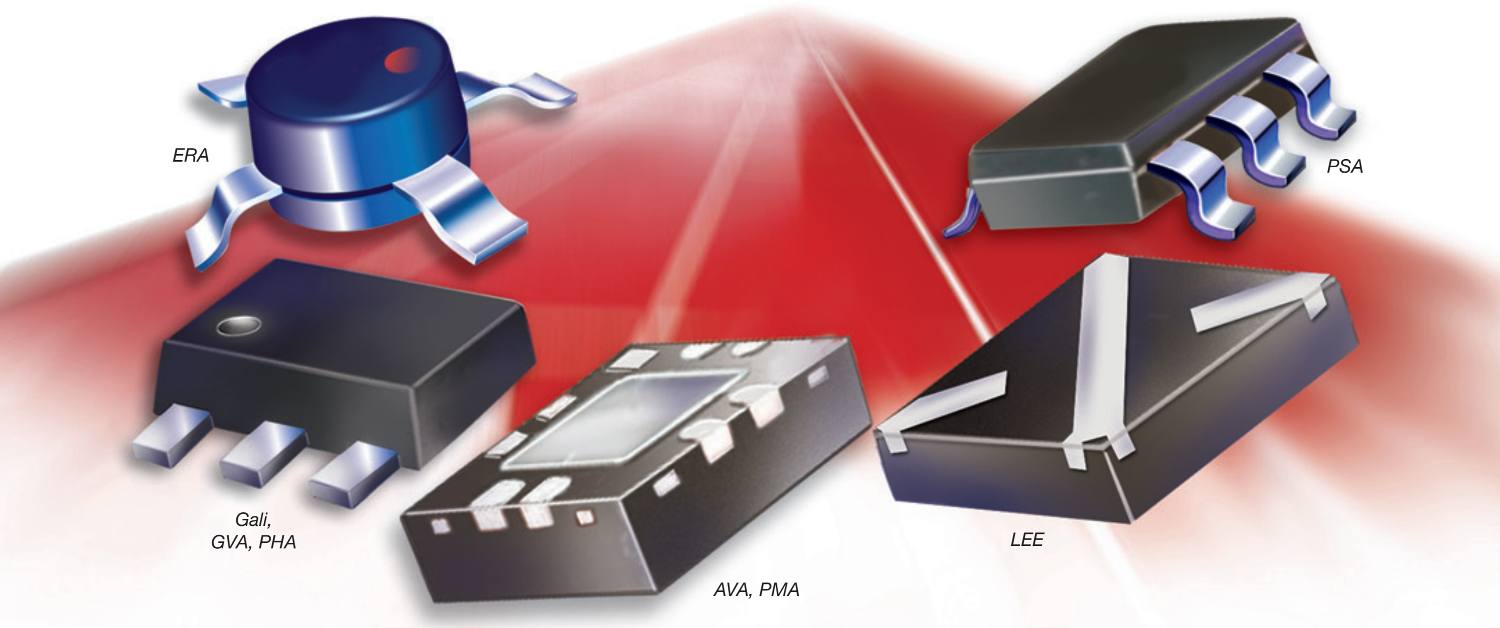

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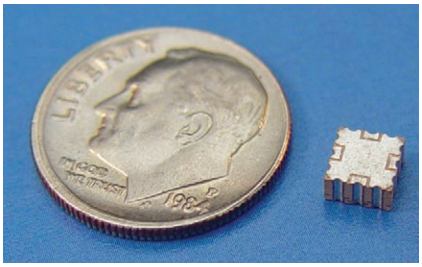
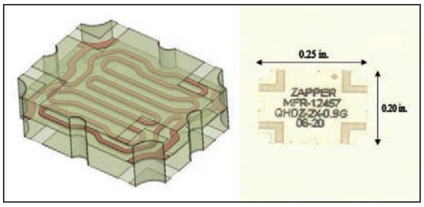
FLUOROPOLYMER COMPOSITE SUBSTRATE TECHNOLOGY FOR RF AND MICROWAVE INTEGRATION

The following article describes a process for microwave, multi-layer integrated circuits and micro-multi-function modules (MMFM™) based on fluoropolymer composite substrates called Multi-Mix®. The fusion bonding of multi-layer structures provides a homogeneous dielectric medium for superior electrical performance at microwave frequencies. The bonded layers may incorporate embedded semiconductor devices, etched resistors, passive circuit elements and plated-through via holes, to form a 3D subsystem enclosure that requires no further packaging. In fact, the structure is the package. The small-footprint, low profile units are rugged, lightweight and with the various external interfaces, make it compatible with most RF structures (see ***Figure 1***).



▲ *Fig. 1 Miniature quad hybrid coupler made with the Multi-Mix® process.*



▲ *Fig. 2 Sub-miniature quad 3 dB hybrid coupler.*

The process controls for the described method allow a low cost manufacturing approach that is suitable for high or low volume production. The platform strategy of MMFM modeling and simulation reduces engineering cycle time and enables the resulting product to be an economical solution for new circuit designs. Some of the benefits of the technology process include:

- High density circuit integration
- Industry-leading electrical and mechanical performance
- Improved quality
- Size and weight reduction
- Reduced cost
- High yield and full panel utilization
- Increased reliability over other techniques
- Adaptable for millimeter-wave applications.

Figure 2 shows an example of a sub-miniature quad 3 dB hybrid with low loss of 0.35 dB, high isolation of 20 dB, power handling of 30 W operating from 800 to 1000 MHz. The device has good amplitude and phase tracking in a surface-mount structure that can be handled

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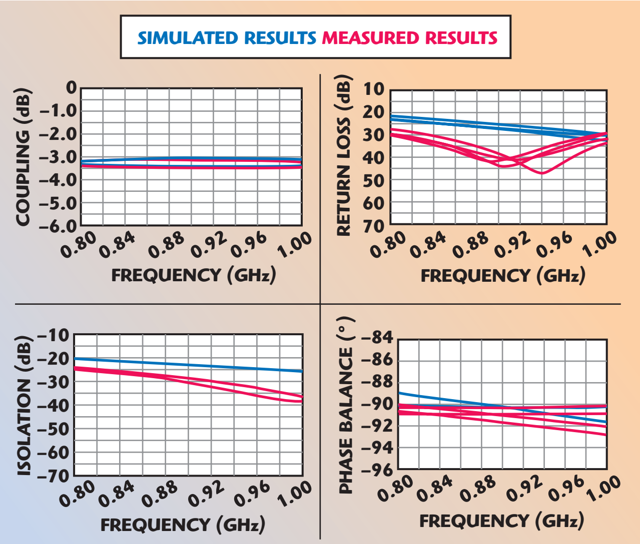
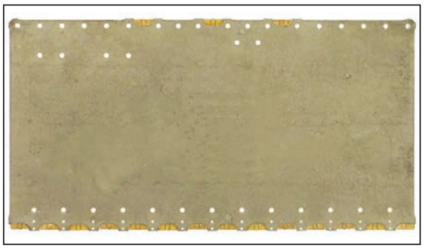
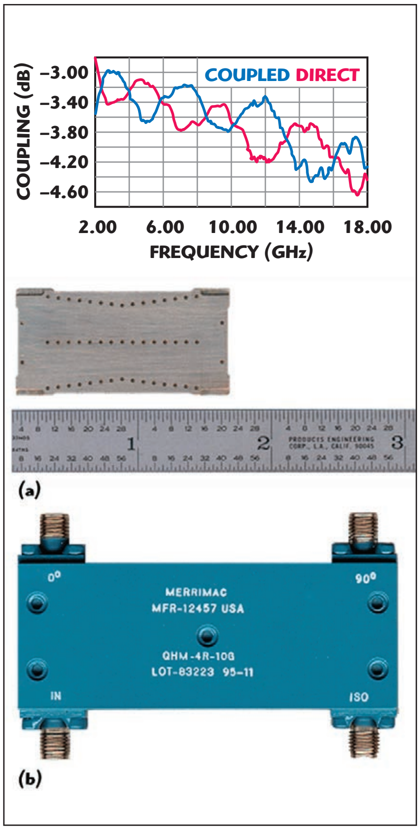


▲ *Fig. 3 Simulated and measured results for quad 3 dB hybrid coupler.*



▲ *Fig. 4 Filter bank.*



▲ *Fig. 5 Quad hybrid multi-layer construction and performance data (a) compared to traditional design (b).*

via tape and reel. ***Figure 3*** shows the performance graphs for key parameters, including coupling, isolation, return loss and phase balance.

The homogeneous medium of the process is also well-suited for the beamformers found in applications, such as phased array antennas, where the stability of the material allows for the addition of low Dk foams to form dipoles and patch antennas. In addition, process support for surface-mount components, such as circulators, resistors and other components, can be added to create a highly integrated structure.

One example of the size and weight reduction made possible through this process is a S/C-Band multi-channel filter bank shown in ***Figure 4***. In this filter, six multi-layer boards comprise the assembly. There are 14 contiguous filter channels distributed over three circuit substrates separated by three dielectric and ground plane spacers. After fusion bonding and edge plating, the finished assembly is approximately 3" × 4" × 3/8" and weighs less than 2 ounces. The multi-layer package replaced a considerably larger and heavier solution. The weight is now measured in ounces as opposed to pounds.

THE PROCESS IN DETAIL

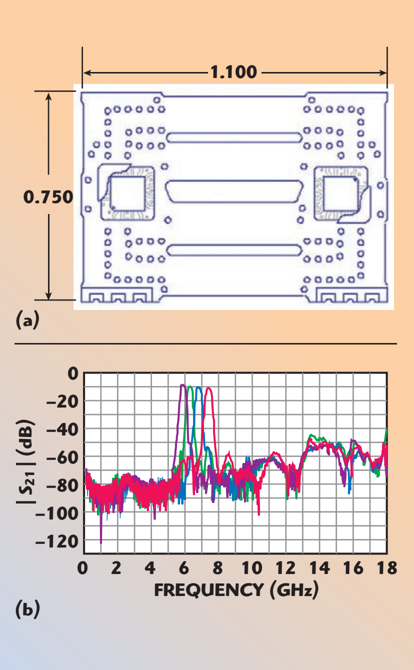
The process begins with commercially available polytetrafluoroethylene (PTFE) composite, copper-clad laminate material having inherently low dielectric loss and stable microwave properties. A low Z-axis coefficient of thermal expansion (CTE), close to that of copper and aluminum, ensures excellent reliability of plated-through holes and blind and buried vias. Controlled XY-plane thermal expansion, together with a low modulus, affords excellent reliability of surface-mounted devices in the most severe thermal cycling and thermal shock environments. Further, a low and uniform thermal coefficient of dielectric constant, coupled with the low CTE, result in consistent electrical performance over a wide operating temperature range and operating frequency. ***Figure 5*** shows a traditional quad hybrid compared to one produced with the Multi-Mix process, which realized a 18× reduction in volume.

Complex microwave circuit patterns and transmission-line geometries may be chemically photoetched on the copper, maintaining dimensional tolerances of ±0.0005 inch. The incorporation of thin metal-film etched resistors is under qualification and will be available in the near future. Indexing holes for layer-to-layer alignment in assembly are precision machined or drilled into each board. Layer-to-layer plated-through holes (blind and buried vias) may be realized with a minimum diameter of 0.008 inch and aspect ratios of 6:1. Stacked layers can be fusion bonded directly to copper or aluminum plates offering exceptional thermal dissipation for the structure.

Active device attachments are embedded in cover layer cavities to provide environmental protection and allow pre-cap inspection and test. The pick and place of discrete components can be demonstrated on array panels up to 12 × 18 inches, with the potential to accommodate flip chip packages and ball grid arrays. Operating-frequency capability of current circuit designs range from VHF through Ka-Band. Properly sized and spaced blind and buried vias are used between ground planes to isolate lines and other RF structures within a ground plane. The ability to offer a high degree of isolation within a given layer allows a designer to run various signal traces on the same layer, reducing size without the worry of cross-talk or unwanted resonance. In fabricating a bonded multi-layer assembly, the stacked layers are placed in a fixture to which carefully controlled, uniform pressure and temperature is applied to meet the substrate fusion bonding requirements. After cooling and removal from the fixture, edge plating for EMI shielding and ground-plane integrity is performed. Finish plating layers for environmental protection include annealed matte tin, tin/lead and electrolytic nickel/gold.

PLATFORM STRATEGY OF MODULE ARCHITECTURE

Whether it is for military or commercial applications, improved elec-



▲ *Fig. 6 6 to 7.5 GHz multi-layer switch filter bank footprint (a) and performance data (b).*

tronic design automation (EDA) modeling/simulation tools have been developed for microwave and millimeter-wave circuits and packages in order to support the RF/microwave circuit designer. Integrated mathematical, electromagnetic, thermal and mechanical modeling capabilities allow total package analysis to be performed prior to actual hardware fabrication, resulting in rapid turn-around and lower-cost prototypes.

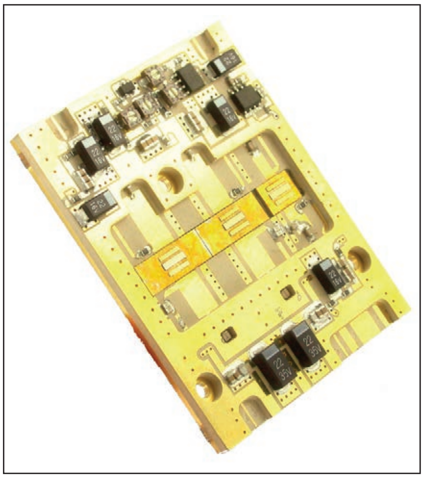
It is important for RF designers to have access to simulation models that accurately represent the electrical behavior of the physical module. The module architecture described in this article utilizes a structural template, which overlays outlines and creates common interconnection paths. Process steps are based on design guidelines for each layer of a multi-layer microwave assembly. Actual test data for functional layer blocks are stored in a pre-designed library. Ansoft HFSS software has been utilized to provide the designer with access to S-parameter data for the purpose of predicting system performance, thus permitting co-design database availability. Experience with this approach thus far has been met with a high level of positive feedback. Complete design concepts from schematic to circuit layout and test may be performed within a single operating environment. Functional components may be inserted utilizing drag-and-drop techniques from ADS for insertion into system designs, which can be tailored for a specific application.

MULTI-LAYER INTEGRATED CIRCUIT CONSIDERATIONS

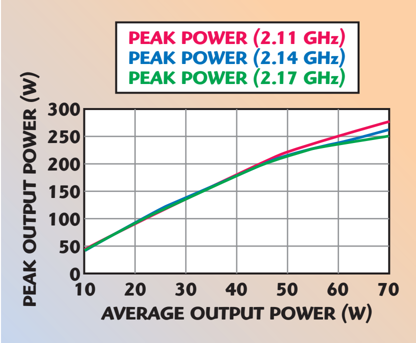
To meet rigid system specifications, a multi-layer integrated circuit process for RF/microwave applications must maintain tight dimensional tolerances in the fabrication process to enable circuits with reproducible characteristics. Such a process should lend itself to an almost unlimited number of microwave component and subsystem product designs, including lowpass, highpass and bandpass filters, power dividers, couplers, delay lines and impedance transformers. These RF functional blocks will allow a designer to create more complex antenna feed distribution networks, array beamformers or comparators for monopulse receiving systems. Integration of beam-lead receiver or detector diodes in singles, pairs, quads or multi-ring configurations enable the manufacture of mixers and modulators to satisfy a broad range of application requirements in radar, electronic warfare and commercial communications systems. As an example, ***Figure 6a*** shows the footprint and ***Figure 6b*** the performance data of a multi-layer switch filter bank used in various applications.

Support for additional signal control and power conditioning devices, such as digital attenuators, limiters and switch matrices that may be prepackaged with their driver circuitry and embedded in cover layer cavities within the multi-layer assembly, allows designers to further reduce the physical footprint of the overall module. Interfacing each device with its necessary RF transmission lines and video/bias traces to external connectors is accomplished during the product design and layout phase. Connectorized assembly products typically utilize SMA, SMP, SSMP and SSSMP along with Corning Gilbert's line of connectors.

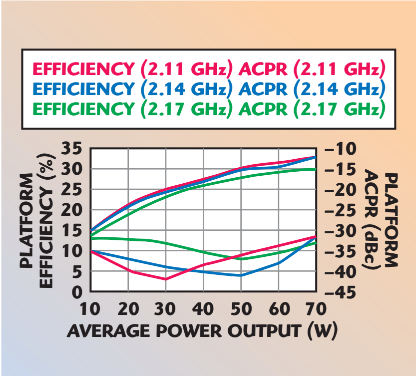
Active devices, including amplifiers, oscillators, frequency multipliers and dividers, can also be integrated in this manner. An example of this higher level integration is an amplifier module shown in ***Figure 7***. High



▲ *Fig. 7 Integrated power amplifier module.*



▲ *Fig. 8 Peak power vs. average power.*



▲ *Fig. 9 Efficiency and ACPR vs. average output power for UMTS GaN 200 W Doherty platform.*

isolation is maintained between parallel conductors and between adjacent multi-layers by following established design guidelines and using buried vias that act like RF fences between traces. The amplifier uses a Doherty combiner and operates from 2110 to 2170 MHz. It has 40 dB minimum power gain, ± 1.0 dB maximum gain flatness, 200 W peak and 50 W average output power with 27 percent minimum efficiency and ACPR of -30 dBc maximum. The pallet size is 3.45" × 2.65." ***Figures 8*** and ***9*** show the performance of the amplifier module for output power, efficiency and ACPR for single carrier TM-1 6.5 dB P/A ratio at 0.01 percent probability with DPD not applied.

Applications that have used the older coaxial and waveguide microwave component technologies will experience the most dramatic improvements from a multi-layer integrated module approach. However, even more recent system designs using conventional stripline and microstrip hardware are realizing the advantage of increasing performance by combining functions to reduce overall size. Increasing circuit density can improve electrical performance and lead to reduced system cost by eliminating parts, especially cables and connectors, and shrinking the overall footprint required.

The key military applications that will benefit from innovations in micro-multi-function modules technology are the microwave systems on airborne, space and land-based radar and electronic warfare platforms. Reduced size and weight translates directly into increased payload and performance. Many millimeter-wave smart munition sensors are candidates for this packaging approach, as well. The micro-multi-function modules technology described in this article has been fully qualified for space under various programs and meets the requirements of various quality standards for military hardware.

SUMMARY

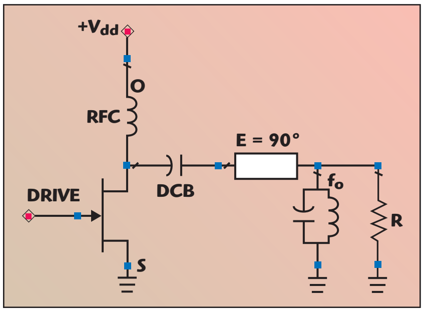
The Multi-Mix micro-multi-function module technology described in this article is being used for highly integrated assemblies. These include frequency converters, T/R modules, beamformers, radiating elements and advanced switch matrices. The belief is that the use of this technology will allow designers greater flexibility and the ability to add further levels of integration in the same footprint currently being utilized. The platform also provides for low loss, highly reliable structures without the sacrifice of cost and size.

Multi-Mix® is a patented technology developed at Crane Aerospace & Electronics, Merrimac Industries location. ■

High Efficiency L-Band GaN Power Amplifier

This article illustrates the design and development of a 60 W pulsed Class F power amplifier over the frequency range of 1.25 GHz ± 50 MHz. The power amplifier has been designed and fabricated using a GaN HEMT transistor. This amplifier shows a competitive drain efficiency of 70 percent with a pulse output power of 60 W over the bandwidth of 100 MHz and a compressed gain of 15 dB. It has been fabricated and tested using an alumina substrate (ε_r=9.9) with three layers of metallization (Cr-Cu-Au) and the measured result is congruent with the simulated results. A comparison of linearity performance between a Class AB and Class F amplifier using the same GaN HEMT device is also presented.

The rapid growth of wireless communications, as well as space-borne systems, leads to the increasing demand of low power, high efficiency systems. High efficiency is the prime requirement for any space-qualified transmitter or wireless communication systems. Higher efficiency means greater output power with reduced power dissipation. Achieving higher efficiency necessitates the active device to run into heavy saturation, leading to highly nonlinear behavior. In contrast to linear classes of amplifier (Class A, B, AB), which have efficiencies of the order of 40 percent, nonlinear switched mode amplifiers (Class D, E, F) offer efficiency better than 60 percent. Among the switched mode schemes, Class E power amplifier requires a fast switching signal, which is not required in Class F operation. Class F is preferred over Class E due to large switching stress on the active device in Class E operation. This power amplifier will be used as the final power stage of the solid-state power amplifier (SSPA) for the Chandrayaan-II mission.



▲ *Fig. 1 Schematic of a Class F amplifier.*

GENERAL THEORY OF CLASS F AMPLIFIER

A Class F amplifier is a reduced angle amplifier with load harmonic tuning to shape the drain voltage and current in a way that they do not coincide or rarely coincide with each other, thus greatly reducing the power dissipated by the device. Theoretically 100 percent drain efficiency can be achieved using an infinite number of harmonic traps. The load must be a short at even harmonics and open at odd harmonics.[1] Thus the drain voltage approximates a square waveform and the drain current, a half wave sinusoid. The two waveforms get displaced in the time domain so as to ensure zero drain current with drain voltage peaking and vice versa. As shown in ***Figure 1***, the output network consists of a quarter wavelength transmission line and a parallel LC tank circuit tuned to resonate at f_0. At f_0, a pure resistive load R is seen by the drain as the tank circuit offers infinite impedance at f_0. At even harmonics, the tank becomes a short and the quarter wave transformer appears to be of length of $n\lambda g/2$, (g being the guided wavelength of the transmission line), thereby providing a short at all even harmonics. This results in a half wave rectified sinusoid drain current. For odd harmonics, the output tank becomes a short

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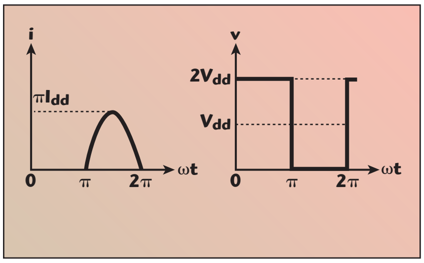
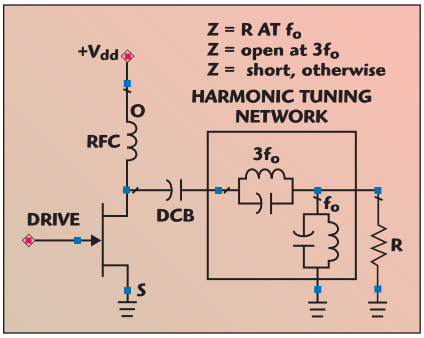


▲ *Fig. 2 Drain voltage and current waveform of an ideal Class F amplifier.*

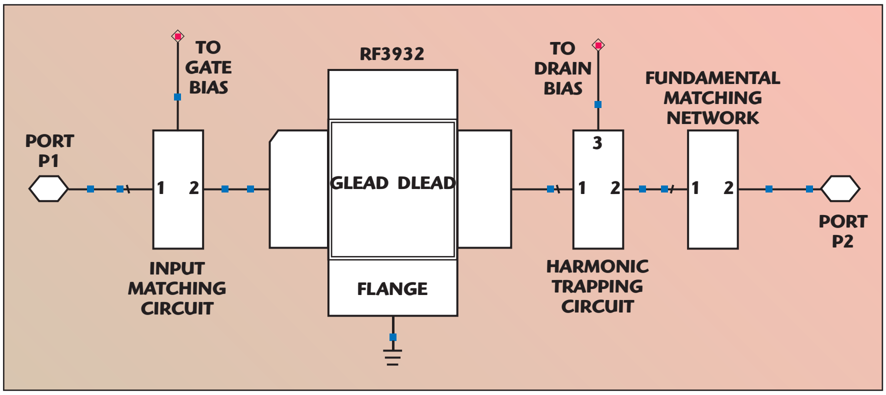


▲ *Fig. 3 Third harmonic peaking.*

again and transmission line appears to be of length (2n + 1) λg/4, thereby transforming the short to an open circuit to the drain. The drain voltage contains only the odd harmonics and results in a square waveform as represented in ***Figure 2***. All the harmonics contain either voltage or current and not both, therefore no harmonic power is generated by the active device. This confirms the realization of 100 percent efficiency, with the assumption that the active device is an ideal switch with no loss and zero output drain capacitance.

PRACTICAL DESIGN CONSTRAINTS

In practice, only a limited number of harmonic terminations can be implemented. The active device has a finite bandwidth, which limits switching speed. This also limits the number of harmonics present. Thus, the design of the output network is implemented considering a tradeoff between efficiency and size. The maximally flat description[2] shows that the lower order frequency components in the Fourier representation of a signal have the most effect on shaping the signal. Thus for practical design, only the second and third order harmonics are considered. In that case, the output network replaces the quarter wave transformer by another parallel tank circuit tuned at $3f_0$ as shown in ***Figure 3***. Realizing this circuit with lumped components would introduce losses inherent to the high frequency lumped components. Instead, by taking advantage of impedance transformation properties of quarter wave long microstrip stubs, an equivalent circuit can be realized using a planar microstrip network.



▲ *Fig. 4 Schematic of a Class F power amplifier.*

TABLE I

OPTIMUM INPUT AND OUTPUT IMPEDANCES OF THE DEVICE

Frequency (GHz)	Z_S	Z_L
1.25 GHz	0.44 - j 1.98	5.096 + j 3.75

DESIGN OF CLASS F AMPLIFIER

An RFMD GaN HEMT device RF3932 has been used to design this amplifier. Using the nonlinear model of the device, the optimum input and output impedance of the device has been found using the ADS load-pull utility. The optimum input and output impedance of the device as found from load-pull simulation are shown in ***Table 1***. ***Figure 4*** shows the schematic

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- *THAAD*
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circuit of the overall amplifier. The input matching circuit of this amplifier is conventional and serves the general purpose of extracting maximum gain out of the device. The output matching circuit of the power amplifier consists of two parts: the harmonic trapping circuit and the fundamental matching circuit. The harmonic trapping circuit, as shown in ***Figure 5***, consists of a short circuited stub (TL2) of length 90° at 1.25 GHz connected to the drain port. This stub presents a short circuit at the second harmonic and also provides the DC drain bias voltage. Thus the second harmonic is added to the drain current, thereby flattening the drain current waveform to approximate a half sinusoid signal. The series lines TL1 and TL3 along with Tee1 constitute a track length of 30° at 1.25 GHz. This, combined with an open circuited stub (TL4) of length 30° at 1.25 GHz, provides an open circuit at the third harmonic. Thus the third harmonic is peaked and added to the drain voltage, giving it the shape of an approximated square wave. The harmonic trap circuit is then followed by a fundamental matching circuit to ensure optimum power match between the drain impedance and the resistive load at f_0. ***Figure 6*** shows the drain impedance provided by the harmonic trapping circuit. The theoretical design is carried out for a single frequency, so an initial performance optimization was carried out to achieve a satisfactory simulated performance over the band of interest. Subsequently, a yield analysis was carried out to assess the initial yield and thereafter the yield was optimized to more than 85 percent to ensure that

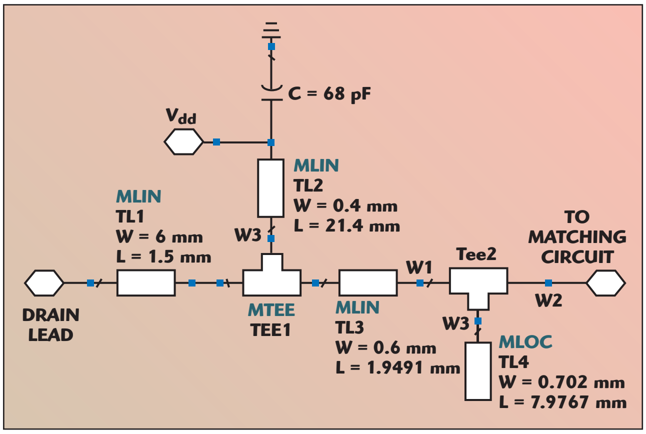

Fig. 5 Load harmonic trapping circuit.

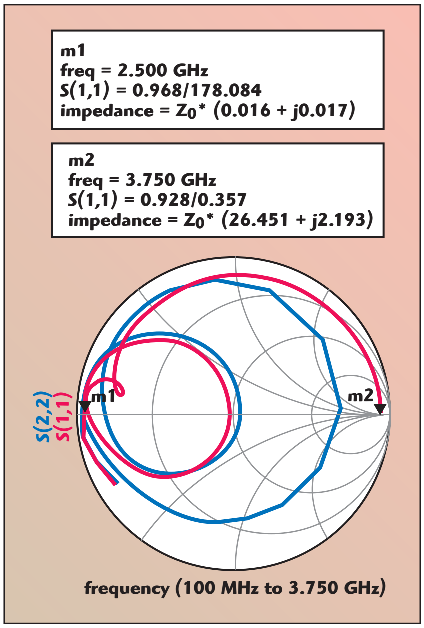

Fig. 6 Drain impedance over frequency.

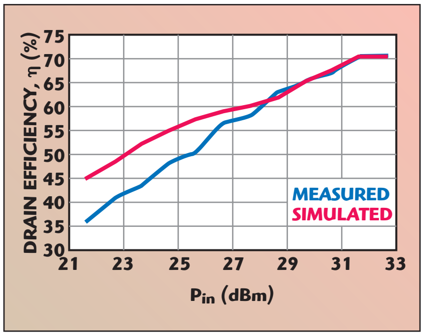

Fig. 7 Drain efficiency (%) of the amplifier.

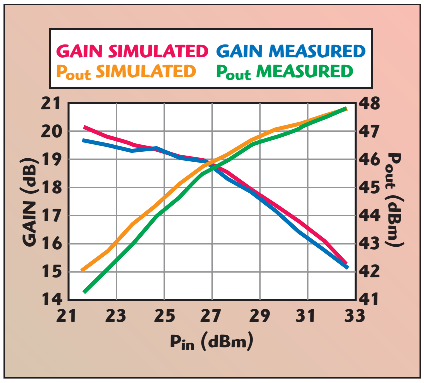

Fig. 8 Gain (dB) and P_{out} (dBm) of the amplifier.


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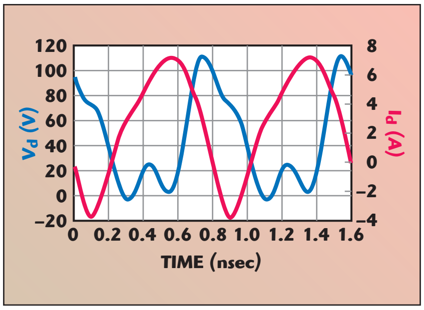
the design sensitivity is within ±20 micron with respect to the nominal value. Momentum simulation for EM analysis has also been carried out to consider parasitic coupling effects in the circuit.

DESIGN VALIDATION

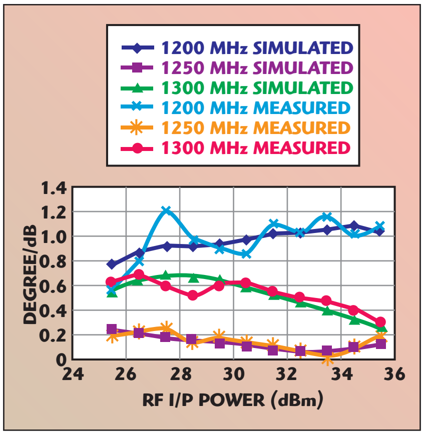
The amplifier, designed as per Class F approach, has been fabricated using an alumina 25 mil thick substrate $\varepsilon_r = 9.9$) and was tested for a pulsed RF condition, with a pulse width of 80 µs and a duty cycle of 24 percent. However, the amplifier can also be operated in CW condition with proper thermal design as the device is rated for continuous operation. The simulated and test results of the amplifier are shown in ***Figures 7*** to ***9***. Also, a comparison of linearity performance between a Class AB and a Class F amplifier is presented in ***Figures 10*** and ***11***.

OUTPUT POWER AND EFFICIENCY

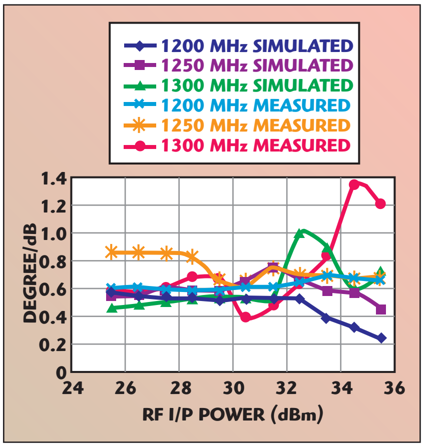
The test results of the implemented Class F amplifier show an output power of 47.8 dBm (60 W) at 70 percent drain efficiency. The active device RF3932 has the capability to produce 70 W power at hard saturation (4 dB compression), if biased at its nominal quiescent voltage and current rating (48 V, 220 mA). To ensure



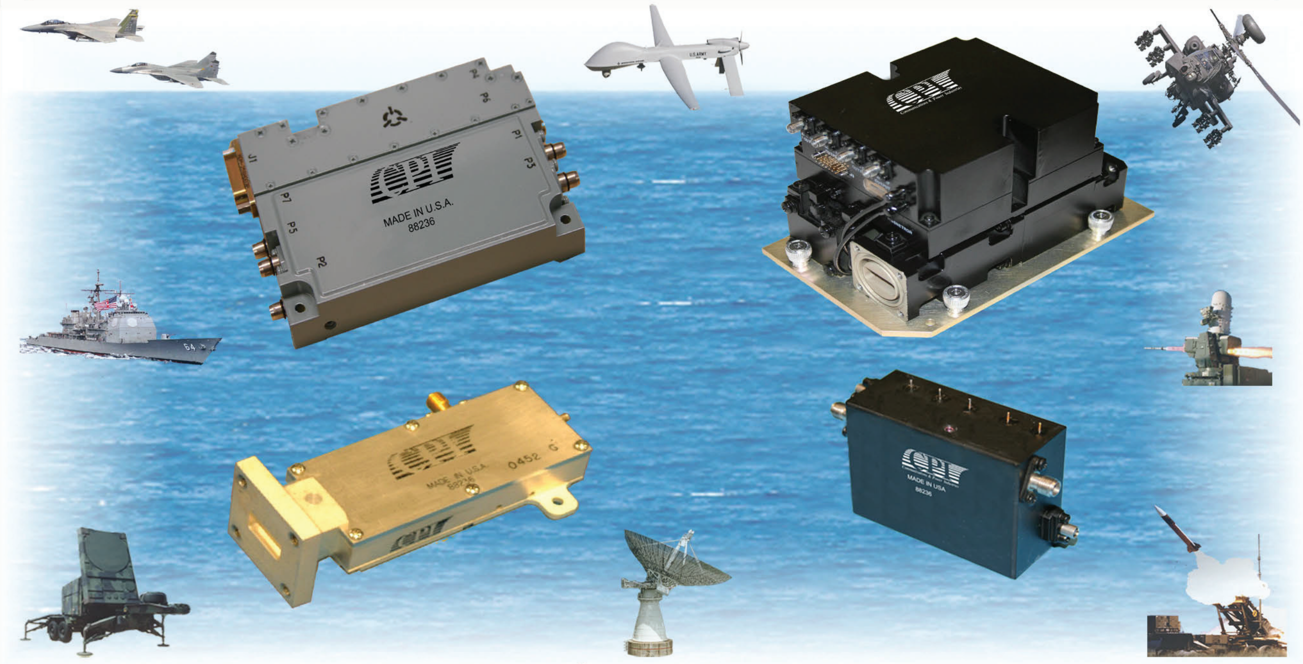
▲ *Fig. 9 Drain voltage and current waveform.*



▲ *Fig. 10 AM to PM conversion of Class AB amplifier.*



▲ *Fig. 11 AM to PM conversion of Class F amplifier.*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reliability over a long period of satellite operation, stress on the device is reduced by applying a drain bias of 45 V. Hence the saturated power of the device is reduced to 60 W, without compromising the efficiency. Figures 7 and 8 represent the drain efficiency, output power and gain of the amplifier, respectively, at 45 V drain bias as a function of swept input power.

DRAIN VOLTAGE AND CURRENT WAVEFORM

Figure 9 represents the voltage and current waveform of the GaN amplifier, probed at the drain lead of the packaged device. As expected in Class F operation, the amplifier has drain voltage and current waveforms such that their peaks occurred at different time, thereby reducing the power dissipation of the amplifier and increasing its efficiency. ***Table 2*** represents the overall performance of the presented 60 W Class F power amplifier.

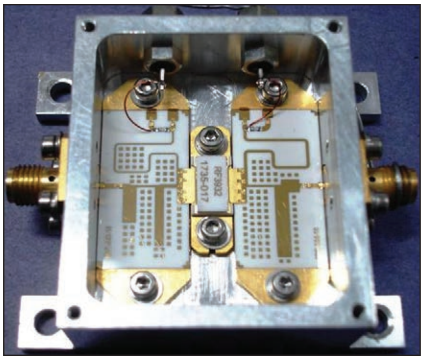

Fig. 12 60 W Class AB amplifier.

Comparison of Linearity Performance

To compare the linearity performance between Class AB and Class F amplifiers, a Class AB amplifier is also designed and fabricated using the same active device RF3932, with a goal to achieve the same specification as in Table 1 (except the efficiency, which is bound to be lower in a Class AB operation). The linearity performance of the two amplifiers was measured in terms of the AM to PM conversion function (degree/dB) for both the amplifiers. Figures 10 and 11 represent the simulated and measured AM to PM conversion of the Class AB and Class F amplifiers. As expected, in Class F amplifier, higher efficiency is achieved, compromising the linearity of the amplifier. The Class F amplifier implemented exhibits a worst-case phase variation of +7.5°/dB to –4°/dB over the entire frequency band of 100 MHz, as compared to a phase variation of 1.2°/dB for the

TABLE II

OVERALL PERFORMANCE OF THE AMPLIFIER

Parameters	Specifications	Achieved Results
Frequency	1.25 GHz ± 50 MHz	
O/P Pulsed Power	60 W	
Gain (3 dB compression)	~16 dB	~15 dB
Gain Flatness	±0.5 dB	±0.6 dB
Input Return Loss	better than 12 dB	
Output Return Loss	better than 12 dB	better than 10 dB
Efficiency (η)	70%	

TABLE III

COMPARISON OF REPORTED L-BAND POWER AMPLIFIERS

Make	Caltech	UCSB	Alcatel	SAC, ISRO, this work
Frequency (GHz)	1.22	1.0	1.5	1.25
Power (W)	74	13	10	60
η (%)	67	58	66	70
Gain (G_{2dB})	12	14	13	15
Class	$E/F_{odd,2}$	D	F^{-1}	F
Device	Motorola Si LDMOS MRT284	Si LDMOS PTF10 135	GaAs HBT	RFMD GaN HEMT RF3932
Size (cm × cm)	5 × 3.5	6 × 20	Not disclosed	5 × 3

Class AB amplifier. The fabricated hardwares of the 60 W Class AB and Class F power amplifiers are shown in ***Figure 12***, respectively. ***Table 3***[8] shows a comparison of the performance reported in the literature for high efficiency amplifiers operating in the same frequency region with that of the present Class F amplifier.

CONCLUSION

A 60 W power amplifier, based on Class F architecture at 1.25 GHz ± 50 MHz, using a packaged GaN HEMT device, RF3932, is presented. The test results are showing very close match with the simulated results and validates the design of the 60 W power amplifier with 15 dB compressed gain and 70 percent drain efficiency. The design utilizes a planar microstrip line load network, with harmonic traps for second and third harmonics only. The nonlinearity of the Class F amplifier is higher than the Class AB amplifier, which is confirmed by comparing the AM to PM conversion test results. ■

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Suman Aich *received his bachelor's degree in electronics and communication engineering from IIEST, Shibpur, WB, India, in 2008. Since September 2008, he has been working in SAC/ISRO as a Microwave Passive and Active Circuit Designer on pulsed SSPAs and transmitters for microwave remote sensing payloads. His research interests include the design of high efficiency transmitters and active and passive microwave components.*

Direct Measurement-based Modeling of Ultra-low Resistance Passive Components

This article presents a methodology for modeling the resistance of MIM capacitors, directly from measured S-parameters, using an ultra-low impedance measurement known as the "S_{21}-shunt" technique. It leverages from the work previously introduced in the modeling of through-wafer VIAs. Model parameters are determined using slope and intercept methods directly from measured data that is acquired on "series-shunt" configured test structures, following on-wafer SOLT calibration. Errors attributable to probe contact resistance (PCR) and its associated variability are eliminated through application of the presented methodology.

Metal-insulator-metal (MIM) capacitors, (MIM caps) have played a vital role in the design of a wide variety of MMIC circuits, particularly where low loss/high-Q is a critical design requirement. Because of their ease of fabrication, they can be found in the design kits of both silicon and compound semiconductor (GaAs as well as GaN) technologies. When used as matching elements in a critical RF signal path, such as in the output network of a power amplifier (PA), the resistance of the MIM has a direct impact upon the achievable gain and PAE. When used in filtering applications, the resistance of the MIM directly affects the achievable Q of the associated network. Consequently, the accurate determination of the series resistance of the MIM is a critical requirement for accurate circuit design. If the MIM is to be used in a shunt configuration (to RF ground), then the same requirement holds with respect to modeling of the associated substrate via or (through) substrate via (SVIA).[1]

TABLE I

TEST STRUCTURE DESIGN TYPES

Test Structure Name	*Layout Config.*	*Measurement Type*
"Series"	2-Port	Transmission
"Shunt"	1-Port	Reflection
"Series-Shunt"	2-Port	Transmission

MEASUREMENT PROBLEMS AND SOLUTIONS

Determination of the series resistance of MIM capacitors via "standard" S-parameter measurement methods has been proven to be a long-standing problem, primarily due to: (1) the ultra-low impedances presented by the DUT, (2) the high degree of accuracy that is required in order to resolve the difference between the resistive and reactive components and (3) the inability to resolve the finite resistive contribution due to probe contact. Standard S-parameter measurement-based attempts at characterization of ultra-low resistance passives typically utilize test structure designs in which the DUT is placed in either the series or shunt configuration, as defined in ***Table 1***.

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The characteristics of the device are thus determined via analysis of S_{21} (transmission), or S_{11} (reflection) data, respectively. The accuracy associated with either type of measurement differs according to the ability of the VNA to resolve the real and imaginary components of low level test signals within the residual (post calibration) dynamic range. Depending upon the VNA architecture, the resulting "phase accuracy" is frequency dependent, and is typically maximized (for a given measurement type) at minimum IF bandwidth, under low power RF drive.

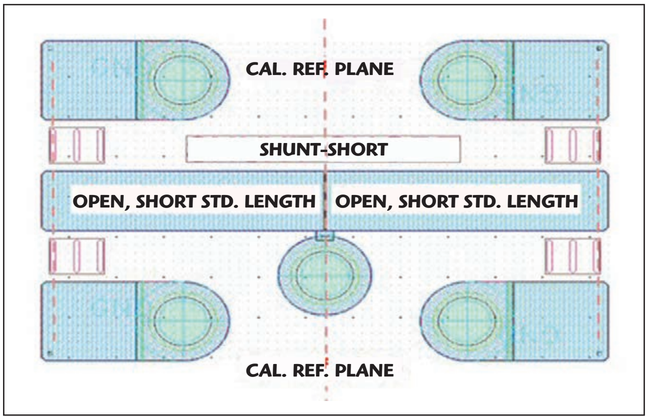


Fig. 1 Series-shunt configured SVIA.

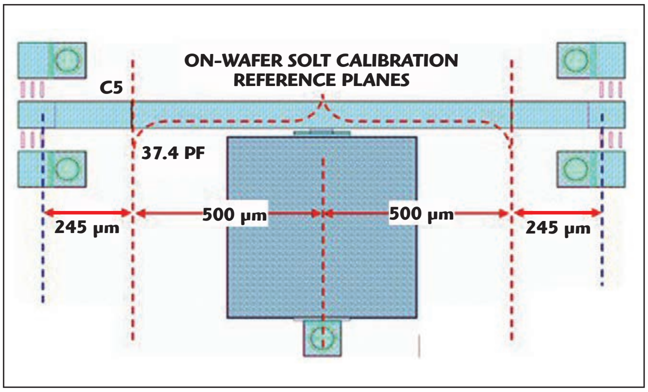


Fig. 2 "Series-shunt" configured MIM cap.

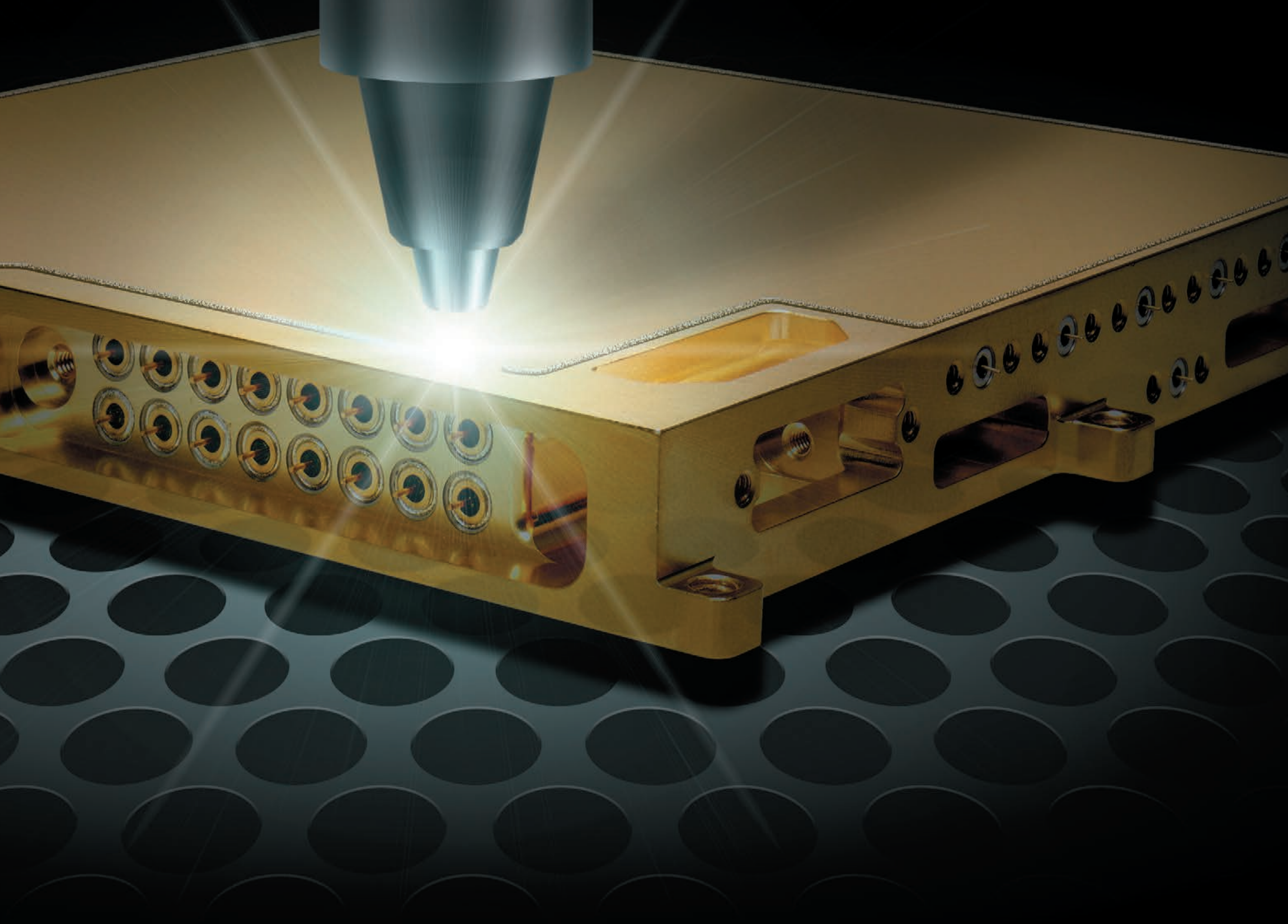
A finite resistance results when the RF probes come in contact with the launch lines of the test structure. The resistance is the result of the work function associated with the dissimilarity in metal systems. This contact resistance (typically on the order of 30 m-Ω < PCR < 60 m-Ω) cannot be removed through the process of calibration, and is always present whenever a one- or two-port measurement is made.[2,3]

Repeatability of probe placement introduces variability in terms of the PCR, which prevents the accurate determination of the statistical characteristics of the underlying series resistance. The problem of (RF) probe contact (and its associated variability) is resolved by using test devices designed in the "series-shunt" configuration, while taking advantage of a special condition of the transmission measurement which arises when measuring shunt resonant devices.

TEST STRUCTURE DESIGN

Layouts for "series-shunt" configured SVIA and MIM cap test structures, suitable for high frequency (> 50 GHz) on-wafer RF characterization, are shown in ***Figures 1*** and ***2***. Both test structures incorporate fixed length launchers, which feature wideband CPW-to-microstrip transitions and probe indexing markers at both ports 1 and 2.

The SVIA test structure is designed such that the physical via is connected directly to the measurement reference plane at the point where the ends of the launch (transmission) lines interconnect. This design configuration was chosen in order to validate that de-embedding is not necessary. The MIM cap test structure incorporates capacitors, defined as square geometries in order to tie the estimation of resistance directly to measured process (PCM) specifications. In the case where MIM caps are defined using two-level metal processes (typical of GaAs and GaN technologies), the sheet resistances associated with the top and bottom plate metals are the only factors that need be considered. In silicon technologies, however, one needs to also consider how to reconcile the resistance associated with the

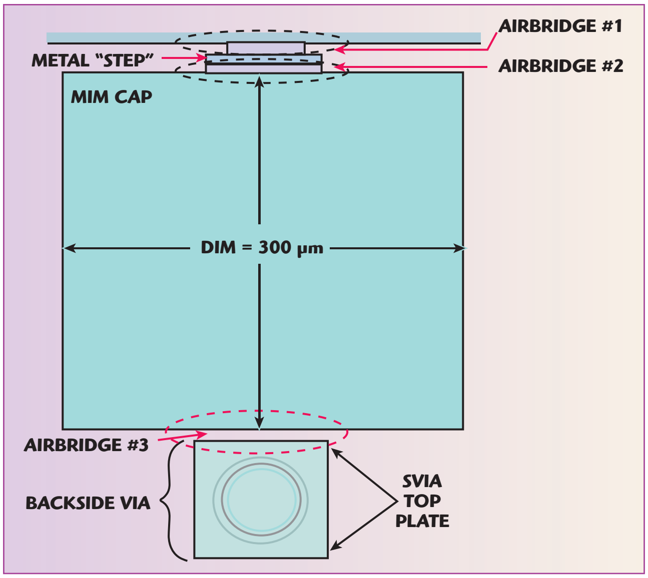


use of multiple via "posts" in the interconnection of the top plate.[4]

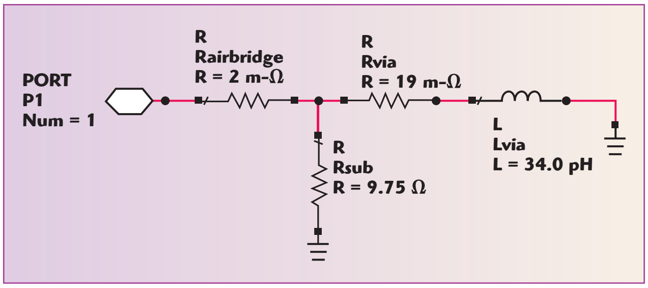
The MIM cap test structure utilizes the identical launch at both ports. However, it is intentionally embedded within an additional 1 mm of (transmission) delay in order to test the validity of the Thru standard based de-embedding methodology. Each test structure is designed such that its size varies according to the "insertion length" of the DUT. In this manner, de-embedding with a common set of (embedding) transmission line characteristics is facilitated. A detail view of the MIM cap, highlighting the sources of residual measurement resistance is shown in **Figure 3**. The detail shows the use of a thick airbridge metal to connect the MIM cap to the transmission line, as well as to the top of the SVIA. An estimate of the resistances associated with all of the metal interconnects is provided in **Table 2**.

EQUIVALENT CIRCUITS/ MODELS

The equivalent circuit for the SVIA is defined using ideal lumped-element equivalent-circuit (LE-EC) elements as shown in **Figure 4**. Similarly, the equivalent circuit for the shunt-connected MIM cap is defined in terms of ideal LE-EC elements, as is shown in detail in **Figure 5**. For analysis purposes, a low frequency approximation simplification of the MIM Cap LE-EC is made by combining each



▲ *Fig. 3 "Series-shunt" MIM cap detail.*



▲ *Fig. 4 SVIA lumped element equivalent circuit.*

TABLE II

MIM CAP INTERCONNECT RESISTANCE ESTIMATION

Structure	Width (μm)	Length (μm)	# sq.	Resistance (m-Ω)
Airbridge #1	60	10	0.167	0.833
Metal Step	75	5	0.067	0.333
Airbridge #2	90	10	0.111	0.556
Airbridge #3	90	5	0.056	0.278
Via Top Plate	100	100	0.360	18.000
			SUM	20.000
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Rsh #1	5	(m-Ω/sq)		
Rsh #2	50	(m-Ω/sq)		

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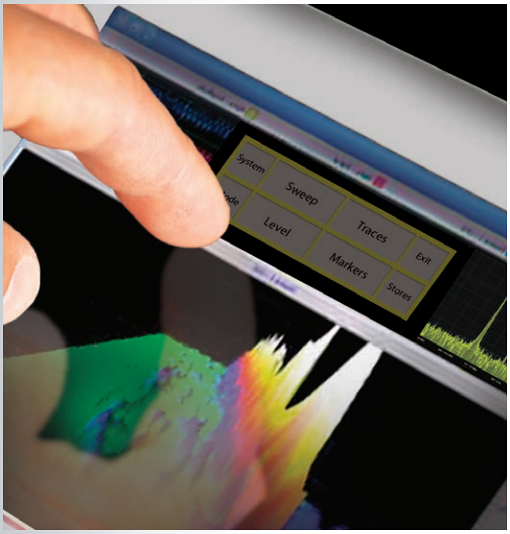

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Dual, 16-bit, 20/40/65/80 MSPS ADC. 16-bit accuracy at 80 MSPS. Integrated error correction for dc offset, gain, channel phase mismatch. SFDR 80 dBc @ 200 MHz input; 112 mW power per channel @ 80 MSPS.

AC Performance and Power Consumption at 80 MSPS Sample Rate

Part Number	Channels	Resolution (Bits)	Power/ Channel (mW)	SFDR @ 200 MHz Input (dBc)	SNR @ 200 MHz Input (dBFS)
AD9609-80	1	10	83	75	61.5
AD9629-80	1	12	93	95	70.9
AD9649-80	1	14	95	92	73.6
AD9266-80	1	16	124	93	76.6
AD9265-80	1	16	254	94	79.6
AD9204-80	2	10	71	75	61.1
AD9231-80	2	12	80	92	70.9
AD9251-80	2	14	82	92	72.5
AD9269-80	2	16	112	90	76.3
AD9268-80	2	16	243	91	79.0
AD9650-80	2	16	266	86	81.0

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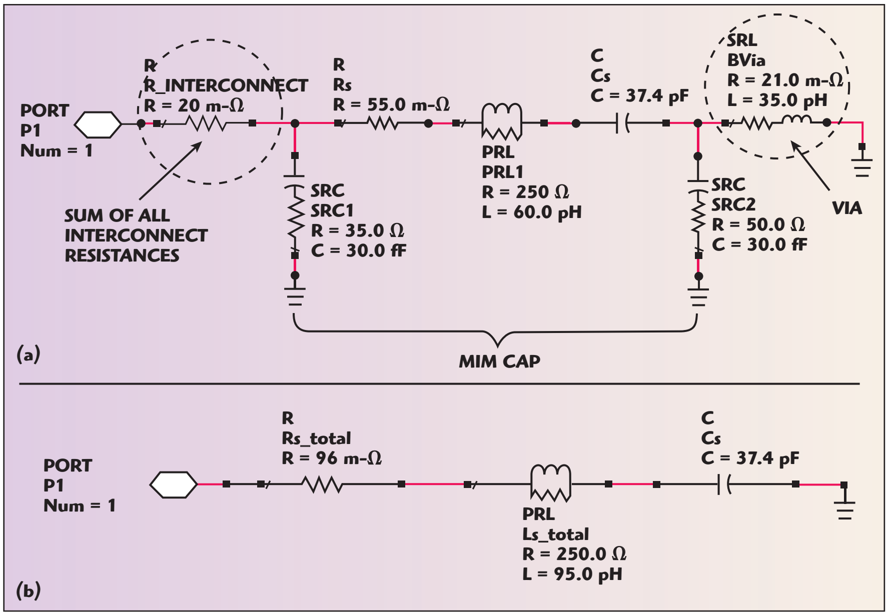
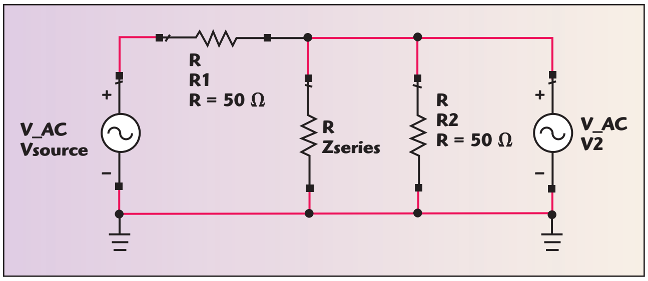


▲ *Fig. 5 (a) "Shunt-connected" MIM cap lumped element equivalent circuit and (b) simplified MIM cap.*

of the components of the total series resistance in to a single element (Rs_total), as also shown.



▲ *Fig. 6 S_{21}-shunt test configuration.*

MEASUREMENT THEORY

As was described,[2] the "S_{21}-Shunt" measurement technique is the RF equivalent of the DC measurement procedure that is used to make highly precise resistance measurements. Because of the unique advantages offered by the technique, the derivation of the series impedance (Z_{series}) shown in ***Figure 6*** is repeated here.

Using the 50 Ω test configuration shown schematically in the figure, the series impedance (Z_{series}) is derived in terms of the simplifying equations defined as:

$$(Z_{series} = 25(S_{21}/(1-S_{21})) \qquad (1)$$

where:

$$V2 = Vsource(Zdut/(50+2Zdut))$$

$$V1 = 1/(2Vsource)$$

$$S_{21} = V2/V1$$

PARAMETER EXTRACTION

As is customarily the case for any networks in which the equivalent circuit can be defined via lumped-elements using simple analytical formulations, the model parameters are extracted directly from measured (intrinsic) data by determining the slope and Y-intercept of the constituent real and imaginary parts. In the case of the SVIA, the series impedance is expressed by Equation 2, assuming that $\omega^2 L_{via}^2 << 1$.

$$Z_{series} = \underbrace{(R_{via}+\omega^2 L_{via}^2/R_{sub})}_{\text{Real}} + \underbrace{j(\omega L_{via})}_{\text{Imaginary}} \qquad (2)$$

R_{via} is extracted graphically from a plot of real (Z_{series}) versus ω^2, by finding the y-intercept of the data. L_{via} is extracted graphically from a plot of imag (Z_{series}) versus ω by finding the slope of the data. In the case of the MIM cap, the series impedance is expressed by Equation 3, assuming that $\omega^2 L_s^2/R_p << 1$.

$$Z_{series} = \underbrace{(R_s+\omega^2 L_s^2/R_p)}_{\text{Real}} + \underbrace{j(\omega L_s - 1/\omega C_s)}_{\text{Imaginary}} \qquad (3)$$

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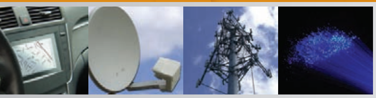

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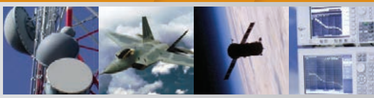

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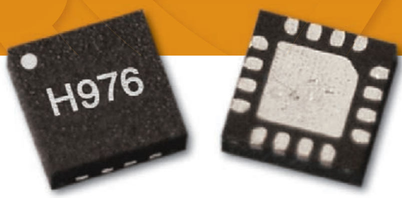

1µA Power Down Current

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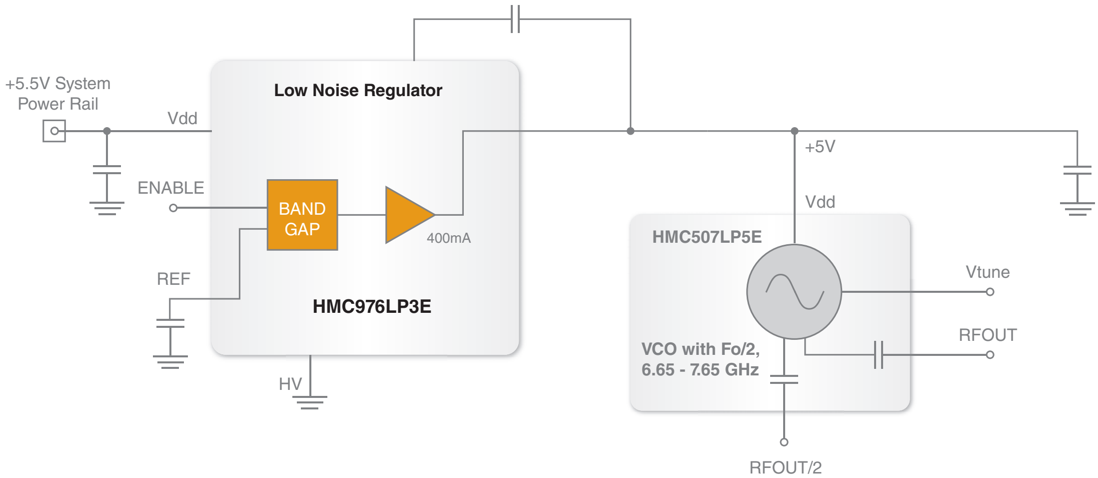
  3nV/√Hz at 10 kHz, 6nV/√Hz at 1 kHz
- ***High PSRR: >60 dB at 1 kHz, >30 dB at 1 MHz***
- ***Adjustable Voltage Output:***
  VR 1.8V to 5.1V @ 400mA



HIGH PSRR - QUAD LINEAR VOLTAGE REGULATOR

Input Voltage (V)	Function	Output Voltage (V)	Output Current (mA)	Power Supply Rejection Ratio (PSRR) (dB)		Output Noise Spectral Density (nV/√Hz)		Regulated Outputs	Part Number
				1 kHz	1 MHz	1 kHz	10 kHz		
3.35 - 5.6	Quad High PSRR	2.5 - 5.2	15 - 100	80	60	7	3	4	**HMC860LP3E**
3.3 - 5.5	Low Noise, High PSRR	1.8 to 5.1	400	60	30	6	3	1	**HMC976LP3E**

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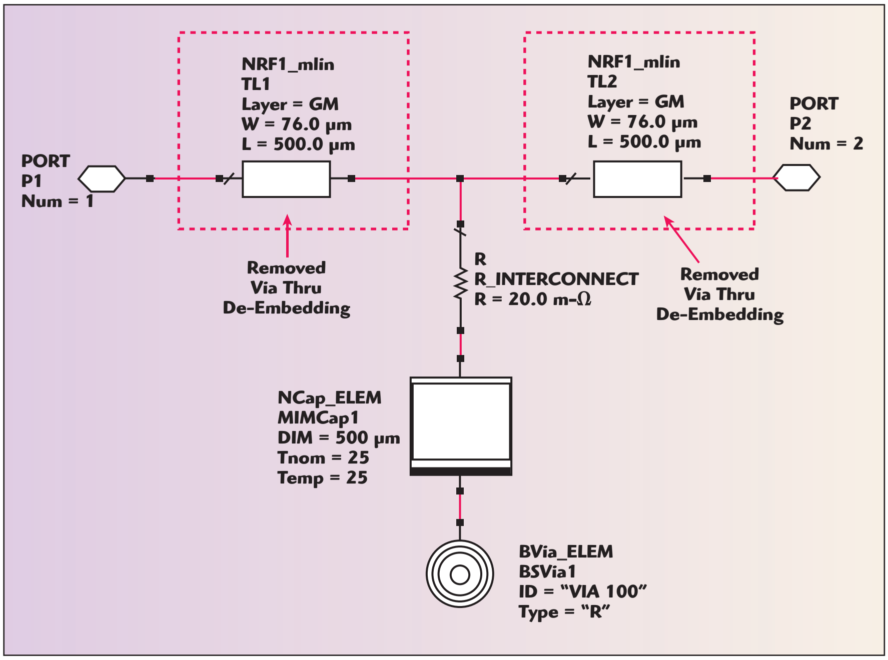
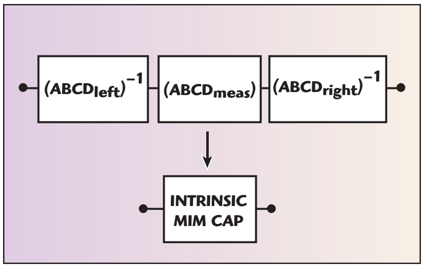


▲ *Fig. 7 "Series-shunt" MIM cap two-port thru-de-embedding configuration.*

Using similar graphical extraction methods to those used in the modeling of the SVIA, C_s is extracted graphically from a plot of ω_{imag} (Z_{series}) versus ω^2 as the y-intercept, where L_s is extracted from the slope of the same data. R_s is determined from the y-intercept of the real (Z_{series}) versus ω^2 data. Having determined L_s, R_p is determined by dividing $\omega^2 L_s^2$ by the slope of the real (Z_{series}) versus ω^2 data. Extraction of the shunt/substrate model parameters is accomplished from the LE-EC in a similar manner via the definition of the equivalent substrate admittance Y_{sub}.[5]

(ON-WAFER) CALIBRATION AND VERIFICATION

An on-wafer SOLT calibration is utilized as the basis for characterization, because it has been found to provide the most accurate results at the very low frequencies where the impedances associated with the (electrically) largest devices are extracted. Standards should be designed such that the reference plane is defined at the center of the RF padframe housing the (physically) largest DUT. An on-wafer TRL calibration is first performed in order to establish the electrical equivalents (calibration kit constants) for the SOLT standards. In order to support the measurement of the ultra low resistances associated with the DUTs, it is critical that the TRL calibration be verified through the measurement of the SOLT load (match) standards at each port. Proper adjustment of the capacitance associated with the transmission line standard insures that DC and RF derived resistances of the load (match) standard are in agreement. (This procedure is readily facilitated in WinCal XE). Once the calibration has been performed, it is verified using both a standard re-measurement procedure[1,6] as well as through measurement of independent standard devices.



▲ *Fig. 8 Cascaded ABCD de-embedding methodology.*

THRU DE-EMBEDDING

The measurement configuration of the series-shunt connected MIM cap is shown in ***Figure 7***. Parasitics associated with the microstrip transmission lines, which extend from the center of the MIM cap to each of the calibration reference planes, are removed via a Thru de-embedding procedure, which utilizes cascaded ABCD ma-

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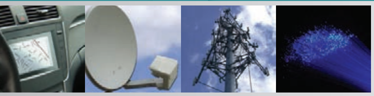

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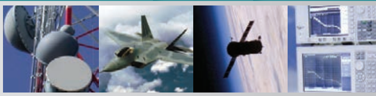

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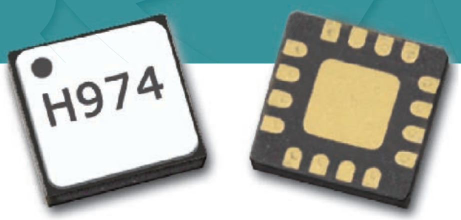

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- ***Low Propagation Delay: 88 ps***
- ***Minimum Pulse Width: 60 ps***

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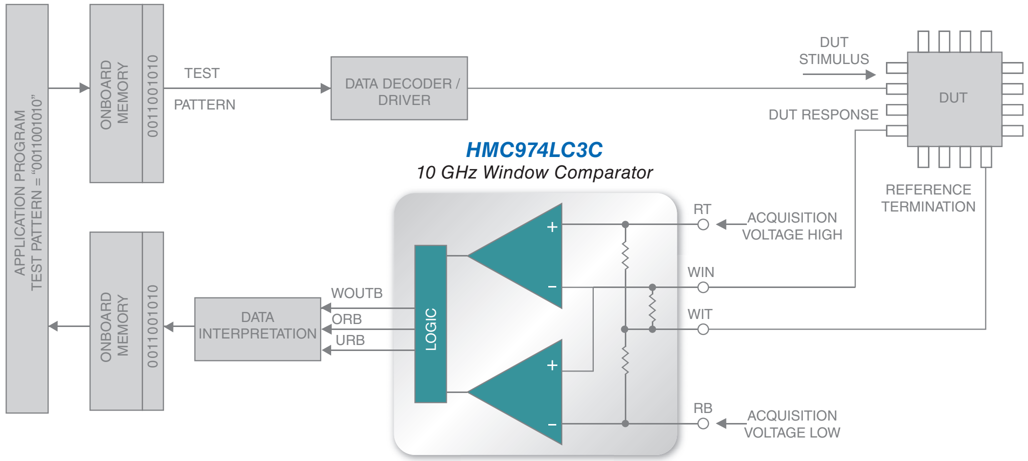

IN-STOCK HIGH SPEED COMPARATORS

Analog Input BW (GHz) / Clock Rate (Gpbs)	Function	Deterministic Jitter (ps)	Propagation Delay (ps)	Output Voltage Swing (Vdc)	DC Power Consumption (mW)	Vcco / Vterm [1] Power Supply (Vdc)	ECCN Code	Part Number
10 / 20	Clocked Comparator - RSPECL	<3	120	0.4	150	+3.3 / +1.3	3A001.a.11.b	**HMC874LC3C**
10 / 20	Clocked Comparator - RSCML	<3	120	0.4	130	0 / 0	3A001.a.11.b	**HMC875LC3C**
10 / 20	Clocked Comparator - RSECL	<3	120	0.4	150	0 / -2.0	3A001.a.11.b	**HMC876LC3C**
10 / [2]	Latched Comparator - RSPECL	2	85	0.4	140	+3.3 / +1.3	3A001.a.11.b	**HMC674LC3C**
10 / [2]	Latched Comparator-RSPECL	2	85	0.4	140	+3.3 / 3.0	3A001.a.11.b	**HMC674LP3E**
10 / [2]	Latched Comparator - RSCML	2	100	0.4	100	0 / 0	3A001.a.11.b	**HMC675LC3C**
10 / [2]	Latched Comparator-RSCML	2	100	0.4	100	0 / 0	3A001.a.11.b	**HMC675LP3E**
10 / [2]	Latched Comparator - RSECL	2	100	0.35	120	0 / -2.0	3A001.a.11.b	**HMC676LC3C**
10 / [2]	Latched Comparator-RSECL	2	100	0.35	120	0 / -2.0	3A001.a.11.b	**HMC676LP3E**
10 / -	Window Comparator	2	88	0.4	240	+2 / 0	3A001.a.11.b	**HMC974LC3C**

[1] Vee = -3.0V & Vcci = +3.3V. [2] These products are pin-for-pin compatible.

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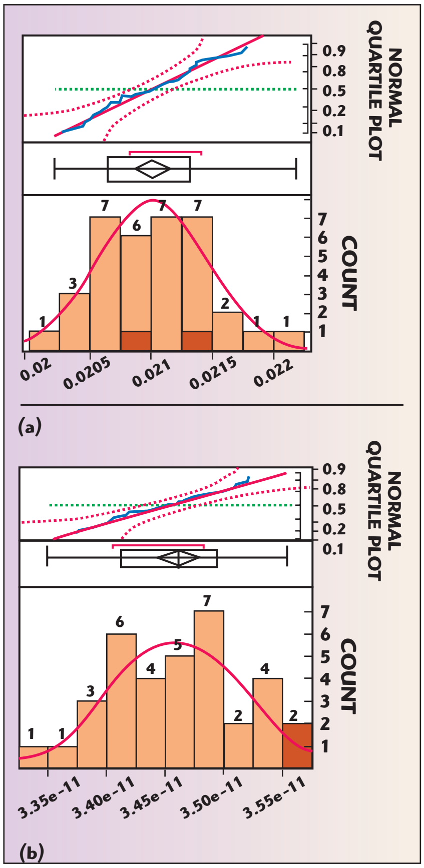
trix methods. (This is identical to the use of reciprocal two-port networks in ADS). Data for the embedding transmission line sections is obtained either via EM (Momentum) simulation or via splitting[7] the S-parameter data measured on the Thru calibration standard. The de-embedding process proceeds according to the illustration shown in ***Figure 8***.[8]

Procedurally, (1) the measured data is converted from S into ABCD format, (2) the DUT is de-embedded (using cascaded ABCD matrices, or via ADS) and (3) the residual (intrinsic) data is converted from ABCD format back into S.

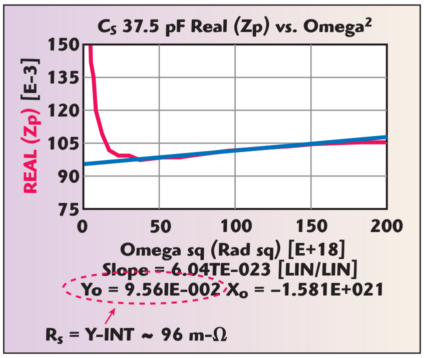
MEASUREMENT RESULTS

Measured data for the "series-shunt" connected SVIA presented previously showed good agreement with statistically derived values for R_{via} (χ = 21 m-Ω) and L_{via} (χ = 34.5 pH),[1] with both parameters demonstrating normally distributed characteristics, as shown in ***Figure 9***.

Typical data for the series-shunt configured MIM cap is shown in ***Figure 10***. For the 37.5 pF capacitor, it is noted that extraction of R_s from de-embedded Real (Z_{series}) data is valid over the range of approximately 900 MHz < freq. < 2 GHz. Below this frequency, the measurement accuracy begins to degrade as a result of the VNA's inability to resolve the resistance from the effects of the ever-increasing, significantly larger, reactive signal component associated with C_s.



▲ *Fig. 9 SVIA R_s (a) and L_s (b) distributions.*



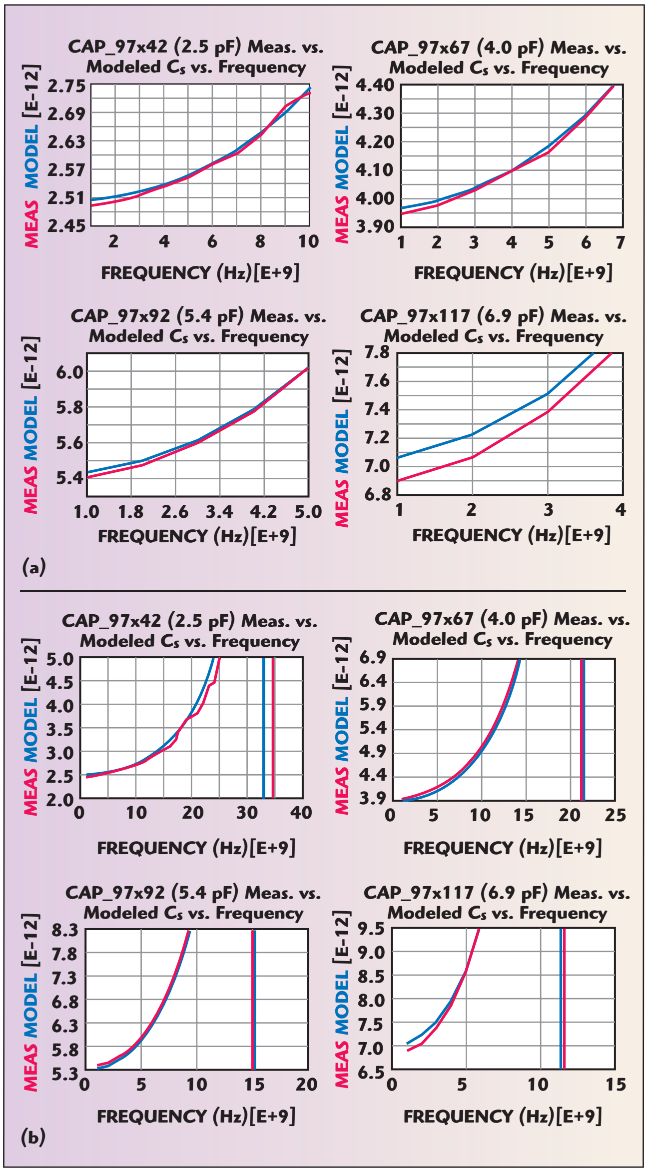
▲ *Fig. 10 MIM cap real (Z_{series}) vs. w^2.*

VALIDATION

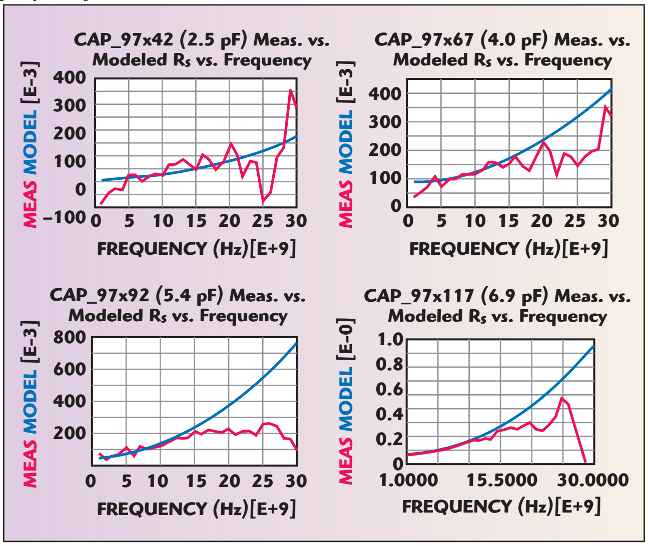
Validation of the modeling technique is demonstrated in terms of the statistical data obtained as a result of application of the combined de-embedding and parameter extraction methodologies during characterization of multiple 37.5 pF square MIM capacitors. The summary provided in ***Table 3*** results from data taken via automatic probing on six co-located die from the same wafer.

An error well less than five percent (2.6 m-Ω), between the measured and estimated MIM resistance, results by recalling the sum of the via and interconnect resistances (per Table 2.) as is shown in ***Table 4***. Further validation of the device characterization and associated MIM cap modeling methodology comes in terms of playbacks of C_s, R_s and Q_{11} seen in ***Figures 11*** through ***13***.[9] The data shown was generated on rectangular MIMs from TQP15.

The accuracy associated with the extraction of C_s can be seen in the plots of C_s versus frequency (Figure 11a), where a narrow bandwidth is displayed. The accuracy associated with the extraction of L_s can be seen in the plots of C_s versus frequency (Figure 11b), where a wider bandwidth is displayed. The accu-



▲ *Fig. 11 (a) (Close-in) vs. frequency and (b) (far away) C_s vs. frequency.*



▲ *Fig. 12 R_s vs. frequency.*

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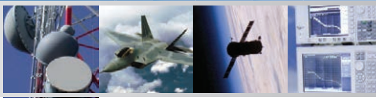
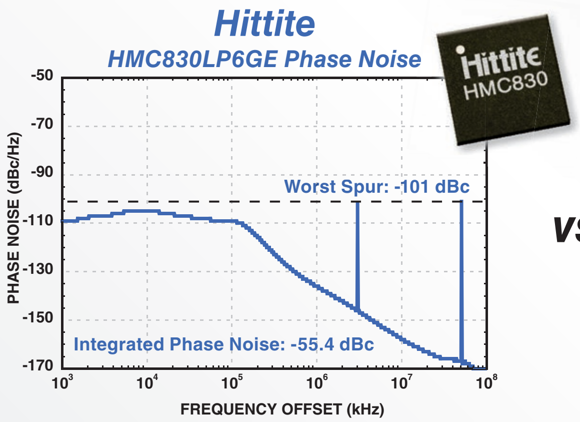
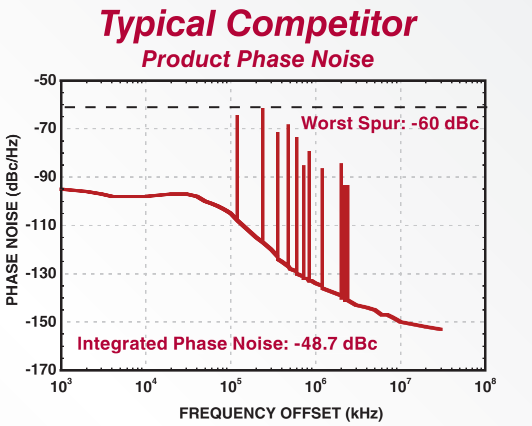




2646.96 MHz, PFD= 50 MHz, Channel Spacing = 240 kHz, Jitter = 144fs

VS.



2646.96 MHz, PFD= 25 MHz, Channel Spacing = 240 kHz, Jitter = 310fs

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Wideband Continuous Tuning							
25 - 3000	**WidebandRF VCO**	**-114 dBc/Hz @ 2 GHz**	**-141 dBc/Hz @ 2 GHz**	**5**	**159**	**0.114 @ 2 GHz**	**HMC830LP6GE**
45 - 1050, 1400 - 2100, 2800 - 4200	Wideband RF VCO	-108 dBc/Hz @ 4 GHz	-134 dBc/Hz @ 4 GHz	4	159	0.229 @ 4 GHz	**HMC829LP6GE**
fo/2							
665 - 825	Tri-Band RF VCO	-118 dBc/Hz	-148 dBc/Hz	11	180	0.05	**HMC822LP6CE**
795 - 945	Tri-Band RF VCO	-123 dBc/Hz	-148 dBc/Hz	10	180	0.06	**HMC838LP6CE**
860 - 1040	Tri-Band RF VCO	-118 dBc/Hz	-147 dBc/Hz	10	180	0.07	**HMC821LP6CE**
1025 - 1150	Tri-Band RF VCO	-123 dBc/Hz	-147 dBc/Hz	12	180	0.07	**HMC837LP6CE**
1050 - 1205	Tri-Band RF VCO	-121 dBc/Hz	-146 dBc/Hz	10	180	0.08	**HMC839LP6CE**
1095 - 1275	Tri-Band RF VCO	-118 dBc/Hz	-147 dBc/Hz	10	180	0.08	**HMC820LP6CE**
1310 - 1415	Tri-Band RF VCO	-121 dBc/Hz	-145 dBc/Hz	10	180	0.09	**HMC840LP6CE**
fo							
1330 - 1650	Tri-Band RF VCO	-112 dBc/Hz	-142 dBc/Hz	6.5	180	0.11	**HMC822LP6CE**
1590 - 1890	Tri-Band RF VCO	-118 dBc/Hz	-143 dBc/Hz	7.5	180	0.12	**HMC838LP6CE**
1720 - 2080	Tri-Band RF VCO	-112 dBc/Hz	-141 dBc/Hz	6.5	180	0.13	**HMC821LP6CE**
2050 - 2300	Tri-Band RF VCO	-117 dBc/Hz	-141 dBc/Hz	10.5	180	0.15	**HMC837LP6CE**
2100 - 2410	Tri-Band RF VCO	-115 dBc/Hz	-140 dBc/Hz	7.5	180	0.16	**HMC839LP6CE**
2190 - 2550	Tri-Band RF VCO	-112 dBc/Hz	-141 dBc/Hz	6.5	180	0.17	**HMC820LP6CE**
2620 - 2830	Tri-Band RF VCO	-115 dBc/Hz	-139 dBc/Hz	9	180	0.18	**HMC840LP6CE**
2fo							
2660 - 3300	Tri-Band RF VCO	-106 dBc/Hz	-136 dBc/Hz	-4	180	0.21	**HMC822LP6CE**
3180 - 3780	Tri-Band RF VCO	-112 dBc/Hz	-135 dBc/Hz	-4	180	0.24	**HMC838LP6CE**
3440 - 4160	Tri-Band RF VCO	-106 dBc/Hz	-135 dBc/Hz	-4	180	0.27	**HMC821LP6CE**
4100 - 4600	Tri-Band RF VCO	-111 dBc/Hz	-135 dBc/Hz	-0.5	180	0.30	**HMC837LP6CE**
4200 - 4820	Tri-Band RF VCO	-108 dBc/Hz	-135 dBc/Hz	-4	180	0.31	**HMC839LP6CE**
4380 - 5100	Tri-Band RF VCO	-106 dBc/Hz	-135 dBc/Hz	-4	180	0.33	**HMC820LP6CE**
5240 - 5660	Tri-Band RF VCO	-109 dBc/Hz	-133 dBc/Hz	-3	180	0.37	**HMC840LP6CE**

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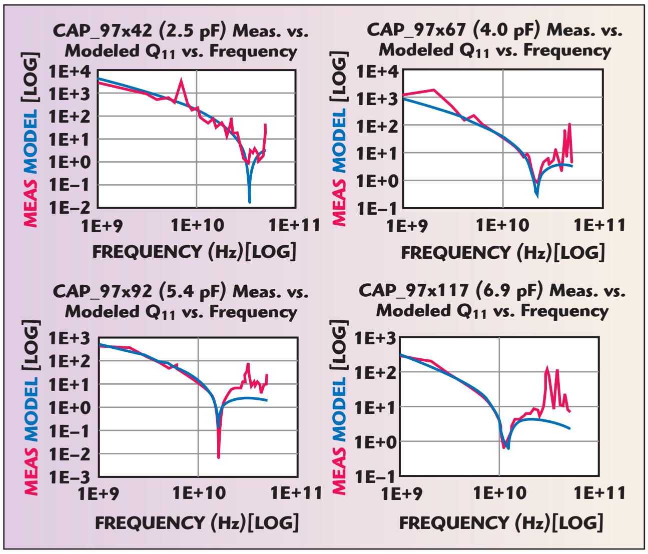
racy associated with the extraction of R_s can be seen in the plots of C_s versus frequency (Figure 12) where a wider bandwidth is displayed. The accuracy associated with the overall model extraction process can be seen in the plots of Q_{11} versus frequency in Figure 13. The impact of fitting errors associated with both the real and imaginary parts of Z_{series} are displayed over the full characterization bandwidth of 50 GHz.

CONCLUSION

A methodology, developed for determination of the series resistance of SVIAs, has been successfully applied to the characterization of MIM Caps. The methodology has shown that the resistance of MIM Caps can be readily obtained from measured S-parameter data through: (1) the design/use of "series-shunt" configured test structures, (2) application of the "S_{21}-shunt" ultra-low impedance measurement technique, and (3) proper VNA configuration/setup. The series resistance for a large, square geometry MIM cap that has been extracted directly from



▲ Fig. 13 Q_{11} vs. frequency.

TABLE III

37.5 pF MIM CAP STATISTICAL DATA

	R_s	R_sq
Die	**(Ω)**	**R_sq**
2, 2	9.0986×10^{-2}	0.9944
2, 3	9.4345×10^{-2}	0.9952
3, 2	8.8307×10^{-2}	0.9976
3, 3	9.5368×10^{-2}	0.9899
4, 2	9.5490×10^{-2}	0.9935
4, 3	9.5912×10^{-2}	0.9892
MEAN	9.3401×10^{-2}	0.9933
STDEV	3.0727×10^{-3}	0.0032
Std. %	3.29	0.32

TABLE IV

(SERIES-SHUNT) MIM CAP ESTIMATED RESISTANCE

Interconnect		MIM Cap		
Resistance Source	Estimated Value (m-Ω)	Resistance Source	Estimated Value (m-Ω)	Grand Total (m-Ω)
Rvia	21.0	Top Plate	50	
Rint	20.0	Bottom Plate	5	
R-Total	41.0	R-Total	55	96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measured S-parameter data (based on the use of slope and intercept methods), compares well with data obtained with other, similar modeling procedures.[10] Data taken on six die clearly demonstrates that the effects of probe contact resistance (PCR) and its associated variability have been eliminated as sources of measurement error and statistical variability. ■

ACKNOWLEDGMENTS

The work presented in this article was done while the author was employed at Nitronex Corp. I would like to thank John Kearney for layout of the test structures, and would also like to acknowledge Prity Patel for her effort in the construction of the on-wafer calibration kit as well as during collection of the associated S-parameter data.

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DESIGN OF V-BAND MILLIMETER-WAVE CMOS LOW NOISE AMPLIFIER

A V-Band millimeter-wave CMOS low noise amplifier (LNA) fabricated with the 0.13 μm process is presented. A three-stage cascaded common source structure is adopted. The measurement results of the fabricated LNA show the peak performance at 50 GHz exhibiting a gain of 11.7 dB and a noise figure of 7.9 dB. The input P_{1dB} and IIP3 are –9.5 and –1.65 dBm, respectively. The total power consumption is 21.6 mW from a 1.2 V power supply.

In recent years, the 7 GHz of contiguous bandwidth have been opened for unlicensed use at millimeter-wave frequencies around 60 GHz (known as V-Band) in the US and Japan. High rate wireless communication technology operating at millimeter-wave frequencies has been an interesting topic with various applications and tremendous potentials. This led to a strong demand for RF circuits operating above 20 GHz. In the past, these frequency bands were dominated by III-V semiconductor technology, such as GaAs-based HEMT and HBT. However, the advantage of combining baseband and RF front-end on one single chip for cost savings is strongly desired for highly integrated system-on-chip (SOC) applications. Thus, the CMOS process is one of the most attractive solutions to implement RFICs because of its low cost and high level of integration. Recent works have proven that the CMOS process is a promising technology for RF circuits in low GHz applications. Due to the advancement of the CMOS process, the improvement of the unity gain frequency f_T of CMOS devices suggests a potential for utilizing the CMOS process in millimeter-wave applications.

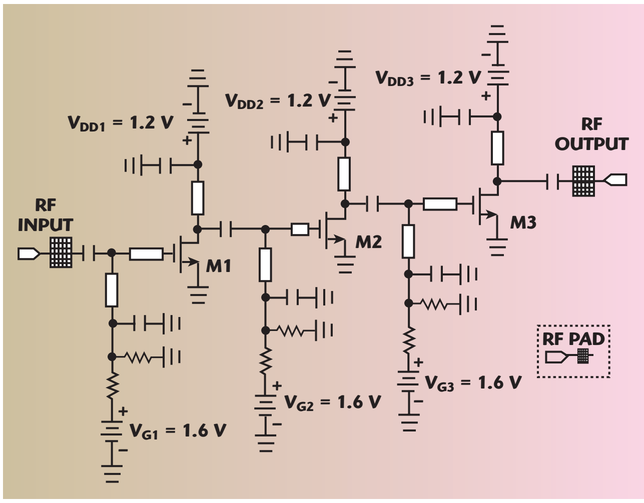

Fig. 1 Schematic V-Band CMOS LNA.

Recently, efforts to design millimeter-wave amplifiers by using CMOS processes have been reported, using 0.13 μm and 90 nm CMOS.[1-3] In this article, the aim of this work is to design a V-Band, low noise amplifier that is suitable for SoC and wireless communication systems. It achieves a peak gain of 11.7 dB while consuming 21.6 mW.

V-BAND LNA CIRCUIT DESIGN

This circuit was fabricated in commercial standard 0.13 μm 1P8M CMOS process. Passive elements, including metal-insulator-metal (MIM) capacitors, are available between metal 7 and 8. The schematic of the three-stage cascaded common source V-Band LNA is shown in ***Figure 1***. Generally, the noise factor (F) of

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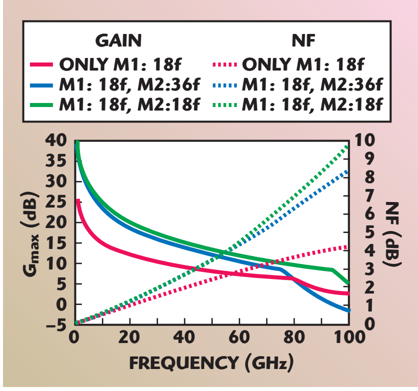
a common source amplifier is usually defined as:

$$F = 1 + \frac{R_i}{R_s} + \frac{R_g}{R_s} + \frac{\gamma}{\alpha}\frac{\chi}{Q_{in}}\left(\frac{\omega_0}{\omega_T}\right) \quad (1)$$

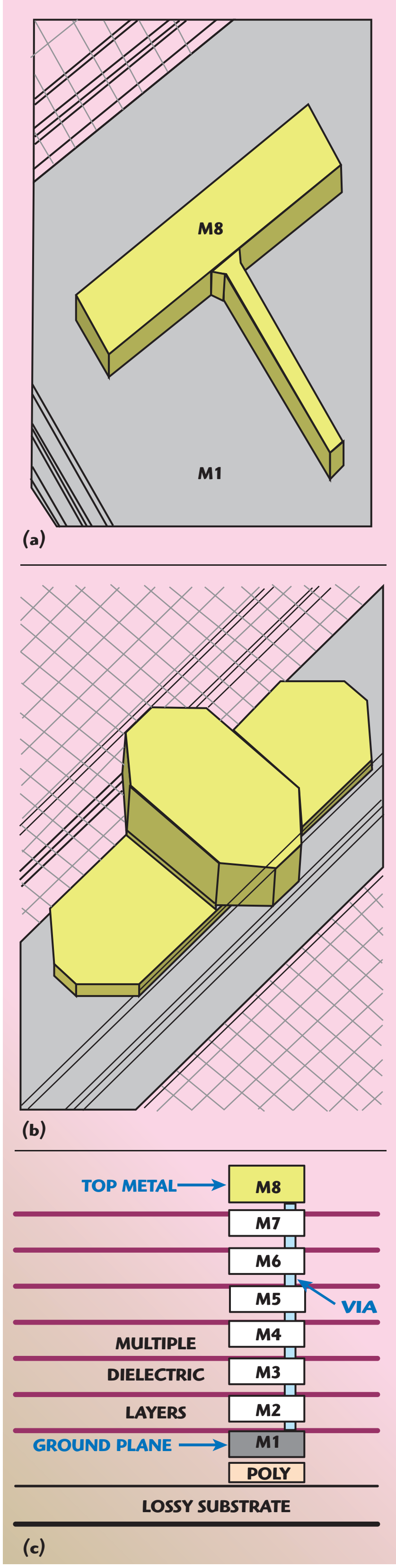
From Equation 1, the noise factor is proportional to ω_0 and inversely proportional to Q_{in} as well as ω_T. The f_T of a CMOS 0.13 µm NMOS transistor is approximately 91 GHz.[2] ***Figure 2*** illustrates the tradeoffs between the common source (CS) and cascode structures. In order to obtain a lower noise figure, a common source structure is adopted. In addition, the sizes of the transistors are chosen under the consideration of low power consumption, while maintaining a desired circuit performance. The optimal width for the low noise input stage is 18 fingers with a total gate width of 36 µm, corresponding to a current density of 167 µA/µm with a supply voltage of 1.2 V and gate bias of 0.8 V.

In this work, a thin-film microstrip (TFMS) line is used for the matching networks and all interconnections. The TFMS consists of the top metal layer (M8) as the signal microstrip lines and the first metal layer (M1) as the ground plane. As compared to coplanar waveguide (CPW), microstrip lines have more flexibility in interconnection. All of the T-junctions and cross junctions were realized using the same structure, as shown in ***Figure 3***, modeled with a FEM-based 3D full-wave EM solver, Ansoft HFSS.

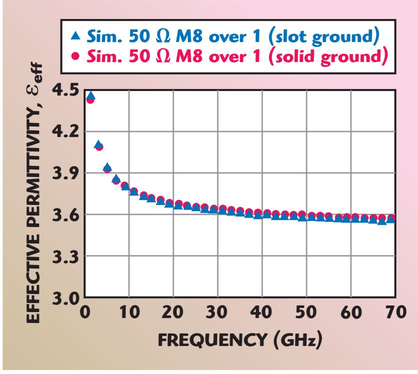
As CMOS technologies advanced beyond the 0.18 µm node, increasingly stringent metal density rules prohibited the design of solid ground planes. In order to accommodate these restrictions, metal ground planes must now be slotted.[5] ***Figure 4*** shows the simulated effective permittivity of the TFMS. It illustrates good agreements between our simulation and Mangan's work[5] under the same conditions. Thus, the reason-



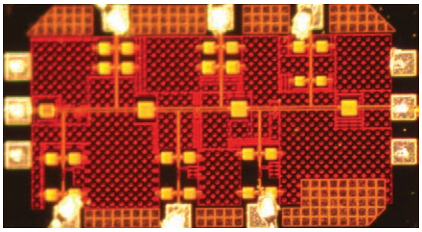
▲ *Fig. 2 Comparison of MSG and NF of different cascade and CS transistors.*



▲ *Fig. 3 (a) Modeled T-junction, (b) cross-junction and (c) 0.13 µm cross-section.*



▲ *Fig. 4 Simulated effective permittivity of TFMS line with a metal 8 conductor in the 0.13 μm process.*

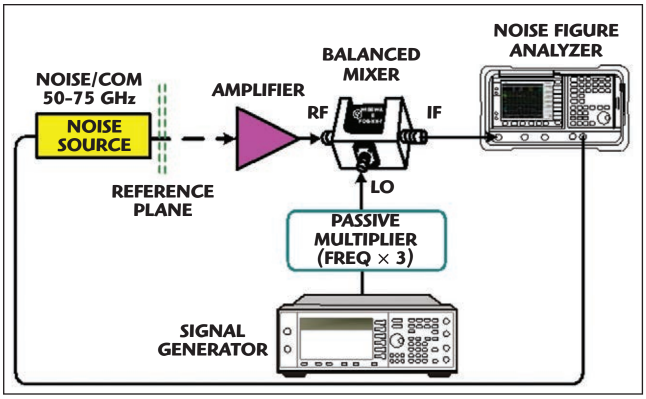


▲ *Fig. 5 Photograph of the V-Band three-stage CMOS LNA.*

able effective permittivity applied to this work is chosen as 3.6.

MEASUREMENT TECHNIQUE AND RESULTS

The chip micrograph of the fabricated CMOS LNA is shown in ***Figure 5*** and the chip size is 1.39 × 0.76 mm. The LNA was measured on-wafer, using high frequency probes. The VDD supply voltage and gate bias voltage were 1.2 and 0.8 V, respectively. The parasitic effects of the RF pads were incorporated while performing simulation, so no de-embedding was required on the measured results. The measurement of millimeter-wave components needs a complex calibration procedure. For example, the available input power from the source is calibrated with a V-Band power sensor (Agilent V8486A) and the frequency dependent loss from the probe loss should be calibrated also. Measurement of noise figure at V-Band or higher frequencies is a challenge. In the measurement, the cable losses, probe losses and DUT intrinsic noise are all measured by a noise figure analyzer (NFA) under testing.



▲ *Fig. 6 Calibration of the NFA with the V-Band noise source, amplifier and down-converter.*

Using the Friis' formula, F_{meas} can be defined as:

$$F_{meas} = F_1 + \frac{F_{LNA}-1}{G_1} + \frac{F_3-1}{G_1 G_{LNA}} \quad (2)$$

where, F_1 is the noise figure of the input cable and input G-S-G probe (which is equivalent to the loss of the cable and the probe, $L_1=G_1^{-1}$). Similarly, F_3 is the noise figure of the output cable and output G-S-G probe. From Equation 2, if the G_{LNA} is high enough, the F_{LNA} can be approximated as:

$$F_{meas} \approx F_1 + \frac{F_{LNA}-1}{G_1} = \quad (3)$$

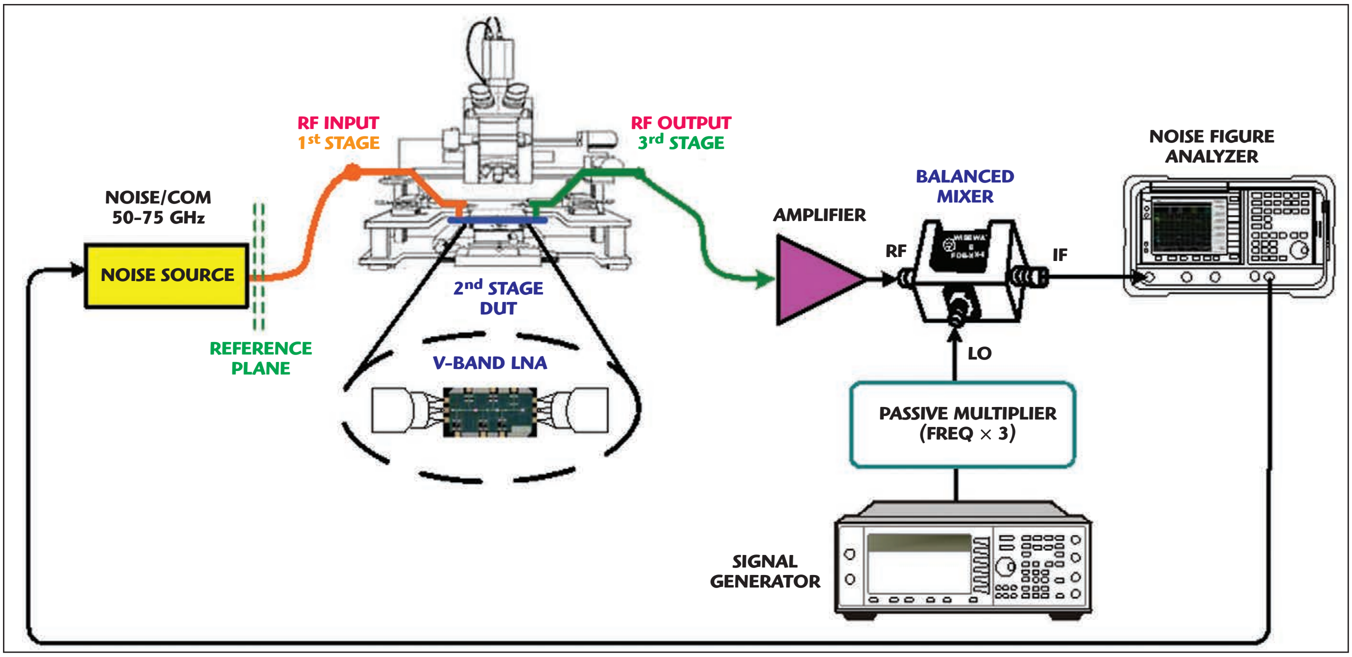
$$F_1 + \frac{F_{LNA}}{G_1} - G_1^{-1}\frac{F_{LNA}}{G_1}$$

$$F_{LNA} \approx F_{meas} \times G_1 \text{ or}$$

$$F_{LNA}(dB) \approx F_{meas}(dB) - L_1(dB)$$

From Equation 3, if the loss of the first stage is known, the additional noise can be calibrated out. ***Figure 6*** shows the calibration of the NFA together with the V-Band noise source, amplifier and down-converter. The V-Band noise figure measurement system is shown in ***Figure 7*** and a photograph of the on-wafer measurement set-up is shown in ***Figure 8***.

The LNA was measured on-wafer using high frequency probes. The

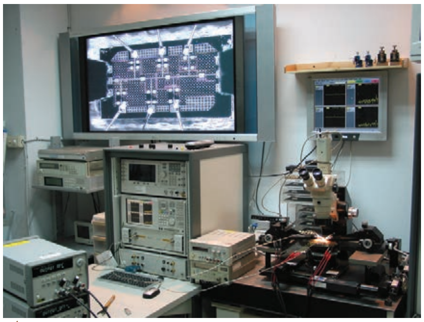


▲ *Fig. 7 V-Band noise figure measurement system.*

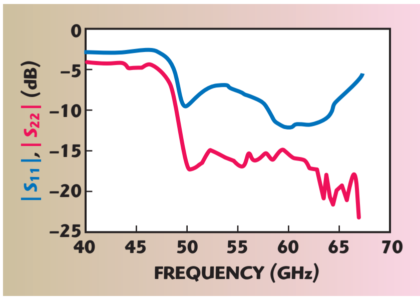
VDD supply voltage and gate bias voltage were 1.2 and 0.8 V, respectively. The parasitic effects of the RF pads were incorporated while performing simulation, so no de-embedding was required on the measured results. The measured input and output return loss are plotted in ***Figure 9***. The input and output return losses were close to 9.4 and 16 dB, respectively. ***Figure 10*** shows that the small signal gain is 11.7 dB at 50 GHz with a noise figure of 7.9 dB, while consuming 21.6 mW from a 1.2 V supply. The 3 dB bandwidth is 6 GHz. As shown in ***Figure 11***, the measured input 1 dB compression point (P_{1dB}) is –9.5 dBm.

CONCLUSION

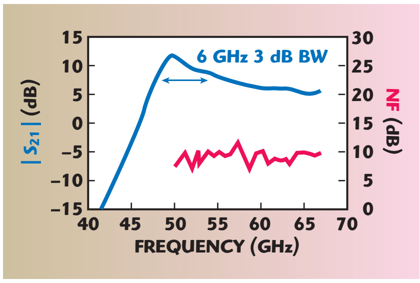
This article presented the design, fabrication and measurement of a proposed V-Band LNA. It was fabricated in a TSMC 0.13 μm standard CMOS process. Compared to other works using 0.13 μm CMOS, this work has shown that the V-Band LNA reduced the power consumption successfully. The circuit was measured using on-wafer probing. The V-Band LNA has demonstrated a gain of 11.7 dB, a minimum noise figure of 7.9 dB. The input P_{1dB} is –9.5 dBm and IIP3 is –1.65 dBm. The total power consumption is 21.6 mW from a 1.2 V power supply. ■



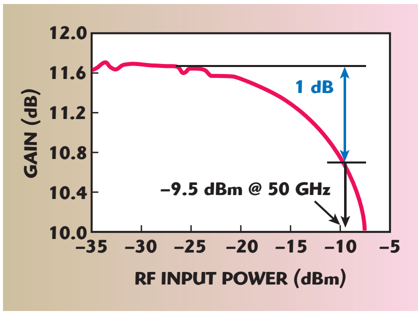
▲ *Fig. 8 Photograph of the on-wafer measurement system.*



▲ *Fig. 9 Measured input (S_{11}) and output (S_{22}) return losses.*



▲ *Fig. 10 Measured gain and noise figure.*



▲ *Fig. 11 Measured input 1 dB compression point.*

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HIGH TUNING SENSITIVITY DIELECTRIC RESONATOR OSCILLATOR FROM OPTIMIZATION OF DIELECTRIC RESONATOR $TE_{01\delta}$ MODE

In the design of a dielectric resonator oscillator to be used as a local oscillator, the objective of this study is to find a method to achieve a wide tuning range with a tuning sensitivity of 1 MHz/V or higher for the dielectric resonator oscillator operating at 3.6 GHz. The tuning structure dimensions of the dielectric resonator circuit were varied, in order to understand the resonator behavior and limitations to achieve the desired tuning sensitivity for the dielectric resonator oscillator. A practical method is proposed for dielectric resonator oscillators, which yield a high tuning sensitivity as well as a wide bandwidth. A dielectric resonator oscillator with tuning sensitivity of 1.9 MHz/V at 3.6 GHz has been developed using this method.

Dielectric resonators (DR) are widely used to construct microwave frequency filters and oscillators due to their temperature stability and high dielectric constant, ε_r, which enable miniaturization of the circuits. A high ε_r means that the electric field of the particular resonant mode is concentrated within the DR and the external field attenuates very rapidly with the distance from the surface, thus giving small radiation loss and high unloaded Q factor, QU, which is limited only by the dielectric loss (loss tangent, tan δ) of the DR material. The QU is approximately 1/tan δ.[1] Various dielectric resonators are made from various titanate compounds ceramics[2] and the DR used in this study is a zirconium titanate-based ceramic, which has an excellent temperature stability, that is a temperature coefficient, $\tau_f \approx 0$ ppm and a $Q_U > 9500$ at 4.3 GHz.[3,4]

TYPICAL CONSTRUCTION OF DR CIRCUITS FOR OSCILLATOR APPLICATIONS

Setting the DR Resonant Mode

The DR can be excited in various modes, but the principal transverse electric mode, $TE_{01\delta}$, is employed because the magnetic field can be conveniently coupled to microstrip transmission lines. In these lines, a signal propagates in transverse electric magnetic mode, TEM. The DR comes in a cylindrical shape for ease of fabrication and assembly, as shown in ***Figure 1***.

The dimensions or the size of the DR determine its resonant frequency. But to resonate the DR in $TE_{01\delta}$ mode, the ratio of its outer diameter (OD) to its thickness (L), that is OD/L, must be greater than 1.42[5] and, specifically, the

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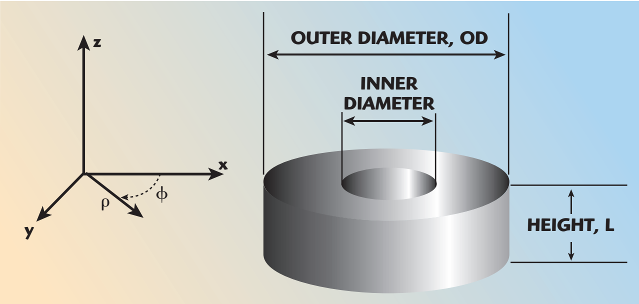
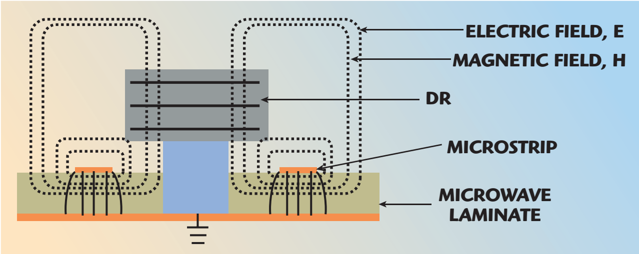


▲ *Fig. 1 A cylindrical DR for practical assembly.*



▲ *Fig. 3 DR $TE_{01\delta}$ resonant mode coupling to a TEM mode microstrip.*

ratio must be kept between 2 and 3.33 to minimize interference of spurious modes.[6] With reference to the axis shown in the figure, the DR transverse electric resonant mode standing wave pattern has 0 wave variation in the circumferential, Φ direction, 1 wave variation in the radial, ρ direction and the δ indicates that the standing wave is not a complete half-sinusoid pattern along the z direction.

Metal Enclosure Assembly

The DR must be placed in a metal enclosure to avoid radiation loss and interference from external fields. The enclosure dimensions must be approximately twice of those of the DR dimensions (OD and L) to minimize the effect on Q_U from the current induced on the metal surface by the external field of the DR.[1] Experimental studies have been done[7] to determine the effect of ground plane distance (in the z-axis direction) to the DR, on several resonant frequencies of the DR. The results show that the $TE_{01\delta}$ mode resonant frequency increases as the distance gets closer because of the magnetic field perturbation by the ground plane.[7,8] Thus, to compensate for variations in the DR material, a metallic tuning disc is added onto the top of the enclosure. The tuning disc height is adjustable mechanically to tune the resonant frequency. The enclosure height, L_c is made to be slightly more than twice the DR height, L.

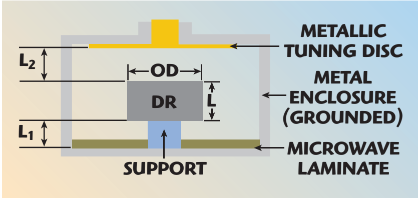
When the tuning disc is completely retracted, there is a gap, L_2 between the tuning disc (ground plane) and the top of the DR. This mechanical frequency adjustment is very slow compared to electrical tuning and is meant for a one-time tuning to set the center frequency of the circuit.

In order to realize the high Q_U of the DR, it must be located away from the conducting shield or the ground plane.[9] A cylindrical ceramic support with a low ε_r, that is below 10, is placed between the DR and the bottom ground plane. This seems like contradicting the earlier statement for having a metallic tuning disc in the top of the enclosure; in fact this is a compromise between the high Q_U and the accurate resonant frequency. The basic construction of the DR circuit described above is presented in ***Figure 2***.

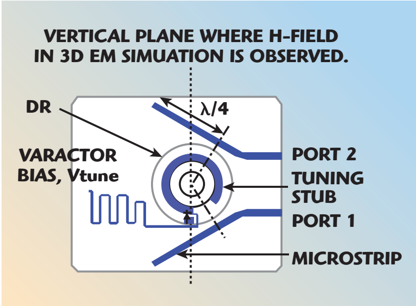
ANALYSIS OF THE TUNING STRUCTURE FOR DR

Varactor-tuned DR Circuit

As mentioned earlier, the DR circuit resonating in the $TE_{01\delta}$ mode can be conveniently coupled to a microstrip line, which is a TEM waveguide. This is the approach for the dielectric resonator oscillator (DRO) design, but before going into the oscillator, the DR will be first characterized as a passive circuit. A varactor coupled to a stub is introduced into the DR circuit for electrical tuning. The tuning stub is circular in shape, as opposed to a straight line stub used by Yom et al;[10] this is to allow a locking screw insertion at the center of the DR. The main objective of the characterization is to find a method that will give the DRO a maximum tuning sensitivity, KV. There are many references describing varactor coupled techniques that achieve high tuning bandwidth for the DR circuits; some are impractical due to tuning complexity,[11] cumbersome enclosure or assem-



▲ *Fig. 2 Typical assembly of the DR circuit for a $TE_{01\delta}$ mode oscillator.*



▲ *Fig. 4 The varactor-tuned DR circuit for analysis.*

blies as described by Virdee.[8] However, one potential method described by Virdee[12] will be the basis for this study, but with some modification.

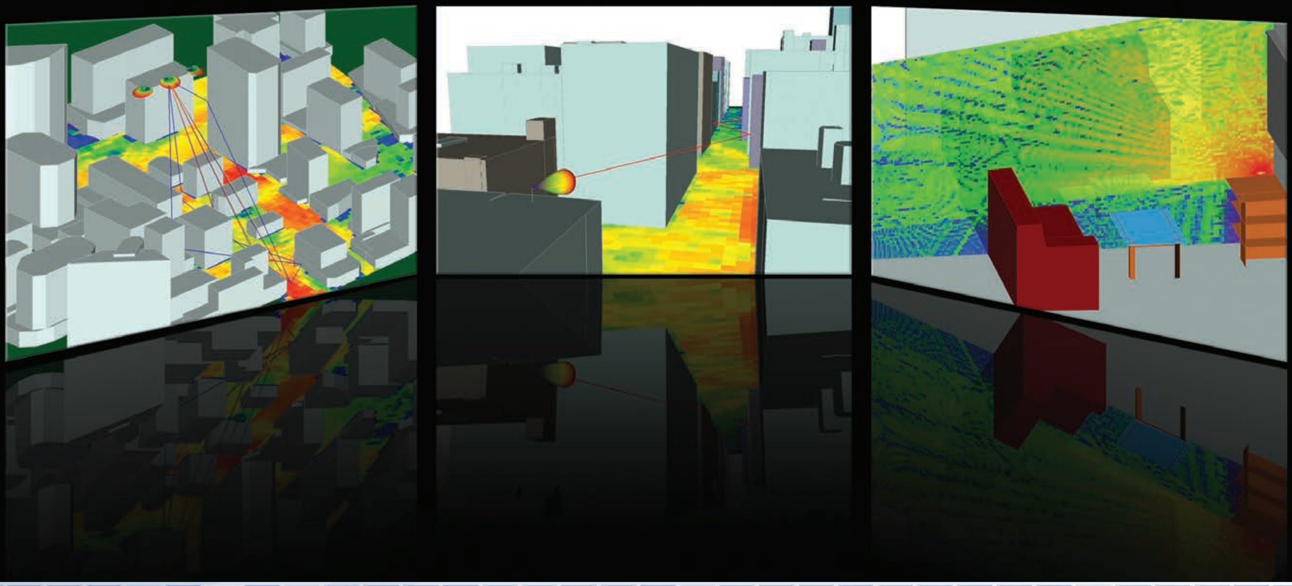
The DR $TE_{01\delta}$ mode resonance coupling to the TEM microstrip line is depicted graphically in ***Figure 3***, and the proposed varactor coupled tuning circuit, analogous to a bandpass filter circuit, is shown in ***Figure 4***. Effectively, the varactor introduces a variable capacitance into the circuit. By varying this capacitance, the overall electromagnetic field of the DR circuit changes, thus varying the resonant frequency. The mechanism is similar to the tuning circuit proposed by Virdee,[12] where the tuned resonant frequency of the DR is given by:

$$\omega_0^2 = \omega_{DR}^2 \left(\frac{1 + n^2 C_{DR} / C_v}{1 + n^2 L_{stub} / L_{DR}} \right) \qquad (1)$$

Where $\omega_{DR}^2 = 1/L_{DR}C_{DR}$ is the untuned DR resonant frequency, L_{DR} being the equivalent DR inductance and C_{DR} being the equivalent DR capacitance, n is the turns ratio between the DR and the tuning circuit. Equation 1 shows the relationship of the tuned resonant frequency with the coupling n, the varactor capacitance, C_v, and the inductance of the tuning stub, L_{stub}.

Designs of the Varactor-tuned DR Circuits for Analysis

The final DRO is intended as a local oscillator in a spectrum analyzer,



with the operating frequency specified as 3.6 GHz. The circuit was built on a RO4350B laminate, 20 mils thick, with a dielectric constant of 3.48. The microstrip lines characteristic impedance is Z_0 = 50 Ω and the electrical length is λ/4 at 3.6 GHz, measured from the open end to the maximum coupling point to the DR, as marked by the dotted line. With the presence of these two coupling lines (ports 1 and 2), this configuration is identical to a narrow bandpass filter. The varactor was biased from a low noise voltage supply, where the narrow and winding V_{tune} bias line offers a high impedance at the microwave frequency, that is 3.6 GHz, so that it will not load the DR tuning circuit.

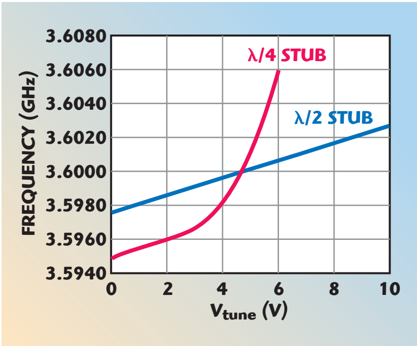
Variation of the Tuning Stub Electrical Length

The tuning stub length was varied arbitrarily; the lengths were set at λ/4 and λ/2 at 3.6 GHz. For each variation, the V_{tune} was adjusted from 0 to 10 V at 1 V intervals and the resonant frequencies and the corresponding insertion loss (IL) were recorded. The results were compared for their tuning bandwidth and IL at resonant frequencies.

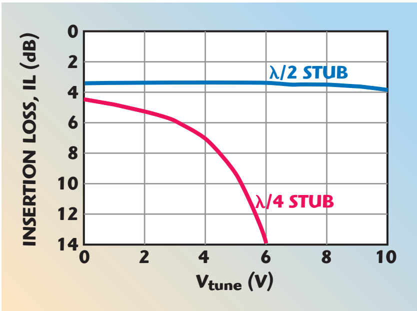
Figures 5 and ***6*** show the resonant frequencies and ILs, respectively; the width of the tuning stub was kept at Z_0 = 50 Ω. For the λ/4 stub length, the circuit ceased to resonate after V_{tune} = 6 V. Although λ/4 tuning stub gives wider tuning bandwidth, it is very nonlinear and beyond V_{tune} = 6 V, resonance ceases to exist, possibly because of a decrease in Q, due to strong coupling. Secondly, the IL is very high, from more than 4 dB and up to 14 dB. A nonlinear frequency tuning would complicate a PLL design and a high IL would demand a very high gain amplifier. On the contrary, the λ/2 tuning stub, though it gives a much smaller tuning bandwidth, offers an approximately linear tuning and a more consistent and very low IL across the tuning bandwidth.

Variation of the Tuning Stub Characteristic Impedance

The λ/2 tuning stub was further investigated by arbitrarily varying



▲ *Fig. 5 Resonant frequency of the varactor-tuned DR circuit with different stub lengths.*



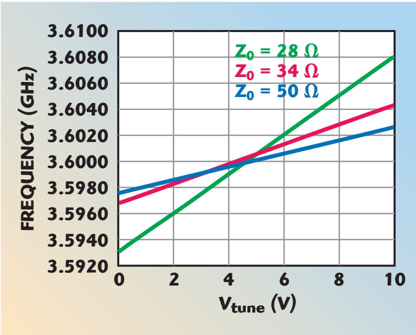
▲ *Fig. 6 Insertion loss of the varactor-tuned DR circuit for different tuning stub lengths.*

the stub characteristic impedance. Apart from the width corresponding to $Z_0 = 50\ \Omega$, the width was also set corresponding to $Z_0 = 34$ and $28\ \Omega$. ***Figures 7*** and ***8*** show the tuning bandwidths and ILs at resonance for three different stub impedances. The plot shows that, as the impedance gets lower, the tuning bandwidth increases with an increase in ILs at resonance. However, the ILs are relatively flat across the resonant frequencies. For a tuning stub with $Z_0 = 28\ \Omega$, a tuning bandwidth of 15 MHz is achieved with the ILs approximately 6 dB.

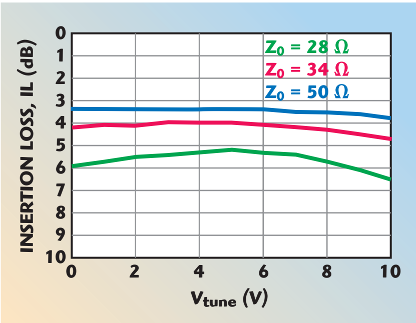
3D EM SIMULATIONS OF THE VARACTOR-TUNED DR CIRCUITS

The varactor-tuned DR circuits with different tuning stub widths were simulated in a three-dimensional electromagnetic field (3D EM) simulator, using Agilent EMDS software, to understand how the K_V increases as the tuning stub width increases. The varactor-tuned DR circuit is more of a three-dimensional physical structure rather than a typical planar electrical circuit. To simulate it in a circuit simulator would be complicated considering the modeling of the cavity, the DR and its mounting, the electromagnetic field coupling and any other physical structure that may affect the resonance. As for the varactor, which is an active device, it can be modeled as a simple parallel plate capacitor shunted to ground. Its capacitance can be varied by changing the dielectric constant of the material in between the parallel plates. The DR resonates in the $TE_{01\delta}$ mode, so its magnetic field (H-field) is the one that couples to any microstrip lines on the circuit. Therefore, the 3D EM simulation was concentrating on the H-field distribution. In ***Figure 9***, the H-field was observed on a vertical plane crossing the DR center marked by the dotted line shown in Figure 4. Note that the uniform circular lines are the input and output ports of the circuit.

The H-field pattern was monitored at the vertical plane that cuts across the center of the DR, the tuning stub and the microstrip lines, similar to that in Figure 3. In Figure 9, the H-field strength is displayed in two ways – first, by means of the contour lines, and secondly, by means of the color



▲ *Fig. 7 Resonant frequency of the varactor-tuned DR circuit with different stub impedances.*



▲ *Fig. 8 Insertion loss of the varactor-tuned DR circuit for different stub impedances.*

TABLE I

SUMMARY OF MEASUREMENT RESULTS FOR V_{tune} FROM 0 TO 10 V AND 3D EM SIMULATIONS FOR THE $\lambda/2$ TUNING STUBS

Tuning Stub Z_0 (Ω)	*IL (dB)*	*Bandwidth (MHz)*	*H-field*
50	3.4-3.8	5.1	Weak coupling between DR & tuning stub
34	4.0-4.7	7.8	Strong coupling between DR & tuning stub
28	5.2-6.5	15.0	Very strong coupling between DR & tuning stub

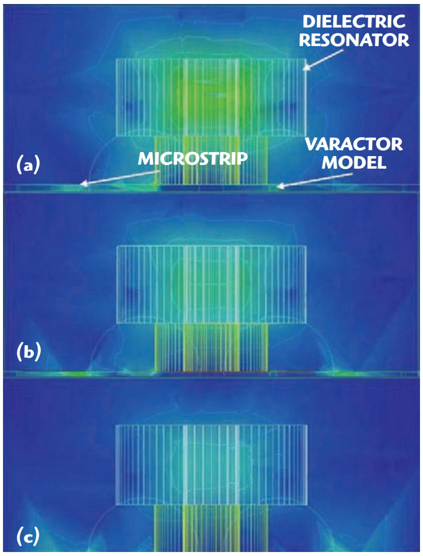


Fig. 9 H-field pattern for three DR circuits with different stub widths (a) Z_0 = 28 Ω, (b) Z_0 = 34 Ω and (c) Z_0 =50 Ω.

spectrum, with the red shade being the strongest H-field region and, following the rainbow colors sequence, dark blue is the weakest.

The simulation shows that the circuit with the widest stub (Z_0 = 28 Ω) has the strongest H-field coupling between the DR and the tuning stub – the contour lines covering the widest region and stretching from the DR to the tuning stub. However, the H-field coupling to the microstrip is the weakest, with hardly noticeable contour lines. On the contrary, the circuit with the narrowest tuning stub of Z_0 = 50 Ω, the H-field is the weakest in the vicinity of the DR and weak coupling to the tuning stub, but there are strong H-fields in the microstrip lines, indicating a strong signal.

Compared with the measurement results in Figures 7 and 8, there is a good correlation with the simulation. For the lowest Z_0 tuning stub, where there is a strong H-field coupling between the DR and the tuning stub, the tuning bandwidth is the largest; it also has the highest IL at resonance. With the highest Z_0 (50 Ω) tuning stub, where the simulation shows the weakest coupling between the DR and the tuning stub, the measurement shows it has the smallest tuning bandwidth. But on the other hand, it has the least IL at resonance as expected because the simulation shows strong H-field around the microstrip lines that couple the signal out to ports 1 and 2. This finding is summarized in ***Table 1***.

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IMPLEMENTATION IN DRO CIRCUIT

DRO Design

Now that the varactor-tuned DR circuit has been characterized and the configuration that gives the biggest tuning bandwidth is identified, the DRO can be designed. The design is based on a negative resistance oscillator or a one-port oscillator. The strong H-field concentration around the DR and the tuning stub apparently reduces the H-field coupling to the microstrip, as can be seen in Figure 9a. Hence, the tunable DR circuit with tuning stub of Z_0 = 28 Ω has a high IL, ~ 6 dB. To reduce this loss, the microstrip is slightly widened (to Z_0 ≈ 37 Ω) to improve the field coupling between the DR and the microstrip. Only one microstrip line is used because it will be a one-port oscillator. The final varactor-tuned DR circuit is shown in **Figure 10** and the active device circuit, which is based on a Si bipolar transistor and provides the negative resistance, is shown in **Figure 11**. The varactor-tuned DR circuit is coupled at port 1. However, the negative resistance occurs over a wide frequency range and in this case more than 2.5 GHz wide. This will potentially cause instability within the range.[11] The DR circuit and the active device were coupled together to form the DRO. When the DRO output was monitored, spurious signals were observed along with the DRO oscillation. A 50 Ω termination is then added to the open end of the λ/4 stub of the microstrip line that couples to the DR; this eliminated the spurs.[13]

DRO Results

At V_{tune} = 0 V, the oscillation frequency is f_{0V} = 3.591 GHz and at V_{tune} = 9 V, the oscillation frequency is f_{9V} = 3.608 GHz, giving a tuning bandwidth of 17 MHz or 0.47 percent. **Figure 12** shows the spectrum

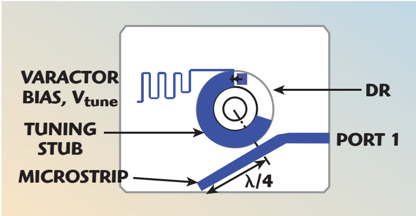

Fig. 10 Final tunable DR circuit with only one port.

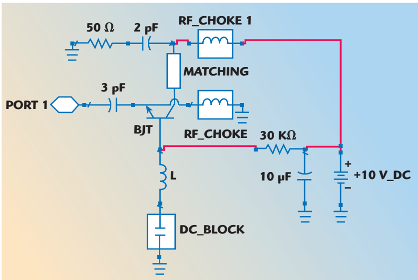

Fig. 11 Schematic of the circuit that generates the negative resistance.

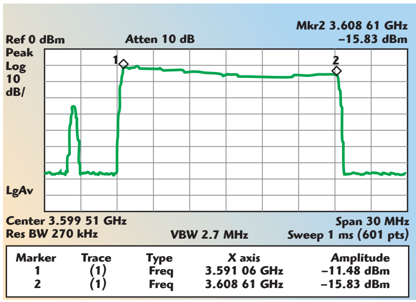

Fig. 12 Frequency sweep of the designed DRO showing a tuning bandwidth of 17 MHz.

analyzer sweep of the DRO with V_{tune} swept from 0 to 9 V. The output power varies from approximately 0 dBm to about +4.5 dBm. The power is 16 dB lower, because the measurement was done using a directional coupler (16 dB coupling factor). The phase noise at 100 kHz, 1 MHz and 10 MHz offsets from the center frequency, is -125 dBc/Hz, -147 dBc/Hz and -161 dBc/Hz, respectively. This is shown in ***Figure 13***. ***Figure 14*** shows the complete DRO. Notice that a 50 Ω resistor termination was added at the end of the λ/4 stub to eliminate spurs. The plastic screw holding the DR in place is also visible.

DISCUSSION AND CONCLUSION

Experiments on a DR circuit excited in the $TE_{01\delta}$ resonant mode were carried out, with its tuning stub in circular shape. It is found that the tuning stub dimensions can affect the DR tuning range. A linear tuning pattern can be achieved by keeping the tuning stub electrical length at λ/2, and by reducing the tuning stub Z_0, that is increasing its width, the tuning bandwidth is increased. 3D EM simulation reveals that as the tuning stub width is increased, the H-field coupling between the DR and the tuning stub increases, which explains the increase in K_V. Based on this finding, a DR tuning method that offers wide tuning bandwidth for applications with a small varactor tuning range is proposed. The method is applied to a 3.6 GHz DRO that would be employed in a phase-locked local oscillator with a specified tuning voltage of 0 to 10 V. Comparing this circular tuning stub to the straight line tuning stub used by Yom,[10] the circular tuning stub seems to yield a wider tuning range and higher K_V, that is 0.47 percent and 1.89 MHz/V, respectively, as opposed to 0.003 percent and 0.04 MHz/V. ■

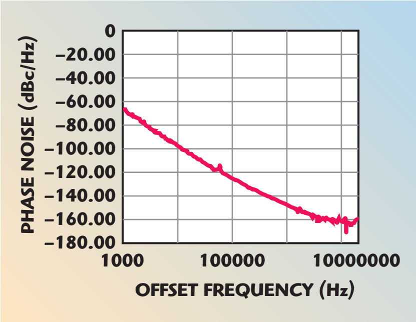

Fig. 13 Phase noise of the DRO at 3.6 GHz with V_{tune} = 5 V.

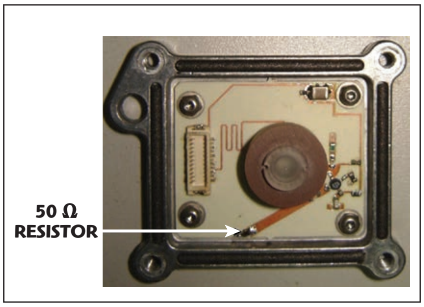

Fig. 14 Photograph of the complete DRO.

ACKNOWLEDGMENT

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Directional/Bi-Directional

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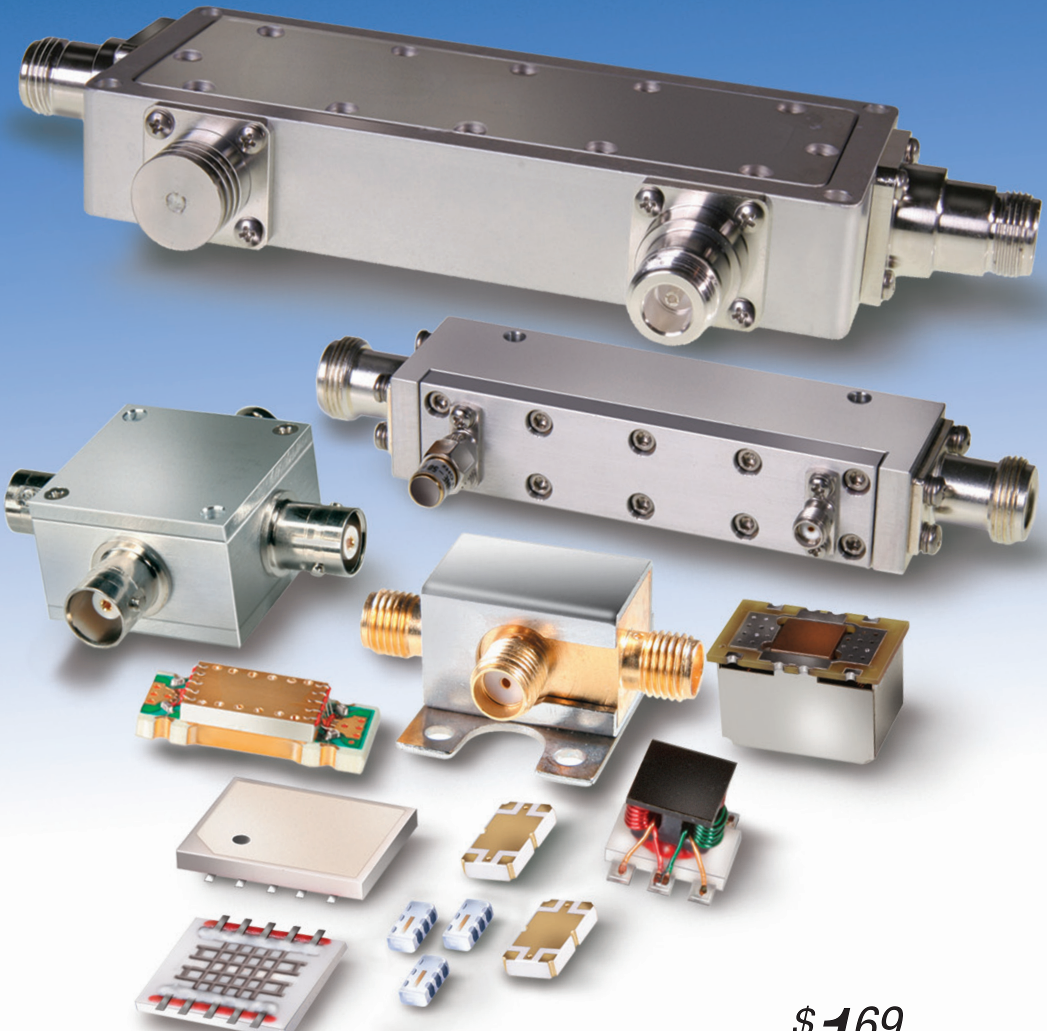

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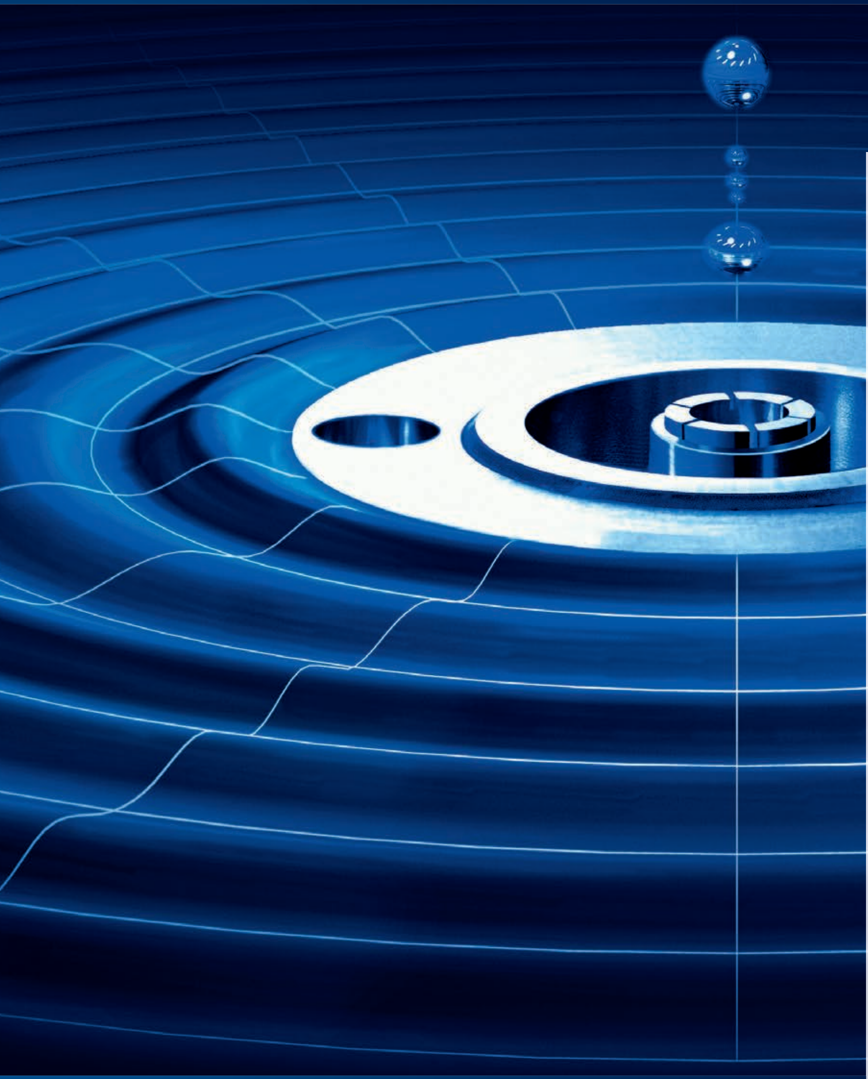

BROADBAND BANDSTOP FILTER USING PERIODIC FRACTAL ELECTROMAGNETIC BANDGAP STRUCTURES

A broadband, bandstop filter with sharp cut-off frequencies is presented, using novel designs of periodic fractal electromagnetic bandgap (EBG) structures. The sharp selective bandstop filter is constructed by cascading two EBG dual-ear cells with good performance and compact sizes, using coplanar waveguide (CPW) transmission lines. The circuit models of the EBG structures are derived by using an equivalent circuit approach and full-wave electromagnetic simulation is used for extracting the values of the lumped elements in the circuits. The 20 dB bandwidth of the bandstop filter (BSF) is 2 GHz (9.9 to 11.9 GHz) and the center frequency is 11.5 GHz. The 20 dB fractional bandwidth is 18.3 percent. In the 20 dB stopband range, the return loss ripple is less than 0.5 dB. The proposed BSF is fabricated with surface micromachining and the measurement and simulation results agree well.

With the rapid development of modern communications, efficient utilization of more and more frequency channels is necessary. Microwave filters have been widely used in modern communication systems. In recent years, more novel filters, using new technologies, continue to challenge traditional radio frequency (RF) components with ever more stringent requirements, including better properties, smaller dimensions and lower power consumption.[1]

Periodic structures have recently attracted much attention in the microwave and millimeter-wave community, owing to their filtering properties or inhibition of signal propagation in certain directions. These structures have been usually referred to as electromagnetic bandgaps (EBG) or electromagnetic crystals. EBG structures can be embedded in the dielectric substrate or etched in the metal layer.[2] This helps to suppress the surface waves and results in a better radiation pattern, higher transmission efficiency and good slow-wave[3] characteristic to obtain frequency-selective features.[4] EBG structures realized on metal layers are useful for constructing filters, including bandstop filters (BSF),[5] lowpass filter (LPF)[6] and bandpass filter (BPF),[7] phase shifters,[8] power dividers,[9] antennas[10] and resonators.[4] In these studies, the RF components with EBG slot or CPW-fed slot structures are designed to improve radiation patterns and to reduce the higher order harmonics, obtaining good ratio characteristics.

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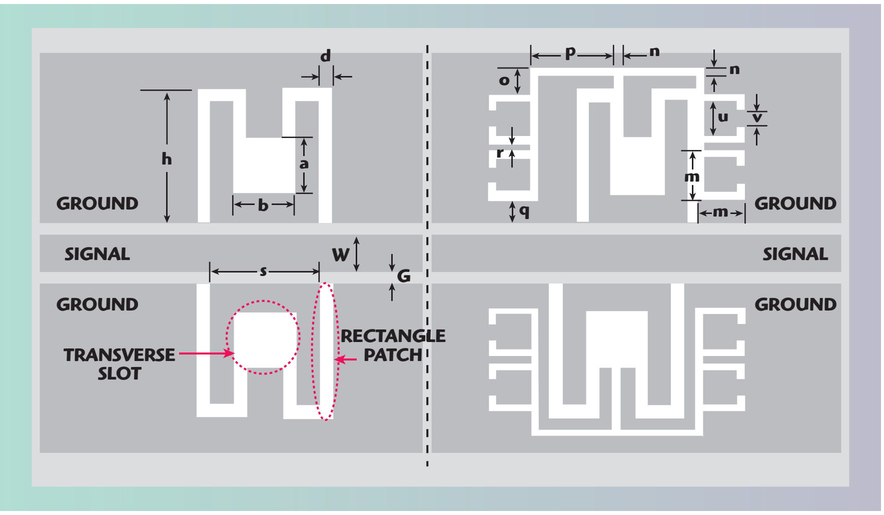
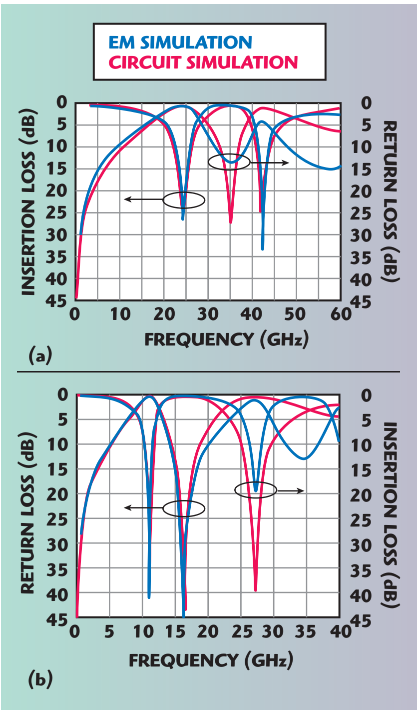


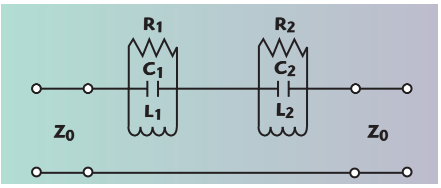
▲ *Fig. 1 EBG unit (a) etched lattice shaped (ELS) unit and (b) the dual-ear unit.*



▲ *Fig. 2 Comparison of EM and circuit simulation RF performance of EBG units (a) ELS unit and (b) EBG-DE structure.*

EBG structures can be patterned on metal layers, such as the ground plane or the signal line of microstrips,[7] as well as coplanar waveguide (CPW) transmission lines.[3] The EBG lattice can offer extreme flexibility in the design of filters based on CPW transmission lines. The inductance and capacitance values of the EBG can be adjusted by varying the dimensions of the EBG lattice geometries, thus can effectively cancel the reactive part of the characteristic impedance.

In this article, a broadband bandstop filter, with sharp cut-off frequencies, is constructed by cascading two dual-ear EBG cell resonators with good performance and compact-size CPW transmission lines. The circuit models of the EBG structures are derived by an equivalent circuit approach and full-wave electromagnetic simulation is used for extracting the values of the lumped elements in the circuit. The 20 dB bandwidth of the BSF is 2 GHz (9.9 to 11.9 GHz) and the center frequency is 11.5 GHz. The 20 dB fractional bandwidth is 18.3 percent. In the 20 dB stopband range, the return loss ripple is less than 0.5 dB. The proposed BSF is fabricated using surface micromachining, and measurement and simulation results are in agreement.



▲ *Fig. 3 Equivalent parallel circuit model of the EBG cell.*

THE EBG UNIT CELL

An etched lattice shaped (ELS) EBG unit is machined on a CPW line with a 50 Ω characteristic impedance (G/W/G= 60/100/60) for good impedance matching, as shown in ***Figure 1***. The substrate is high resistivity silicon (ρ = 4000 Ω cm) with a dielectric permittivity of $\varepsilon_r = 11.9$ and a thickness of 450 μm. The metal thickness of CPW signal line is 0.5 μm, and the other parameters are h = 800 μm, a = 350 μm, b = 300 μm, d = 60 μm and s = 700 μm. The width of the ground line is sufficiently larger than that of the signal line, and is assumed to be semi-infinite (set as 2000 μm in the simulation). The RF performance of the structure is shown in ***Figure 2***. The 3 dB bandwidth is 9.5 GHz, from 18.4 to 27.9 GHz. The 20 dB bandwidth is 1.7 GHz, from 23.3 to 25 GHz.

From the simulation results, the lumped-element equivalent circuit is derived by cascading two parallel resonant circuits to model this EBG unit cell, as shown in ***Figure 3***. Each EBG unit cell is represented by two series RLC tanks instead of only one as that of Karim.[11] It is necessary to extract the lumped circuit parameters to analyze the EBG unit deeply. The equivalent impedance equation of the single resonant model may be expressed as

$$Z = \left(j\omega C_1 + \frac{1}{j\omega L_1} + \frac{1}{R_1}\right)^{-1} + \left(j\omega C_2 + \frac{1}{j\omega L_2} + \frac{1}{R_2}\right)^{-1} \quad (1)$$

Where the subscripts "1" and "2" denote the two different resonant circuit parameters. According to microwave network theory, assuming that $R \gg Z_0$, the S-parameters are reduced to

$$|S_{11}| = \left|\frac{Z}{2Z_0 + Z}\right| \text{ and } |S_{21}| = \left|\frac{2Z_0}{2Z_0 + Z}\right| \quad (2)$$

From Elamaran et al.,[8] the equivalent circuit parameters, C_1 and C_2 can be extracted as

$$C_1 = \frac{\omega_c(\omega_0^2 - \omega_c^2)(\omega_2^2 - \omega_1^2)}{2Z_0(\omega_1^2 - \omega_c^2)(\omega_2^2 - \omega_c^2)(\omega_0^2 - \omega_1^2)} \quad (3)$$

and

$$C_2 = \frac{\omega_c(\omega_0^2 - \omega_c^2)(\omega_2^2 - \omega_1^2)}{2Z_0(\omega_1^2 - \omega_c^2)(\omega_2^2 - \omega_c^2)(\omega_2^2 - \omega_0^2)} \quad (4)$$

Then, the parameters L_1 and L_2 can be extracted from $\omega = 1/\sqrt{LC}$. The resistances R_1 and R_2 of the circuit can be obtained approximately from the resonant frequencies, ω_1 and ω_2, respectively.

TABLE I

PARAMETERS EXTRACTED FROM THE EQUIVALENT CIRCUIT

	ELS-EBG unit cell	DE-EBG unit cell		BSF constructed by cascading two DE-EBG unit cells
L_1 (nH)	0.31347	0.53839	C_g (pF)	0.0938 pF
C_1 (pF)	0.13795	0.38447	L_g (nH)	0.2219 nH
R_1 (kΩ)	1.6465	11.109	C_p (pF)	0.6838 nH
L_2 (nH)	0.085547	0.28907	L_p (pF)	0.1898 pF
C_2 (pF)	0.16890	0.11901		
R_2 (kΩ)	1.6083	9.9282		

$$R_1 = 2Z_0 \frac{1-|S_{21}|_{\omega=\omega_1}}{|S_{21}|_{\omega=\omega_1}} \text{ and } R_2 = 2Z_0 \frac{1-|S_{21}|_{\omega=\omega_2}}{|S_{21}|_{\omega=\omega_2}} \qquad (5)$$

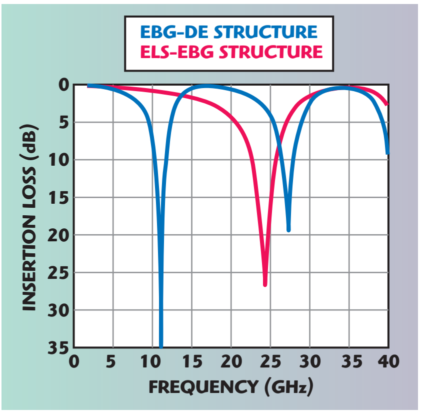
Therefore, this model can predict the EBG unit cell over the relatively wide frequency range from DC to 40 GHz, in which the circuit simulation results and the EM simulation results show good agreement. The resistors, capacitances and inductances are evaluated from the resonant frequencies of the EBG unit cell and listed in ***Table 1***.

THE BANDSTOP FILTER

EBG Dual-Ear (DE) Structure

From the above analysis, it is implied that it is difficult to change the resonant frequency over a large range, unless the dimensions of the ELS-EBG unit cell have a large change, and the cut-off frequencies of the filter using the ELS-EBG units are not sharp enough to be used in this application. Moreover, the cut-off frequency of the filter, using dual-ear structures, can be adjusted and become sharper than before.[12] For these considerations, an improved compact EBG structure with dual-ear structures (EBG-DE) based on the ELS-EBG unit is introduced (see Figure 1). The dimensions of the EBG-DE structure, m, n, o, p, q, r, u, and v, are 300, 40, 120.6, 559, 108, 50, 220 and 42.66 μm, respectively.

The unit cell's equivalent circuit is represented by two series RLC tanks analyzed like before, and the EBG-DE structure simulation curves are shown in Figure 2. It is easy to observe that the EM simulation curves are consistent with the circuit simulation curves, which means that the two series RLC tanks circuit model is fit for the EBG-DE structure as well. The circuit model's parameters, including resistances, capacitances and inductances, are shown in Table 1.

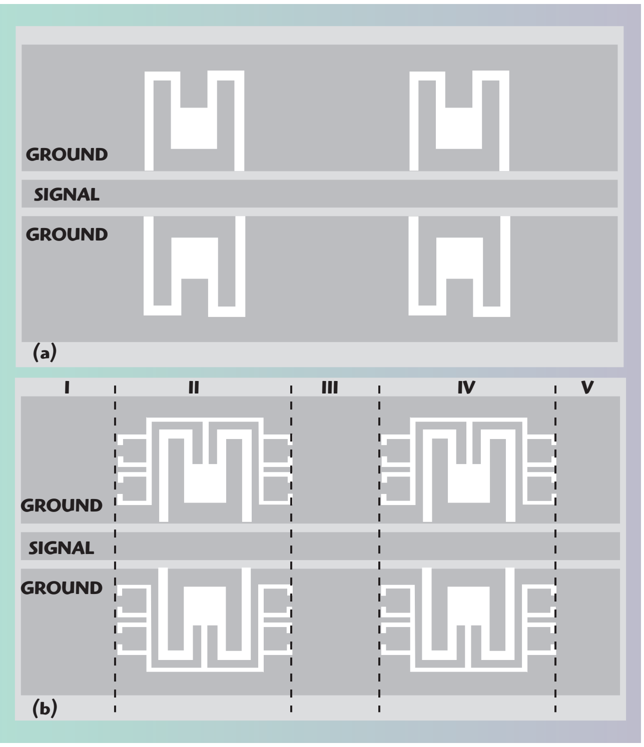


▲ *Fig. 4 Frequency response comparison between ELS-EBG and EBG-DE structures.*

FREQUENCY RESPONSE COMPARED BETWEEN ELS-EBG AND EBG-DE

The comparison of the frequency responses between ELS-EBG and EBG-DE is shown in ***Figure 4***. Compared with the ELS-EBG structure, the first resonant frequency of the improved EBG-DE structure is shifted from 24.2 to 11.1 GHz. The shift of the resonant frequency with a large range of 13.1 GHz is realized using the dual-ears structure.

The distributed capacity and inductance of the EBG-DE structure are increased by the introduction of dual-ears structures, listed in Table 1. Therefore, the resonant frequency of the improved EBG-DE structure is decreased, as shown in the figure. At the same time, the resistance of the BSF using the EBG-DE structure is increased, and



▲ *Fig. 5 Bandstop filters made by cascading two proposed EBG structures (a) ELS-EBG structures and (b) EBG-DE structures.*

results in the increase of the insertion loss.

The EBG-DE unit cell can be used in an oscillator at 11.1 GHz. For the oscillator, the frequency spectra of phase perturbation $\delta\phi(\omega)$ of the oscillating signal is derived using the phase noise estimation:[13]

$$|\delta\phi(\omega)|^2 = \frac{2|e|^2}{\omega^2 A_0^2} \cdot \frac{\omega^2 \left|Z_c'(\omega_0)\right|^2 + A_0^2\left[\left(\frac{\partial R_d}{\partial A}\right)^2 + \left(\frac{\partial X_d}{\partial A}\right)^2\right]}{\omega^2 \left|Z_c'(\omega_0)\right|^2 + A_0^2 S^2} \quad (6)$$

where

$$S = \frac{\partial R_d}{\partial A} X_c'(\omega) - \frac{\partial X_d}{\partial A} R_c'(\omega)$$

In this oscillator model, the active device for negative resistance generation is represented by $Z_d = R_d + jX_d$ and the impedance of the resonator is represented by $Z_c(\omega) = R_c + jX_c$. The entire circuit is expressed as a series connection of Z_d and $Z_c(\omega)$, where e(t) represents noise that may be present.

From Equation 6, the reduction of phase noise can be achieved by increasing the magnitude of $Z_c'(\omega_0)$, which means a drastic impedance variation of a resonator with respect to frequency at the point of resonance.

From Table 1, the equivalent resistances extracted from the equivalent circuit of the ELS-EBG unit cell are 1.6465 and 1.6083 kΩ, which are much less than the equivalent resistances of the DE-EBG unit cell, 11.109 and 9.9282 kΩ. This means that the magnitude of $Z_c(\omega_0)$ of the oscillator using the EBG-DE unit cell is larger than that using the ELS-EBG unit cell. Thus, the oscillator using the EBG-DE unit cell has sharper frequency characteristics than that using the ELS-EBG unit cell.

BSFS CONSTRUCTED BY CASCADING EBG-DE AND ELS-EBG STRUCTURES

According to the preceding analysis, bandstop filters with wider bandwidth are constructed by cascading two proposed EBG units, including the ELS-EBG and EBG-DE structures, as shown in ***Figure 5***. The length of the filter is approximately 4000 µm.

The RF performance of the filters is shown in ***Figure 6***. The stopband of the filter using EBG-DE units lies within X-Band, while the stopband of the filter using ELS-EBG units stays within K-Band.

The 3 dB bandwidth of the BSF using the ELS-EBG structure is 10.1 GHz, from 17.9 to 28 GHz and the center frequency is 24.3 GHz. The 20 dB bandwidth is 4.6 GHz, from 21.2 to 25.8 GHz. In the 20 dB stopband range, the return loss ripple is less than 0.19 dB. The 3 dB band-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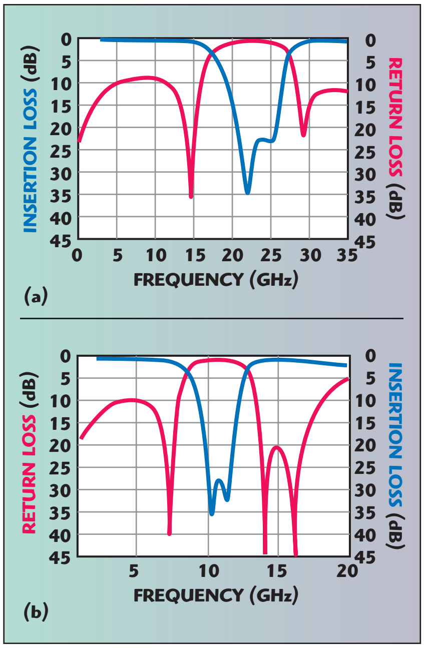
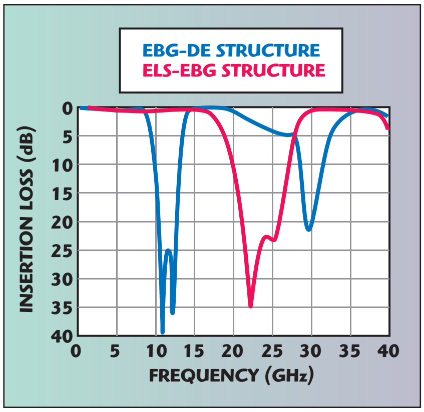
width of the BSF using the improved EBG-DE structure is 4.2 GHz, from 8.6 to 12.8 GHz and the center frequency is 11 GHz. The 20 dB bandwidth is 2 GHz, from 9.9 to 11.9 GHz. In the 20 dB stopband range, the return loss ripple is less than 0.05 dB. It is easy to see that the BSF using the improved EBG-DE structure has a narrower stopband width and a smaller ripple than the BSF using ELS-EBG structure.



▲ *Fig. 6 Simulated performance of two cascaded EBG structures (a) ELS-EBG and (b) EBG-DE.*

The comparison of the frequency responses between the filters using ELS-EBG and EBG-DE structures is shown in ***Figure 7***. Comparing the two filters, the cut-off frequencies of the filter using the EBG-DE unit cell is sharper. From the simulation results, the sharp selectivity is observed and it is noticed that the 20 dB stopband is from 10.3 to 12.6 GHz. The stopband return loss is less than 0.5 dB. In the passband, the insertion loss is less than 0.6 dB, and the return loss is greater than 8 dB. The 3 dB fractional bandwidth is 34.6 percent. Thus, the filter with EBG-DE structure possesses a better frequency selectively and it would be possible to design sharply selective bandstop filters with the dual-ear EBG structure.



▲ *Fig. 7 Frequency response comparison between filters using ELS-EBG and EBG-DE structures.*

EQUIVALENT CIRCUIT ANALYSIS

The equivalent circuit of the BSF, formed by cascading EBG-DE structures, is shown in ***Figure 8***. The conformal mapping and Green's function methods are used to calculate the per unit length capacitance for a finite electrode thickness with the buffer layer,[14] which can be written as

$$\Delta C = C_0 + C_t \tag{7}$$

Where C_0 is the per unit length capacitance of the CPW without considering the thickness of the metal layer, C_t is

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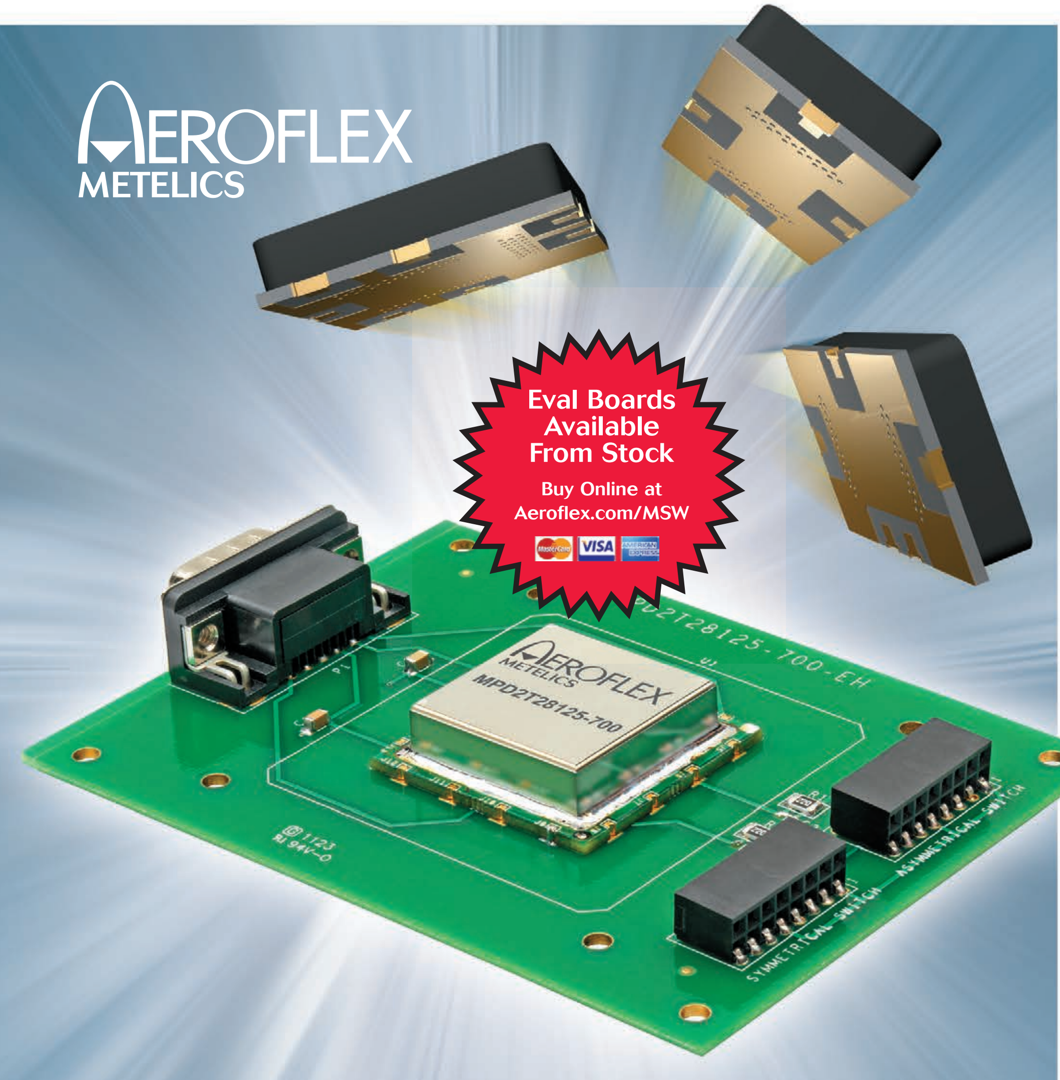

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MSW2001–200	T-R Switch, TX Left	+V Only	MPD2T28125-700	400 to 4,000
MSW2002–200	T-R Switch, TX Left	+V Only	MPD2T28125-700	2,000 to 6,000
MSW2022-200	T-R Switch, TX Right	+V & -V	MPD2T5N200-702	2,000 to 6,000
MSW2050–205	T-R Switch, TX Left	+V Only	MPD2T28125-700	20 to 1,000
MSW2051–205	T-R Switch, TX Left	+V Only	MPD2T28125-700	400 to 4,000
MSW2030–203	Symmetrical SP2T	+V Only	MPD2T28125-700	10 to 1,000
MSW2031–203	Symmetrical SP2T	+V Only	MPD2T28125-700	400 to 4,000
MSW2032–203	Symmetrical SP2T	+V Only	MPD2T28125-700	2,000 to 6,000
MSW2040–204	Symmetrical SP2T	+V Only	MPD2T28125-700	50 to 1,000
MSW2041–204	Symmetrical SP2T	+V Only	MPD2T28125-700	400 to 4,000
MSW2060-206	Symmetrical SP2T	+V & -V	MPD2T5N200-702	10 to 1,000
MSW2061-206	Symmetrical SP2T	+V & -V	MPD2T5N200-702	400 to 4,000
MSW2062-206	Symmetrical SP2T	+V & -V	MPD2T5N200-702	2,000 to 6,000
MSW3100–310	Symmetrical SP3T	+V Only	MPD3T28125-701	10 to 1,000
MSW3101–310	Symmetrical SP3T	+V Only	MPD3T28125-701	400 to 4,000
MSW3200-320	Symmetrical SP3T	+V & -V	MPD2T5N200-703	10 to 1,000
MSW3201-320	Symmetrical SP3T	+V & -V	MPD2T5N200-703	400 to 4,000

* +V Only = Up to +28V and +125V
+V & -V = Up to +5V and -200V

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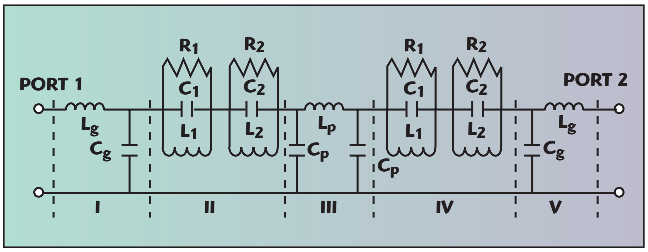


▲ *Fig. 8 Equivalent parallel circuit model of the BSF composed of two cascaded proposed EBG-DE structures.*

the capacitance value increasing caused by side-face area after considering the thickness of the metal electrodes. Approximate expressions containing empirical fitting parameters are given below:[15]

$$C_0 = 2\varepsilon_0(\varepsilon_r + 1)\frac{K(k)}{K(k')} \tag{8}$$

and

$$C_t = \frac{2\pi\varepsilon_0\left[a_1 - a_2\ln\left(\frac{W}{G}\right) + a_3\ln\left(a_4 + \frac{t}{G}\right)\right]}{\ln\left(\frac{4G}{t}\right) + \frac{1}{8}\left(\frac{t}{G}\right)^2} \tag{9}$$

where $k = \frac{W}{W+2G}$ $k' = \sqrt{1-k^2}$

$a_1 = 0.49254$, $a_2 = 0.01709$, $a_3 = 0.21918$, and $a_4 = 0.10357$. Here K is the complete elliptic integral of the first kind, ε_0 is the permittivity of free space and ε_r is the relative permittivity of the material.

In Figure 5, the layout of the BSF is divided into five parts, two EBGs and three CPWs. According to microwave theory,[15] a CPW transmission line can be modeled as a lumped element with a very large number of elements. The total line length has been divided into an infinite number of sections.

Each lumped element represents an infinitesimal piece of the physical transmission line. The values of ΔR, ΔC, ΔL and ΔG are the resistance per length, capacitance per length, inductance per length, and conductance per length, respectively. These are the distributed parameters of the transmission line.

From the equations above, it is easy to obtain values of capacitances in the equivalent circuit:

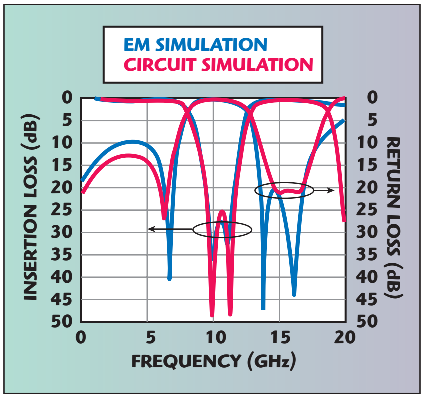
$$C_g = \Delta C\, l_1, C_p = \Delta C\, l_2 \tag{10}$$

In Figure 5, the length of part I and part V is l_1, and the length of part III is l_2. However, the CPW parts are short enough and it is reasonable to neglect their resistances and conductances. According to microwave theory, L_g can be written as

$$L_g = \frac{1}{\omega^2 C_g} \tag{11}$$

Where ω represents the resonance frequency of the CPW at part I and also at the others. Additionally, the equivalent circuit of the BSF composed by cascading two EBG-DE structures is shown in Figure 8. The parameters,

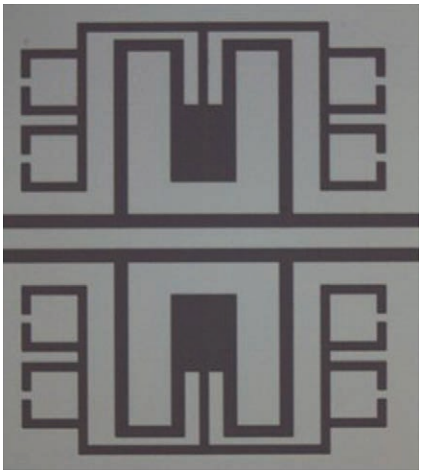
including capacitances, C_p and C_g, and inductances, L_p and L_g, are listed in Table 1. The RF performance, compared between the EM and circuit simulation, is shown in ***Figure 9***. The circuit simulation results agree well with the EM simulation results.



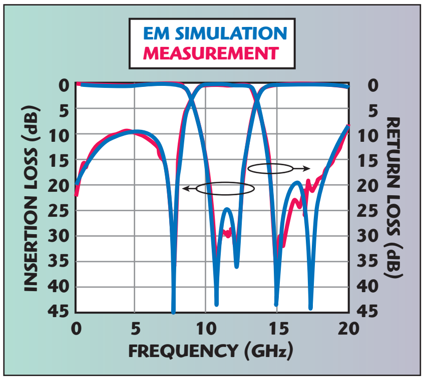
▲ *Fig. 9 Comparison between EM and circuit simulation of two cascaded EBG-DE structures.*

MEASUREMENT RESULTS AND DISCUSSION

The designed BSF structures are fabricated on a high resistivity silicon substrate (ρ = 4000 Ω cm) using a surface micromachining fabrication technology. A 1000 Å thick thermal oxide was introduced on the substrate as buffer layer. The metal layer is made by sputtering a 0.5 µm thick aluminum layer, with careful stress control. The final BSF patterns are defined by lithography and wet etching. Compared to normal MMIC fabrication, the surface micromachining technology can precisely control small dimensions and mass production can be obtained. An optical photo of EBG dual-ear structure is shown in ***Figure 10***.



▲ *Fig. 10 Photograph of an EBG dual-ear structure.*



▲ *Fig. 11 Comparison between simulated and measured performance of the EBG-DE bandstop filter.*

The RF performance of the BSFs is obtained using an HP8510C vector network analyzer and a RF probe station with 150 µm probes. A full thru-reflect-line (TRL) routine is used to calibrate with the NIST software MULTICAL.

Figure 11 shows the measured results for the BSF using EBG-DE units. The measurement results of the BSF made by cascading the proposed double EBG-DE units agree well with the simulated results. The small difference

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between the simulation results and the measurement results can be attributed to the fabrication error.

CONCLUSION

In this article, a bandstop filter using novel ELS-EBG structures has been studied. An equivalent circuit is provided to show the performance of the ELS-EBG structure with different dimensions. An improved EBG-DE structure with compact size has a low resonant frequency. A sharp bandstop filter with good performance is made by cascading two EBG-DE unit cells. The measurement and simulation results of the BSF agree well. It is expected that the EBG-DE structure for CPW will have potential applications in RF and microwave circuits. ■

ACKNOWLEDGMENT

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DCO7075-3	700 - 750	0.5 - 3	+3 @ 12 mA	-108	0.3 x 0.3 x 0.1
DCO80100-5	800 - 1000	0.5 - 8	+5 @ 26 mA	-111	0.3 x 0.3 x 0.1
DCO8190-5	810 - 900	0.5 - 16	+5 @ 34 mA	-118	0.3 x 0.3 x 0.1
DCO100200-5	1000 - 2000	0.5 - 24	+5 @ 36 mA	-95	0.3 x 0.3 x 0.1
DCO1198-8	1195 - 1205	0.5 - 8	+8 @ 30 mA	-115	0.3 x 0.3 x 0.1
DCO170340-5	1700 - 3400	0.5 - 24	+5 @ 29 mA	-90	0.3 x 0.3 x 0.1
DCO200400-5 DCO200400-3	2000 - 4000	0.5 - 18	+5 @ 46 mA +3 @ 46 mA	-90 -89	0.3 x 0.3 x 0.1
DCO300600-5 DCO300600-3	3000 - 6000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-80 -78	0.3 x 0.3 x 0.1
DCO400800-5 DCO400800-3	4000 - 8000	0.5 - 18	+5 @ 20 mA +3 @ 20 mA	-78 -76	0.3 x 0.3 x 0.1
DCO432493-5 DCO432493-3	4325 - 4950	0.5 - 11	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.1
DCO473542-5 DCO473542-3	4730 - 5420	0.5 - 22	+5 @ 20 mA +3 @ 20 mA	-88 -86	0.3 x 0.3 x 0.1
DCO490517-5 DCO490517-3	4900 - 5175	0.5 - 5	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.1
DCO495550-5 DCO495550-3	4950 - 5500	0.5 - 12	+5 @ 22 mA +3 @ 22 mA	-83 -85	0.3 x 0.3 x 0.1
DCO579582-5	5780 - 5880	0.5 - 10	+5 @ 20 mA	-90	0.3 x 0.3 x 0.1
DCO608634-5 DCO608634-3	6080 - 6340	0.5 - 5	+5 @ 20 mA +3 @ 26 mA	-85 -86	0.3 x 0.3 x 0.1
DCO615712-5 DCO615712-3	6150 - 7120	0.5 - 18	+5 @ 22 mA +3 @ 22 mA	-85 -83	0.3 x 0.3 x 0.1

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DXO Series					
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DXO900965-5 DXO900965-3	9.0 - 9.65	0.5 - 12	+5 @ 27 mA +3 @ 27 mA	-80 -78	0.3 x 0.3 x 0.1
DXO10701095-5	10.70 - 10.95	0.5 - 15	+5 @ 25 mA	-82	0.3 x 0.3 x 0.1
DXO11441200-5	11.44 - 12.0	0.5 - 15	+5 @ 30 mA	-82	0.3 x 0.3 x 0.1
DXO11751220-5	11.75 - 12.2	0.5 - 15	+5 @ 30 mA	-80	0.3 x 0.3 x 0.1

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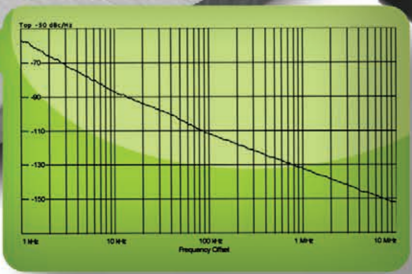

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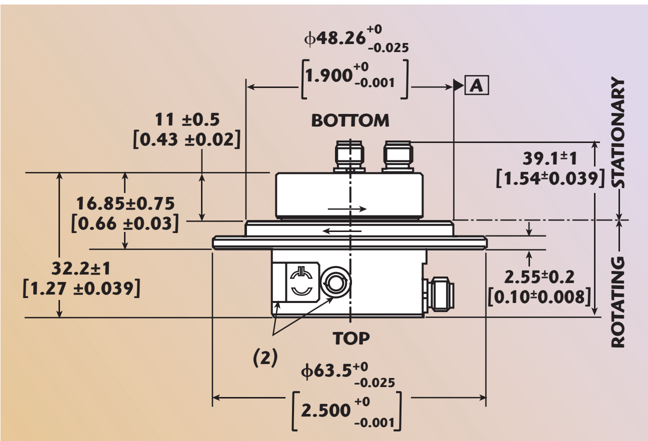
KA-BAND ROTARY JOINT FOR SATCOM APPLICATIONS

Increasingly satellite operators are focusing on utilizing the Ka-Band to expand capacity. Although by definition the Ka-Band covers the frequency band from 26.5 to 40 GHz, Ka-Band for satellite applications generally uses the frequency range around 20 GHz for the downlink and 30 GHz for the uplink. Ever-growing SatCom bandwidth needs, overcrowding of the radio frequency spectrum and the increasing demand of satellite communications have been the main drivers for this development.



▲ *Fig. 1 Outline drawing of the BN 153130 Ka-Band rotary joint [dimensions in mm (in)].*

Iridium, which has announced the launch of Iridium NEXT via Ka-Band in 2015, and Eutelsat, which already operates on Ka-Band technology, are just two of many operators demanding Ka-Band frequencies. Such satellite communication systems provide broadband network access for mobile ground, maritime and airborne antenna systems. These systems – commonly called SatCom on-the-move – are being introduced on a large scale all over the world for commercial, as well as for governmental (civilian and military) use.

The increase in frequency from Ku- to Ka-Band offers broad coverage of bandwidth in this very rapidly progressing technology. The utilization of higher frequencies requires faster electronic components, which, in the past, have been particularly expensive. However, due to rapid technological progress, competitive components are currently available. With an increase of Ka-Band applications and the associated optimizations of single components that comprise it, the belief is that prices will get closer to the price level of Ku-Band.

A moving satellite terminal requires a highly sophisticated beam steering system in order to

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continuously track the satellite during operation. There are two basic technologies that can be employed for pointing an antenna beam: The electronically phased-array antenna and the mechanically steered pencil beam antenna.

SPACE RESTRICTIONS

When the latter system is used, the strong space restrictions imposed by a mobile SatCom terminal require the adoption of a small aperture antenna together with a low-profile pedestal. Likewise, the rotary joints employed for signal transmission along the mechanical steering axes need to be small and are often shaped specifically for the application. At the same time, bi-directional high data rate communications over Ka-Band SatCom require a bandwidth spread of more than 1 GHz on the uplink and downlink for both commercial and military systems.

In order to provide equipment manufacturers with rotary joints tailored to the specific requirements of SatCom systems, SPINNER has developed the new BN 153130 dual-channel rotary joint for Ka-Band applications. Excellent electrical and mechanical performance and a long lifetime define this solution as a reference standard in electrical and mechanical performance.

The product line follows a common design philosophy that is characterized by excellent electrical and mechanical performance, allied to a highly reliable design. In principle, RF rotary joints can be classified into two categories:

- Contacting rotary joints, where the inner and outer conductor of the fixed and rotating part are connected via galvanic contacts.
- Non-contacting rotary joints, where the RF signals are transmitted via axial and radial chokes (capacitive coupling).

NON-CONTACTING DESIGN

The BN 153130 dual-band rotary joint is realized as a non-contacting design. The main advantages with this design are that as there is no contact then there is no abrasion, and it has small dimensions (39.1 mm maximum length and 63.5 mm flange diameter), while accommodating high frequencies. Besides good RF performance, the Ka-Band rotary joint is characterized by a lifetime of more than 20 million revolutions. ***Figure 1*** shows BN 153130's design.

The ability to produce a rotary joint of such small dimensions is very significant. For many mobile satellite communication systems being developed, there is a requirement to significantly reduce the height of the radomes under which the SatCom system is installed. The reason is the need to improve the drag coefficient, which implies that less installation space is available for the antenna, as well as for the whole pedestal. Thus, there is increasing demand for low profile rotary joints to be used in SatCom radomes. SPINNER has taken up the challenge and developed a Ka-Band rotary joint with reduced height, which means that the overall system can be built lower. This can help save fuel (on an aircraft, for example).

CHARACTERISTICS

Figure 2 shows the L-shaped dual-channel BN 153130 Ka-Band

rotary joint; the main characteristics of this rotary joint are summarized in ***Table 1***. As the table illustrates, to be able to achieve superior system performance, it is necessary to achieve very low insertion loss, VSWR and high isolation values. These superior electrical properties are the result of many years of design experience, careful development, the use of top quality materials and high precision manufacturing.

Significantly, the BN 153130 dual-channel rotary joint also covers the preferential military frequency range for downlink frequencies (19.7 to 21.2 GHz) and uplink frequencies (29.5 to 31 GHz), which military customers are demanding. In addition, a broadband version for civil applications is also available with 17.7 to 21.2 GHz for the downlink and 27.5 to 31 GHz for the uplink. The ability to cover both military and civil requirements is an attractive solution for customers.

▲ *Fig. 2 L-shaped dual-channel Ka-Band rotary joint.*

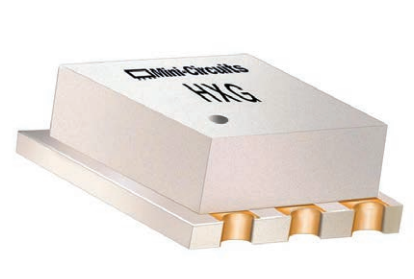
TABLE I
MAIN CHARACTERISTICS OF THE BN 153130 KA-BAND DUAL-CHANNEL ROTARY JOINT

Channel designation	Channel 1	Channel 2
Interface type	2.92 mm-f (50 Ω)	
Frequency range (GHz)	19.7 to 21.2	29.5 to 31
Average power capability (W), max.	1	10
VSWR, max.	1.5	
VSWR variation over rotation, max.	0.1	
Insertion loss (dB), max.	0.8	
Insertion loss variation over rotation (dB), max.	0.1	
Isolation (dB), min.	50	

SUMMARY

The new BN 153130 dual-channel Ka-Band rotary joint completes the SPINNER product portfolio at the upper frequency range. The result of this work is a non-contacting dual-channel Ka-Band rotary joint that guarantees outstanding electrical properties even under severe conditions (–40° to 70°C) over a long service life and offers an excellent price-performance relationship.

SPINNER GmbH, Munich, Germany +49 89 12601 1160, e-mail: info@spinner-group.com, www.spinner-group.com.



ULTRA HIGH IP3 AMPLIFIER MODULE

The HXG-242+ (RoHS compliant) is an advanced amplifier module combining high dynamic range MMIC technology with integrated optimization circuits to provide industry-leading linearity over the optimized frequency range of 700 to 2400 MHz. It is packaged in a Mini-Circuits System-in-Package (MSiP) module (6.4 × 6.4 × 2.4 mm) using a sealed ceramic cover with gold-over-Ni metallization for excellent solderability.

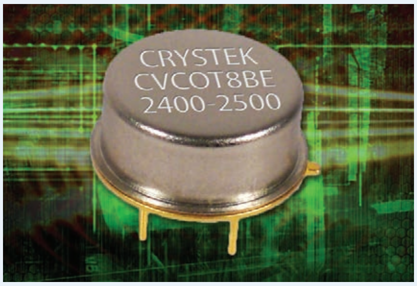
The module offers industry-leading IP3 performance of +46.6 dBm at 1500 MHz relative to device size and DC power consumption of 146 mA at 1500 MHz. The combination of the design and E-PHEMT technology provides enhanced linearity as shown in the high IP3. It covers the primary wireless frequency bands for cellular, PCS and LTE. These features make this amplifier ideal for use in:

- Driver amplifiers for complex waveform up converter paths
- Drivers in linearized transmit systems
- Secondary amplifiers in ultra high dynamic range receivers.

A unique feature of the HXG-242+, which separates this design from all competitors, is the low noise figure of 2.4 dB (typical) in combination with the high dynamic range. Unlike competing products, Mini-Circuits HXG-242+ provides input and output return loss of 10 dB up to 1.5 GHz without the need for any external matching components. The HXG-242+ includes internal matching networks to offer an extremely high dynamic range module in a small package.

VENDORVIEW

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



2400 TO 2500 MHz HERMETICALLY SEALED TO-8 VCO

Crystek Corp. has designed the CVCOT8BE-2400-2500 TO-8 VCO that operates from 2400 to 2500 MHz and provides high performance frequency control in harsh, demanding environments. The VCO features a typical phase noise of -101 dBc/Hz at 10 KHz offset and excellent linearity. Tuning sensitivity is rated at 55 MHz/V. Pulling and pushing are minimized to 11 MHz and 1 MHz/V, respectively; second harmonic suppression is –15 dBc typical.

The CVCOT8BE line features a full-functioning VCO in a rugged, hermetically sealed TO-8 package to protect the VCO from moisture, contaminants and other elements. The metal-can construction features gold-plated pins with no internal wire bonds for enhanced signal integrity. They are sealed in a nitrogen atmosphere with a dew point of –60°C or lower for a true –55°C storage temperature. The VCO line has an operating temperature range of –40° to +85°C

Given the hermetically sealed construction, the CVCOT8 VCO is ideally suited for military and aerospace applications where high temperature/moisture/altitude elements are of concern. Customers can request Class B screening or any additional requirements in terms of specifications, testing and performance reports. At present, the CVCOT8 family is available from 800 MHz to 4 GHz in bands. Custom designs are also available.

Engineered and manufactured in the USA, the CVCOT8BE-2400-2500 VCO features a control voltage range of 0.5 to ~4.5 V with an input voltage of 5 V. Maximum current consumption is 25 mA and output power is +0 dBm.

Crystek Corp.,
Fort Myers, FL
(800) 237-3061,
www.crystek.com.

High Performance 600 MHz Oscilloscope

The R&S® RTO oscilloscopes, with 1 and 2 GHz bandwidth, appeal to users with its high measurement accuracy, operating convenience and speed. These features are also in very high demand for applications at bandwidths below 1 GHz. This is why Rohde & Schwarz has added a 600 MHz model to its high performance oscilloscope family. The new 600 MHz version of the R&S RTO is a unique solution that enables users to perform complex in-depth analyses even in the lower bandwidth range.

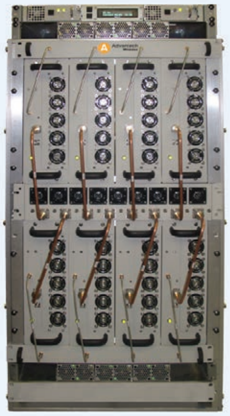
For its R&S RTO high performance product line, Rohde & Schwarz created a special ASIC with real-time processing of the digitized measurement results. Thanks to its multiple parallel processing capability, this ASIC makes it possible to analyze one million waveforms per second. Conventional oscilloscopes capture signals during only 0.5 percent of the acquisition cycle, but Rohde & Schwarz has increased the active acquisition time by a factor of 20, to 10 percent of an acquisition cycle. Even with this high acquisition rate, all of the setting options and analysis functions remain available for measurements without reducing speed.

Rohde & Schwarz has also taken a new approach when designing the trigger system. Due to the all-digital trigger architecture, the trigger and the captured data share a common signal path and a common time base. The result is exceptionally low trigger jitter and exact assignment of the trigger to the signal.

The low noise front-end and the single-core A/D converter in the R&S RTO scope also help to ensure high accuracy. The A/D converter operates at 10 Gsamples per second and achieves an exceptionally high dynamic range of more than seven effective bits. The result is minimal signal distortion and low inherent noise.

VENDORVIEW

Rohde & Schwarz,
Munich, Germany
+49 89 4129 137 74,
North America
(888) 837-8772
www.rohde-schwarz-scopes.com



12 kW Solid-state Pulse Amplifier

The Advantech Wireless model APRA-L12000A is for a 12 kW L-Band solid-state pulse amplifier operating in the band of 1.2 to 1.4 GHz. Intended for radar applications, this unit provides the peak power with a duty cycle of up to 12 percent. The unit consists of 8 × 1.8 kW modular amplifiers that are phase combined using a special high power, low loss combiner.

The product was created in response to an overwhelming demand in the marketplace for robust, solid-state pulse amplifiers that can be vehicle-mounted. It can be used in military and civilian radar systems. Due to the modular architecture, a failed RF module may be safely removed and replaced without service interruption (hot-swapped). A single module failure will cause a drop of only 1.16 dB in output power. The Interface Panel containing a redundant input/driver module provides the Monitor and Control Interface for the entire system. The power supply system is also modular, operating on a load-sharing configuration with hot-swappable capability.

The pulse amplifier operates on the basis of a TTL gating signal that must precede the RF pulse by 5 µs. The pulse rise/fall time is less than 100 ns. The pulse droop is less than 1 percent at 100 µs. The system is fully protected against CW signal applied, pulse length > 120 µs or incorrect duty cycle (>12 percent).

The complete unit occupies a space of 17U with a depth of 20 inches. The cooling fans on the modules may be replaced without removing the unit from its location. The design of the APRA pulse amplifier is based on Advantech Wireless industry-proven reliable solid-state power amplifiers.

Advantech Wireless, Montreal, Canada (514) 420-0045, www.advantechwireless.com.

RF and EMC Testing

VENDORVIEW

AR has released the latest version of its Complete Catalog for RF and EMC Testing. This must-have resource includes product information, specifications and much more. The catalog is easy to use with "find-it-fast" charts and color coding to help get right to whatever you need for RF and EMC testing. It is available for free download, either in full or by section, or request a hard copy from your local AR sales associate.

AR RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181, www.arworld.us.

COMSOL News 2011

VENDORVIEW

COMSOL News 2011 gives readers a broad overview of how COMSOL Multiphysics is used to model and simulate engineering problems in industries as diverse as automotive, aerospace, energy, hydrology, imaging, medical and plastics. Articles in this 64-page magazine range from reducing the noise of wind turbines to using Multiphysics to research microscopic magnetic fields leading to advanced medical instruments for the treatment of cardiovascular, sensory and neurological disorders.

COMSOL,
Burlington, MA (781) 273-3322, www.comsol.com.

PIN Diode Control Products

VENDORVIEW

Practical information about selecting the proper PIN diode-based product for a specific application is extremely hard to find. Narda's new PIN Diode Control Products Application Note was created to fill this void. It includes basic discussions of PIN diode characteristics, the most commonly used PIN-diode based products and the trade-offs encountered in designing products around them. The merits of various types of control products within a specific category (analog and digital attenuators, for example) are discussed as well.

Narda Microwave-East,
Hauppauge, NY (631) 231-1700,
www.nardamicrowave.com.

Product Selection Guide, Newsletter

VENDORVIEW

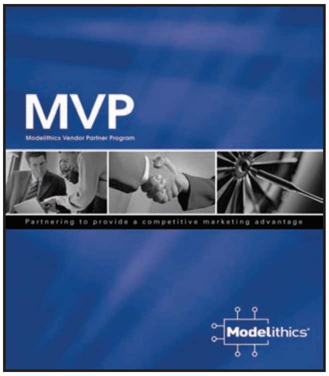
Hittite's October 2011 Off-The-Shelf newsletter features 26 new products with full descriptions, features and applications. Articles include new automatic gain product line, tri-band PLL with integrated VCO and programmable direct conversion receivers. In addition, Hittite's October 2011 Product Selection Guide summarizes more than 960 products, including 10 new products. Products are organized by RF & Microwave, Analog & Mixed Signal and LO & Clock Generation IC sections along with Modules and Instrumentation. View released datasheets and request new literature online.

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

Guide to Digital Multimeters

Keithley Instruments's e-guide to digital multimeters (DMM) can be viewed online. It contains useful selector guides and product information. It also provides access to eight application notes on these topics: Determining Resistivity and Conductivity Type, Solutions for Production Testing of Connectors, Peak Detection, Production Testing of Thermistors, Optimizing Switch/Read Rates, High Speed Testing of High Brightness LEDs, and LLCR PIN Socket Testing. Most DMM models found in the e-guide ship in one to two weeks.

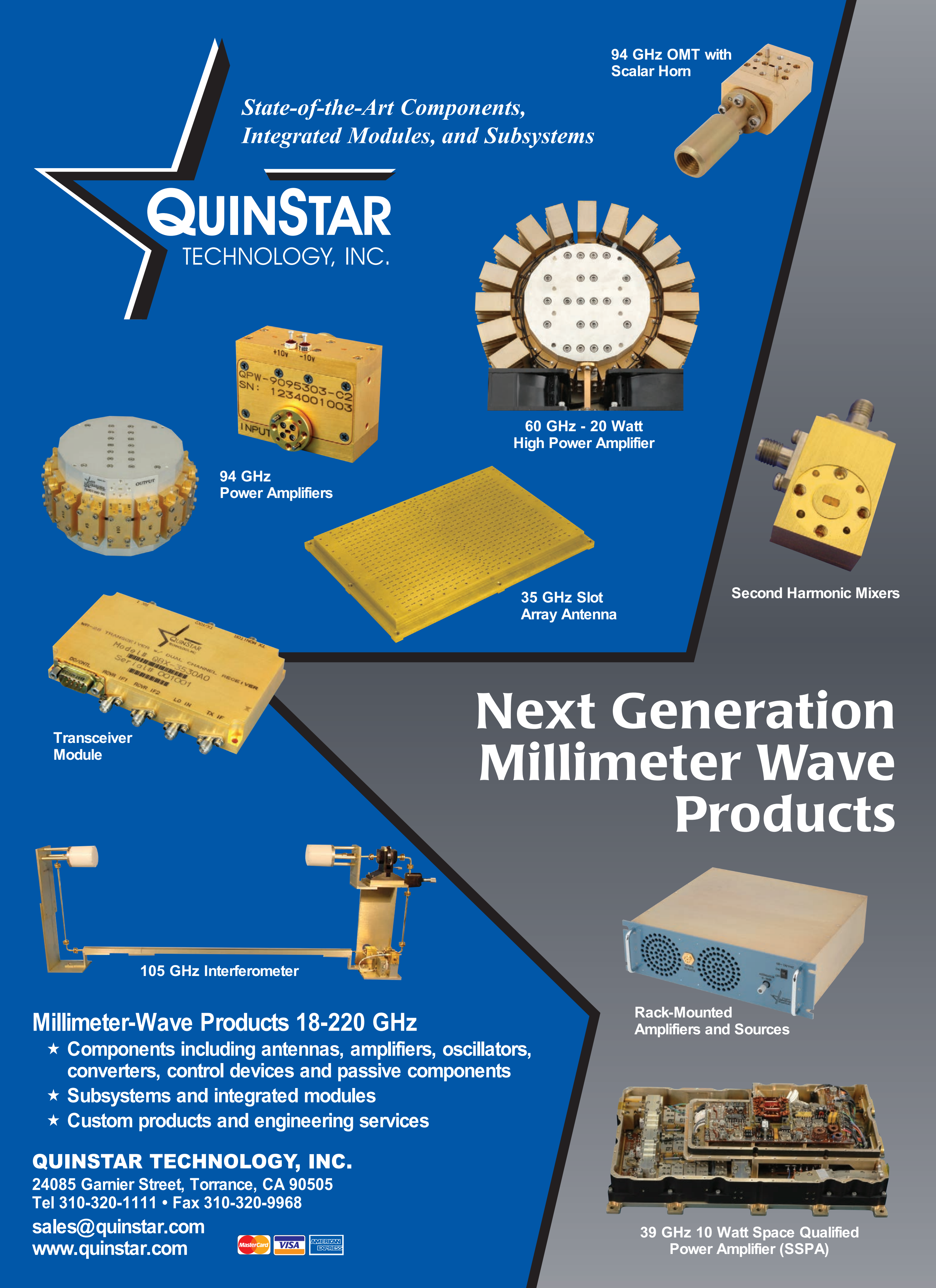
Keithley Instruments,
Cleveland, OH (440) 248-0400, www.keithley.com.



MVP Booklet

The Modelithics Vendor Partner Program (MVP) booklet describes the marketing advantages gained by microwave IC and component manufacturers who partner with Modelithics. MVP engagements range from new model development to supplemental value-added measurements. Benefits include improved support of customer device model and data needs, and qualified sales lead generation.

Modelithics Inc.,
Tampa, FL (813) 866-6335, www.modelithics.com.


State-of-the-Art Components,
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94 GHz OMT with
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Module
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★ Subsystems and integrated modules
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QUINSTAR TECHNOLOGY, INC.
24085 Garnier Street, Torrance, CA 90505
Tel 310-320-1111 • Fax 310-320-9968
sales@quinstar.com
www.quinstar.com
39 GHz 10 Watt Space Qualified
Power Amplifier (SSPA)

CATALOG UPDATE

Microwave Switches Guide

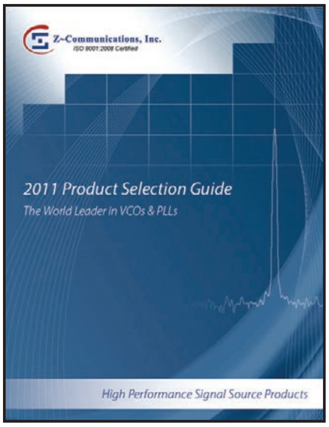
Designed for engineers to easily review data and select coaxial switches, Teledyne Relays has released the latest edition of the Microwave Switches Selection Guide. The Guide contains RF performance plots, electrical control data and schematics for each switch in the range, and includes mechanical outline drawings and mounting detail. Additional performance capabilities include passive intermodulation and insertion loss repeatability developed from a 10 million cycle test program. A new product included is the CAS-37, a three-state attenuated switch. It features three switched RF paths – open, through and 20 dB attenuation.

Teledyne Relays,
Quickborn, Germany +49 (0) 4106 7684-0,
www.teledyne-europe.com.

Prototyping Solutions

This year's 2011 T-Tech catalog features the new QCJ5 with fiducial recognition and IsoPro®3.1; combined, the two are the perfect prototyping solution. The 2011 catalog also showcases industry-leading standard and high frequency quick circuit machines capable of satisfying all PCB requirements. Test samples are available.

T-Tech Inc.,
Norcross, GA (800) 370-1530, www.t-tech.com.



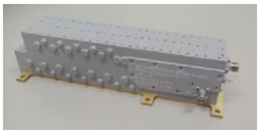
VCOs and PLLs

Z-Communications Inc. announced the release of a new Product Selection Guide. This short form catalog includes a wide variety of surface-mount voltage-controlled oscillators (VCO) and phase-locked loop (PLL) synthesizer modules ranging from 40 MHz to 13.5 GHz. A complete listing of all available parts and specifications can be found on the company's website. Users can also download an electronic version of the product guide online at www.zcomm.com or contact the company at sales@zcomm.com for a hard copy version.

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

Ku-Band TCDL Diplexer

The model Ku5924 Ku-Band TCDL diplexer has a transmit passband of 14.73 ±0.20 GHz and a receive passband of 15.25 ±0.10 GHz with approximately 30 dB of gain in the receive channel and approximately 2 dB insertion loss in the transmit channel. Noise figure is 3.4 dB maximum in the passbands and channel-to-channel isolation is 110 dB minimum. The unit operates with 15 V DC power and draws less than 200 mA.



Delta Microwave,
Oxnard, CA (805) 751-1100,
www.deltamicrowave.com.

Integrated Microwave Assemblies

This X-Band assembly is another example of Microsemi's expertise in designing compact multi-functional integrated microwave assemblies while delivering low phase noise performance. Characteristics include high gain (60 dB), a high Q bandpass filter, a variable phase shifter (360° range) and multiple coupled ports. This IMA is part of a low phase noise oscillator with high spectral purity developed for military radar and communication systems.

Microsemi,
Camarillo, CA (805) 388-1345,
www.amlj.com.

Waveguide Rotary Joints

A pair of new WR90 waveguide rotary joints come in "U" and "F" configurations. In the F-type rotary joint, one inline arm is fixed to the housing and the other arm is free to rotate. In the U-type rotary joint, both waveguide ports are at a right angle to the rotational axis. They provide full frequency coverage from 8 to 12.4 GHz. The maximum insertion loss across the band and insertion loss due to rotational effects is 0.3 dB. The maximum VSWR from 8 to 8.5 GHz is 1.35:1, with maximum VSWR of only 1.20:1 across the remainder of the frequency range, from 8.5 to 12.4 GHz. The maximum VSWR due to rotational effects is 1.05:1. It is constructed with high grade aluminum with a light-weight, corrosion-resistant Iridite finish.

Microwave Development Labs,
Needham Heights, MA (781) 292-6600,
www.mdlab.com.

Bi-Directional Coupler

VENDORVIEW

ZGDC35-93HP+ is a 35 dB DC pass high power bi-directional coupler covering the frequency range of 900 to 9000 MHz. Directivity is 25 dB typical and coupling flatness is ±0.8 dB typical over 1050 to 8000 MHz. The VSWR is 1.10:1 maximum. Power handling is 250 W. Packaged in an IP67 weather-proof case, the coupler's connectors are N-Type/SMA.

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

Circulators

VENDORVIEW

Model 4923 and 4925 circulators cover 2 to 4 and 7 to 12 GHz, respectively, and are well suited for both commercial and defense applications. The model 4923 (7 to 12.4 GHz) has isolation of 18 dB, insertion loss of 0.5 dB, and a maximum VSWR of 1.3:1, handles 50 W peak and 25 W average RF input power, and operates over a temperature range of 0 to +55° C. The model 4925 has isolation of 20 dB, insertion loss of 0.4 dB, VSWR of 1.25:1, peak RF power handling ability of 25 W average power of 10 W, and operates over a temperature range of 0 to +65°C. Both models use SMA female connectors.

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

X-Band Cavity Filter

VENDORVIEW

NIC offers an elliptic design cavity bandpass filter for use in X-Band applications. Some of the features include a wide passband of 500 MHz, low passband insertion loss of < 1.6 dB, high selectivity of > 60 dB at 10,000 MHz and a compact package size of 4" × 1.5" × 0.75" + SMA. Prototypes are available for immediate delivery. Custom configurations are designed up to Ku-Band.

Networks International Corp.,
Overland Park, KS
(913) 685-3400,
www.nickc.com.

Bias Tee

Pulsar Microwave introduces a new high frequency ultra-wideband bias tee, model BT-55-401, covering the frequency range of 30 KHz to 85 GHz with 2.0 dB insertion loss (typical) and 2.0:1 VSWR (typical). DC bias capability is 25 V at 500 mA with RF/DC isolation of 30 dB. RF input and output ports utilize 1.85 mm connectors and the DC port options include SMA, SMB or solder pin.

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

Solid-state Switch

VENDORVIEW

PMI model P4T-500M40G-60-T-55-292FF is an absorptive, solid-state switch that covers the 500 MHz to 40 GHz frequency range. This model offers low insertion loss of 4.8 dB typical, high isolation of 60 dB minimum at 40 GHz and a typical switching speed of 27 nsec. This switch is supplied in a compact package and designed for low power consumption; only 125 mA at +5 V and 70 mA at -5 V required for operation.

Planar Monolithics Industries Inc.,
Frederick, MD (301) 662-5019,
www.pmi-rf.com.

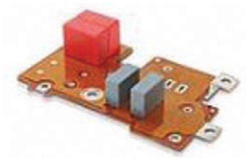
N Female Connector

Where wireless applications require an easily routed, low loss RF cable for in-building systems, Times Microwave's LMR®-400-LLPL has become a popular choice. This is an indoor highly fire-retarded cable intended specifically for runs within return air handling plenums (e.g. dropped ceilings, raised floors). To meet the connection needs of this plenum cable, RF Connectors has designed the RFN-1028-I2 N female connector with crimp attachment to offer the perfect fit and performance. The connector body is made of machined brass with nickel plating. All dielectrics are made of Dupont Teflon® with gold-plated contacts.

RF Industries,
San Diego, CA (800) 233-1728,
www.rfindustries.com.

RO-LINX PowerCircuit Busbars

VENDORVIEW



RO-LINX PowerCircuit busbars combine the performance features of power PCBs and laminated busbars. RO-LINX PowerCircuit busbars are highly engineered solutions for multilayer power distribution delivering optimal thermal management. Unlike two-dimensional power PCBs, PowerCircuit busbars can be made in three dimensions to reduce weight and footprint and to conform to specific engineering designs to maximize efficiency. In addition, PowerCircuits eliminate assembly steps at the end user, reducing complexity and sources of error.

Rogers Corp.,
Chandler, AZ
(480) 961-1382,
www.rogerscorp.com.

PRECISION TEST CABLES now up to 40 GHz

Rugged, reliable, ready to ship, custom lengths on request!

High-quality data requires high-quality cables — and different models to meet different needs. Mini-Circuits Precision Test Cables have been designed with our 40 years of industry experience in mind, and tested beyond any others on the market. It's why we can back them with an unprecedented 6-month guarantee,* and customers can save time and money with fewer false rejects and less retesting.

Flex Test™ Our standard, triple-shielded CBL cables are so tough, we had to invent a new way to test them: Flex Test™. Even after more than 20,000 flex cycles, these cables deliver unimpaired performance from DC-18 GHz. Ideal for design labs or test benches, they're available in lengths up to 25 feet with SMA or N-type connectors.

Quick Lock For high-speed production efficiency and superior electrical & mechanical performance, our QBL cables are the answer. Just push them onto a standard female SMA connector and slide the collar forward to lock. You'll get proven high-integrity DC-18 GHz connections, even after 20,000 flex and 20,000 mating cycles!

Armored For harsh, abusive, outdoor environments, our APC cables can't be beat. Even 1,000 crush cycles with a 440-lb nitrogen tank had minimal effect: attenuation increased only 0.15 dB, while return loss in/out remained ≥20 dB from DC-18 GHz. N-type connectors are standard, with lengths from 6 to 15 feet in stock.

Our new 40 GHz cables are proven through 20,000 flex cycles, and are fitted with high-performance connectors that mate with K®- and SMA-equipped DUTs. Standard lengths range from 1.5 feet to 2 meters.

Low Loss For design work requiring long cable runs or whenever Ka-band signal strength is key, our KBL-LOW cables are ideal. Insertion loss is only 2.46 dB/m at 40 GHz, with a velocity ratio of 84%.

Phase Stable When phase stability is a concern, as in many high-frequency production tests, try our KBL-PHS cables. They offer a phase change ≤0.1°/GHz when wrapped a full turn around a 3" diameter mandrel, and a shielding effectiveness of 110 dB!

RoHS compliant

See minicircuits.com for cable lengths, specifications, performance data, and surprisingly low prices!

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

K-Connector is a registered trademark of Anritsu Company.

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

Power Detector

VENDORVIEW

The SKY77002 is a stand-alone, high dynamic range power detector designed for use in smart phones and data cards in conjunction with Skyworks' power amplifiers in 3G and LTE applications. The detector is manufactured with Skyworks' gallium arsenide heterojunction bipolar transistor process offering state-of-the-art reliability, temperature stability and ruggedness. The SKY77002 detector circuit technology is optimally aligned for transceivers that require external detection for power control. Exceptional temperature and voltage compensation maintains accuracy over extreme operating conditions. The SKY77002 is packaged in the quad flat no-lead package and is fully compliant with current restriction of hazardous substances requirements.

Skyworks Solutions Inc., Woburn, MA (781) 376-3000, www.skyworks.com.

MVU-10 Wideband Mixer

Spacek Labs model MVU-10 is a wide-band mixer with full-band coverage in both the RF and the LO ports. The RF port spans from 50 to 75 GHz in WR-15 and the LO port from 40 to 60 GHz in WR-19. Local oscillator power requirements are +2 to +5 dBm for the biased version and +10 to +14 dBm for the non-biased version. The IF output on the SMA port covers DC to 20 GHz. Conversion loss is 7 dB typical and 13 dB maximum. Lower conversion loss is available on units with reduced bandwidths. The input 1 dB compression point is typically 7 dB below the LO power level.

Spacek Labs Inc., Santa Barbara, CA (805) 564-4404, www.spaceklabs.com.

Four-way Combiner

VENDORVIEW

Model D8746 is the 500 W version of model D7365, which provides an alternate solution in achieving 500 W CW output power. This robust design provides high port-to-port unbalance protection, while operating into high load VSWR conditions. Measuring just 7.2" × 3.5" × 1.4", this unit is more efficient and smaller than most 20 to 1000 MHz combiners in the marketplace.

Werlatone Inc., Patterson, NY (845) 278-2220, www.werlatone.com.

Amplifiers

Solid-state Amplifiers

VENDORVIEW

AR RF/Microwave Instrumentation has introduced a family of new solid-state amplifiers that are more compact, more efficient and more powerful than previous models. The new "S" Series covers 0.8 to 4.2 GHz and powers up to 1200 W. These models employ a new design that delivers more than twice the power of older models. With these improvements, AR has maintained the superior rugged design for mismatch tolerance and excellent linearity.

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

Class "AB" Linear Amplifier

Comtech PST has announced the release of a solid-state Class "AB" linear amplifier, which operates over the full 2500 to 6000 MHz frequency bandwidth and delivers a minimum of 150 W into a 2:1 load VSWR. This high gain amplifier uses the latest GaN technology and is packaged in a standard rack-mountable enclosure measuring 19" × 22" × 5.25." The unit has an internal power supply that operates from 100 to 265 VAC, 47 to 400 Hz single phase making it ideal for both laboratory and airborne applications. The unit is air cooled by an integrated high speed blower. Optional remote control through RS422 is available. This unit weighs 60 pounds and has a standard one-year warranty.

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

700 MHz LTE PA Modules

VENDORVIEW

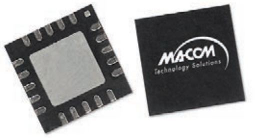
Empower RF Systems has completed both Class AB and Doherty designs for next generation 700 MHz LTE PA modules. These first units are technology demonstration platforms that highlight complex, digital waveform amplification as well as design for manufacturing. Key features include ARM based/web addressable control, advanced analog predistortion, 40 W output power (LTE compliant), power added efficiencies from 24 percent for Class AB (746 to 806 MHz) and up to 32 percent with the narrower band Doherty designs (746 to 776 MHz and 776 to 806 MHz).

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

Push-Pull CATV Amplifier

VENDORVIEW

The MAAM-009455 is a new GaAs broadband push-pull CATV amplifier that is an ideal interstage or output amplifier. The amplifier features 20.5 dB gain, with broadband linear performance. Packaged in a 4 mm QFN, 20-lead plastic package, this differential amplifier uses M/A-COM Tech baluns, input and output. The amplifier also features external feedback, allowing for gain tuning. The MAAM-009455 exhibits an excellent gain flatness of 0.5 dB typical over the 50 to 1000 MHz operating band. Input return loss has been optimized to achieve better than 20 dB across the band. This amplifier exceeds DOCSIS 3.0 DRFI specifications, making it an ideal output stage solution for Edge QAM head-end infrastructure.



M/A-COM Technology Solutions Inc., Lowell, MA (800) 366-2266, www.macomtech.com.

Coaxial LNA

VENDORVIEW

MITEQ Inc. introduces model AMF-2F-00100200-16-15P to its family of extremely low noise and ultra small coaxial LNAs in the 0.1 to 2 GHz band. This LNA has more than 30 dB of gain in a housing that is only 1.22" × 0.88" without the field-replaceable SMA connectors. Gain flatness is a maximum of ±1 dB, though typical is ±0.75 dB. The AMF-2F-00100200-16-15P has a maximum noise figure of 1.6 dB in the fullband, though the typical value is 1 dB. It operates from -40° to +75°C, has a P1dB of minimum 15 dBm, IP3 of typically 25 dBm, and a current draw of maximum 135 mA from a single +15 V DC supply. Port VSWR is less than 2:1 for both input and output. Other models with typical gains ranging from 25 to 50 dB are available in the same outline. The aluminum alloy housing provides excellent thermal performance in addition to being very small and light. Hermetic sealing is an option.

MITEQ Inc., Hauppauge, NY (631) 439-9469, www.miteq.com.

Power Amplifier

VENDORVIEW

The HHPAV-433 power amplifier covers the frequency range from 59.5 to 60.5 GHz and is usable over the range of 58 to 64 GHz. The amplifier has an output power of +28.5 Psat and 18 dB gain. MMIC technology is employed for high reliability and repeatability employing one die. A single +6 V bias is used to power up the amplifier. An onboard voltage regulator and bias sequencing circuitry provide the proper biasing for the unit. A power level of greater than 1 W can be achieved in the same mechanical envelope (1" × 1.3" × 1.35") using two MMICs. The amplifier can be used in transmitters for communication and radar systems and also as part of test equipment suites.

Renaissance Electronics, Harvard, MA (978) 772-7774, www.rec-usa.com.

0.25 W BTS RFIC

TriQuint's new highly linear TQP7M9101 uses patent-pending integration to protect network BTS circuits and lower power consumption for 3G/4G systems. The TQP7M9101 also incorporates matching circuitry to further reduce the BOM. Power consumption is one of the lowest available – just 88 mA. Only TriQuint can cut BOMs while integrating ESD, DC over-voltage and RF over-drive protection. The TQP7M9101 is ideally suited for base station TRx cards, repeaters, femtocells and transmit linear driver amplifiers.

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

Sources

100 MHz OCXO

Bliley Technologies' NV45G1480 Series 100 MHz OCXO offers superior performance in one of the industry's smallest OCXO packages. In addition to exceptional phase noise performance boasting -100 dBc/Hz at an offset frequency of 10 Hz, and a noise floor that exceeds -165 dBc/Hz, the units also offers frequency vs. temperature stability starting at ±50 parts per billion. More than 100 configurations can be specified with delivery in four weeks or less. Bliley OCXOs are ideal for phase-locked microwave signal sources, high speed synthesizers, radar systems, high speed network applications and other frequency conversion and generation applications.

Bliley Stocking Distributor RFMW Ltd., San Jose, CA (408) 414-1450, www.rfmw.com.

VME Master Oscillator

With four different output frequencies, an internal high stability crystal reference and built-in test functions, the VME Master Oscillator is fully tested and guaranteed over the operating conditions. The VME Master Oscillator starts from a low noise, vibration insensitive crystal oscillator from which all of the subsequent signal outputs are derived. The four frequency outputs range from 10 to 1920 MHz and the unit is designed to offer very low spurious signal output and excellent signal stability over the operating conditions. An advanced built-in test function provides indication, through the VME bus, of the signal output presence for each output.

Crane Aerospace & Electronics,
Beverly, MA (978) 524-7200,
www.craneae.com.

Coaxial VCO

The CVCO55CXT-6250-6250 coaxial resonator oscillator (CRO) is a coaxial-based VCO with an internal proprietary frequency doubler.

It operates at 6250 MHz with a tuning voltage range of 0.5 to 4.5 V DC. This coaxial VCO features a typical phase noise of -100 dBc/Hz at 10 KHz offset and has good linearity. It exhibits an output power of 2 dBm typical into a 50 Ω load with a supply of +8 V DC and a current consumption of 35 mA (maximum). It is packaged in the industry-standard 0.5" × 0.5" package. Pushing and pulling are both minimized to 1.5 MHz/V and 0.5 MHz, respectively. Second harmonic suppression is -30 dBc typical. It is ideal for use in applications, such as digital radio equipment, fixed wireless access, satellite communications systems and base stations.

Crystek Corp.,
Ft. Myers, FL (800) 237-3061,
www.crystek.com.

Phase-locked Clock Oscillator

The XLT-360 ultra-miniature, low noise clock oscillator operates at a fixed frequency of 360 MHz as reference clocks in military and commercial RF/microwave systems. Locked to an external frequency reference, the XLT-356 features instantaneous turn-on, excellent phase noise (Fout = 360 MHz, < -120 dBc/Hz at 10 KHz, typical), high vibration tolerance (12 g RMS, operating) and low power consumption at +3.3, +5, +8 or +12 V DC. The XLT is housed in a miniature connectorized package (1.3" × 1.1" × 0.4") to withstand harsh environments, and operates over the standard temperature range of -30° to +70°C.

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

MEMS-based Oscillators

Vectron International has released its next generation MEMS-based oscillators. The new VM 702, 802, and 822 product series have LVDS, LVPECL and HCSL output options with an expanded frequency range to 460 MHz. The VM 702, 802 and 822 compensation algorithm has been enhanced to optimize the frequency vs. temperature performance offering a 2× improvement in temperature stability over earlier models. Other features include peak-to-peak period jitter < 35 ps, ±10 ppm frequency stability over -10° to +70°C and ± 15 ppm frequency stability over -40° to +85°C.

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

RoHS-compliant VCO

Z-Communications Inc. announces a new RoHS compliant VCO model CLV1075A-LF in L-Band. The CLV1075A-LF operates at 830 to1300 MHz with a tuning voltage range of 0.5 to 17 V DC. This VCO features a typical phase

noise of -105 dBc/Hz at 10 KHz offset and a typical tuning sensitivity of 35 MHz/V. It is designed to deliver a typical output power of 4 dBm at 5 V DC supply while drawing 26 mA (typical) over the temperature range of -40° to 85°C. This VCO features typical second harmonic suppression of -18 dBc and comes in Z-Comm's standard MINI-14S package measuring 0.5" × 0.5" × 0.22". It is available in tape and reel packaging for production requirements.

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

Test Equipment

Signaling Tester

VENDORVIEW

A multi-format signaling tester, the MD8475A can test multimode wireless devices, including GSM/GPRS/E-GPRS, 1xRTT, 1xEV-DO, W-CDMA/HSPA, TD-SCDMA, and FDD-LTE. The highest speed commercially available (Category 3) LTE devices can be tested with the MD8475A, with downlink IP-layer throughput to 100 MB/s (including 2 × 2 MIMO) and uplink throughput to 50 MB/s. The MD8475A enables test of many types of mobile device applications ranging from traditional SMS/MMS, browsing, and streaming, to advanced applications, such as augmented reality and real-time multi-player gaming. The MD8475A enables easy testing on the effect of advanced applications on a device's battery performance.

Anritsu Co.,
Morgan Hill, CA
(800) 267-4878,
www.anritsu.com.

VNA Test Port Cables

VENDORVIEW

The ASR Series is a new line of high performance VNA test cables. These high frequency assemblies are available individually, in pairs and phase-matched pairs as required. They are manufactured using durable interfaces for re-

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9. Passive circuit elements.
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31. Sensors and sensor systems.
32. RFID technologies.
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Florida RF Labs,
Stuart, FL
(772) 600-1632,
www.emc-rflabs.com.

Signal Generator

VENDORVIEW

The HMC-T2270 is a 10 MHz to 70 GHz signal generator that delivers up to +29 dBm of CW output power in 0.1 dB steps over a 60 dB dynamic range. Harmonic rejection is better than -40 dBc at 30 GHz output, while spurious products are better than -65 dBc at all integer frequencies. Phase noise is -113 dBc/Hz at 10 kHz offset from 1 GHz, and -79 dBc/Hz at 100 kHz offset from 67 GHz, with insignificant deviation over the temperature range of 0° to +35°C.

The HMC-T2270 exhibits frequency resolution of 1 Hz and fast switching speed of only 500 µs, making it ideal for frequency hopping and threat simulation applications.

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

Mini Signal Generator

VENDORVIEW

Two new models have been added to the Lab Brick® product line. The LMS-203 operates from 10 to 20 GHz, while the LMS-163 operates from 8 to 16 GHz. Both boast 100 micro second switching time and 100 Hz frequency resolution. They offer phase-continuous linear frequency sweeping, optional internal/external

pulse modulation and a selectable internal/external 10 MHz reference. Typical spurious for both is at -80 dBc, with typical harmonics of -40 dBc and subharmonics at -25 dBc. They deliver at least +10 dBm output power, and can be adjusted over a 40 dB dynamic range, with 0.5 dB resolution. The pulse modulation feature offers internal or external triggering with pulse widths as low as 100 ns and pulse repetition intervals of 200 ns. Lab Brick signal generators measure 4.90" × 3.14" × 1.59" and weigh less than one pound.

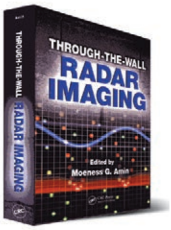
Vaunix Technology Corp.,
Haverhill, MA
(978) 662-7839,
www.vaunix.com.

Software

FEKO Suite 6.1

FEKO Suite 6.1 is packed with new features and comes with a completely revised version of CADFEKO. The introduction of a ribbon style menu reduces clutter and represents the typical workflow. Many CAD and meshing features have been added or extended. The latest version of POSTFEKO will also allow users to export results directly to Microsoft Word, PowerPoint and PDF files. A key feature is the introduction of a method to analyze cable bundles in a complex environment. By using a new combined MoM/MTL arbitrary cable paths can be accommodated and there are no restrictions on or need for a ground-plane.

EM Software & Systems (USA) Inc.,
Hampton, VA
(866) 419-3356,
www.feko.info.



Through-the-Wall Radar Imaging

Edited by
Moeness G. Amin,
Villanova University

Through-the-wall radar imaging allows police, fire and rescue personnel, first responders, and defense/special forces to detect, identify, classify, and track the whereabouts of people and moving objects within buildings, tunnels, etc. *Through-the-Wall Radar Imaging* examines this technology from the algorithmic, modeling, experimentation and system design perspectives. It begins with coverage of the electromagnetic properties of walls and building materials, and discusses techniques in the design of antenna elements and array configurations, beamforming concepts and issues, and the use of antenna array with collocated and distributed apertures.

The chapters in the book discuss wall attenuation and dispersion effects in view of angles of incidence and antenna polarization and covers wideband, low profile and printed antennas, as well as planar/conformal UWB antennas. It also emphasizes the PSF characteristics that result from the use of UWB waveforms and examines the design of emerging waveforms to optimize target detection by increasing target-to-noise and clutter ratio with special emphasis of matched illumination-based signature exploitation techniques. It studies EM wave propagation through walls and shows the dispersion and blurring effects on behind-the-wall target images.

It also covers several suitable waveforms, inverse scattering approaches and the relevance of physical-based model approaches in through-the-wall radar. Theoretical and experimental research in 3D building tomography using microwave remote sensing, high frequency asymptotic modeling methods, synthetic aperture radar (SAR) techniques, impulse radars, airborne radar imaging of multi-floor buildings strategies for target detection and detection of concealed targets are discussed. The book concludes with a section on how the Doppler principle can be used to measure motion at a very fine level of detail.

Through-the-Wall Radar Imaging covers the subject in detail and stresses the multidisciplinary approach needed to design such radars. It is a good book for anyone looking to gain a deep understanding of the subject. Also, a section of colored images and diagrams of radar scans and other images is a nice addition that is not seen in many books.

To order this book, contact:

CRC Press
(800) 272-7737
6000 Broken Sound Parkway NW,
Suite 300
Boca Raton, FL 33487

Pages: 550, $149
ISBN: 978-1-439-81476-5

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IDENTIFY THE BOND VILLAIN AND SAVE HIS LIFE

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CLUES:

$$Pd = \frac{P_t}{4\pi \_\_\_^2}$$

$$\nabla \times H = J_f + \frac{\partial \_\_\_}{\partial t}$$

$$PA\_\_\_ = 100 \frac{\{[P_{out}]_{RF} - [P_{in}]_{RF}\}}{[P_{DC}]_{total}}$$

$$\_\_\_ F = 10 \log\left(\frac{SNR_{in}}{SNR_{out}}\right)$$

$$\_\_\_ = 10 \log\left(\frac{P_{out}}{P_{in}}\right) dB$$

$$\_\_\_ = \frac{V}{d\Psi / dt}$$

$$\omega = 2\pi \_\_\_$$

$$\_\_\_ e = \frac{1000 \text{ amps}}{4\pi \text{ meters}}$$

$$V = \_\_\_ R$$

$$ERP = Pt \_\_\_ t$$

Mixer Solutions

IMAGE REJECTION MIXERS

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Model Number	RF/LO Frequency (GHz)	Conversion Loss (dB) Max.	Image Rejection (dB) Min.	LO-to-RF Isolation (dB) Min.
IMAGE REJECTION MIXERS				
IRM0204(*)C2(**)	2 - 4	7.5	18	20
IRM0408(*)C2(**)	4 - 8	8	18	20
IRM0812(*)C2(**)	8 - 12	8	18	20
IRM1218(*)C2(**)	12 - 18	10	18	20
IRM0208(*)C2(**)	2 - 8	9	18	18
IRM0618(*)C2(**)	6 - 18	10	18	18
IR1826NI7(**)	18 - 26	10.5	18	20
IR2640NI7(**)	26 - 40	12	18	20

Model Number	RF/LO Frequency (GHz)	Conversion Loss (dB) Max.	Balance Phase (±Deg.) Typ./Max.	Balance Amplitude (±dB) Typ./Max.	LO-to-RF Isolation (dB) Min.
I/Q DEMODULATORS					
IRM0204(*)C2Q	2 - 4	10.5	7.5/10	1.0/1.5	20
IRM0408(*)C2Q	4 - 8	11	7.5/10	1.0/1.5	20
IRM0812(*)C2Q	8 - 12	11	5/7.5	.75/1.0	20
IRM1218(*)C2Q	12 - 18	13	10/15	1.0/1.5	20
IRM0208(*)C2Q	2 - 8	12	7.5/10	1.0/1.5	18
IRM0618(*)C2Q	6 - 18	13	10/15	1.0/1.5	18
IR1826NI7Q	18 - 26	13.5	10/15	1.0/1.5	20
IR2640NI7Q	26 - 40	15	10/15	1.0/1.5	20

SSB UPCONVERTERS OR I/Q MODULATORS

Model Number	RF Frequency (GHz)	Conversion Loss (dB) Max.	Carrier Suppression (dBc) Min.	Carrier Suppression Carrier - Fundamental IF (dBc) Min.
IF DRIVEN MODULATORS				
SSM0204(*)C2MD(**)	2 - 4	9	20	20
SSM0408(*)C2MD(**)	4 - 8	9	20	18
SSM0812(*)C2MD(**)	8 - 12	9	20	20
SSM1218(*)C2MD(**)	12 - 18	10	20	18
SSM0208(*)C2MD(**)	2 - 8	9	20	18
SSM0618(*)C2MD(**)	6 - 18	12	20	18

For Carrier Driven Modulators, please contact MITEQ.

MODEL NUMBER OPTION TABLE

(*) Add Letter	LO/IF Power Range	P1 dB C.P. (dBm) (Typ.)	(**) Add Letter	IF FREQUENCY OPTION (MHz)
L	10 - 13 dBm	+6	A	20 - 40
M	13 - 16 dBm	+10	B	40 - 80
H	17 - 20 dBm	+15	C	100 - 200
			Q	DC - 500 (I/Q)

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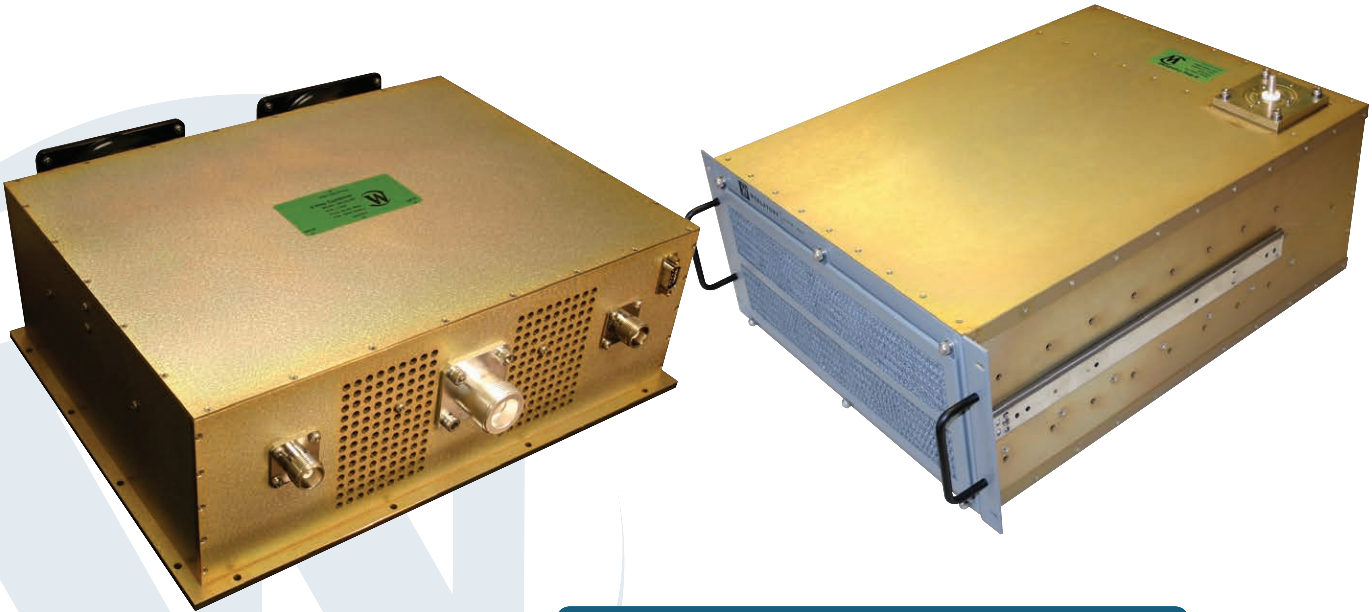

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A few of our Customer driven designs.

Model	Type	Frequency (MHz)	Power (W CW)	Insertion Loss (dB)	VSWR	Isolation (dB)	Size (Inches)
D8265	2-Way	1-50	5,000	0.3	1.25	20	15.5 x 15 x 5.25
D2075	2-Way	1.5-30	6,000	0.2	1.25	20	15.5 x 11.75 x 5.25
D8969	2-Way	1.5-30	12,500	0.2	1.25	20	17 x 17 x 8
D6139	4-Way	1.5-32	5,000	0.25	1.25	20	13 x 11 x 5
D6774	4-Way	1.5-32	20,000	0.3	1.20	20	21 x 17.25 x 11
D6846	6-Way	1.5-30	4,000	0.35	1.35	20	3 U, 19" Rack
D8421	8-Way	1.5-30	12,000	0.3	1.30	20	22.5 x 19.5 x 8.75
D7685	4-Way	2-100	2,500	0.5	1.30	20	14.75 x 13 x 7
D2786	4-Way	20-150	4,000	0.5	1.35	20	18 x 17 x 5
D6078	2-Way	100-500	2,000	0.25	1.20	20	13 x 7 x 2.25
H7521	2-Way (180°)	200-400	2,500	0.3	1.30	20	15 x 10 x 2
D7502	2-Way	400-1000	2,500	0.25	1.20	NI*	9.38 x 3.5 x 1.25

*NI = No Isolating Terminations

Our Patented, Low Loss Combiner designs tolerate high unbalanced input powers, while operating into severe Load Mismatch conditions.

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