

Vol. 55 • No. 4

April 2012

Microwave Journal

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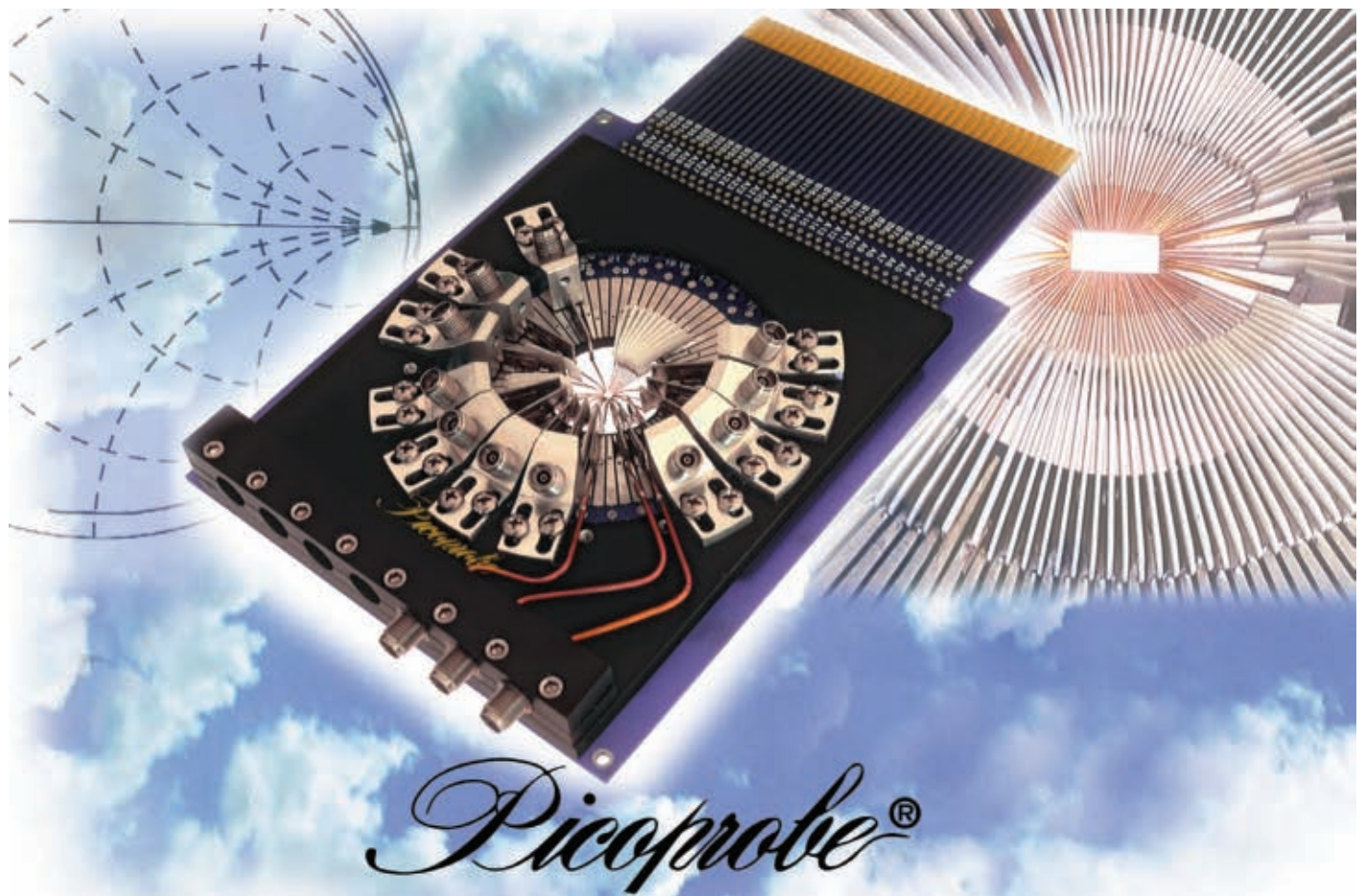
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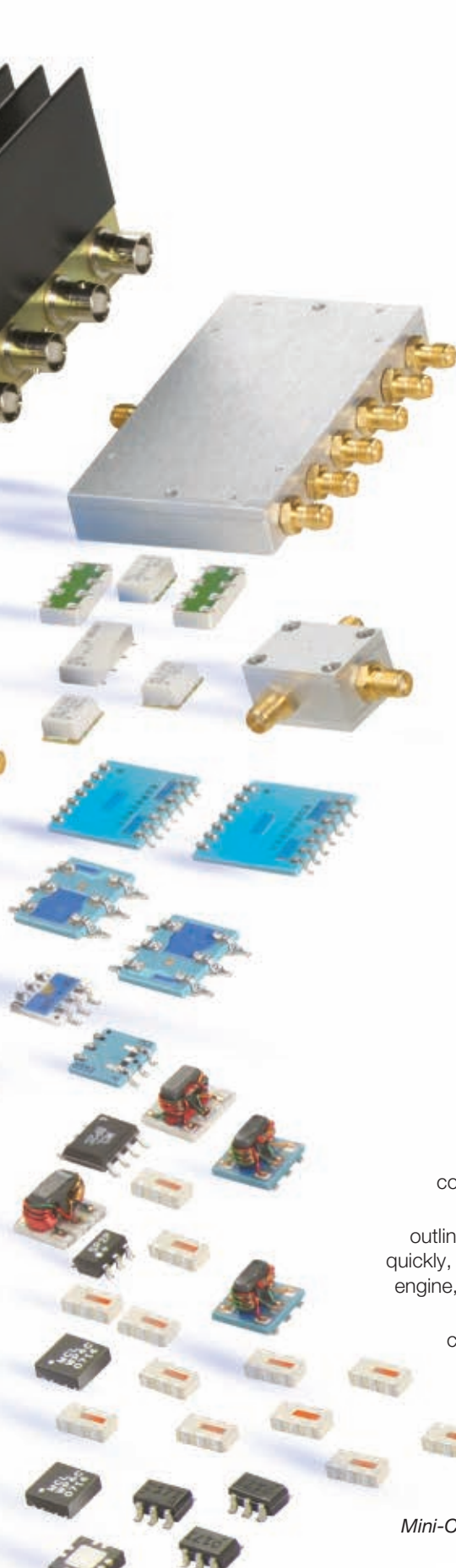
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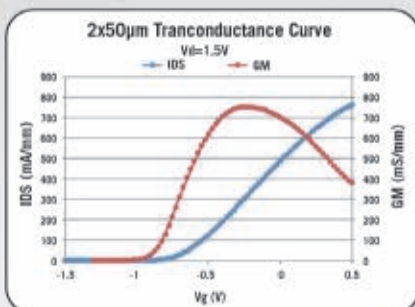
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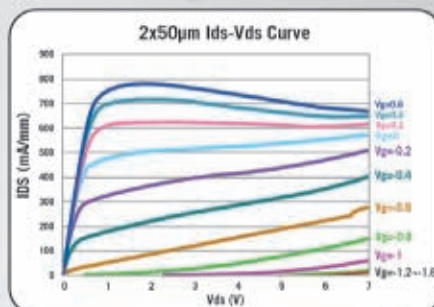
- 0.1 μ m gate length pHEMT technology
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PP10-10, 11 Transconductance Curve



PP10-10, 11 I-V Curves



Comparison of WIN's millimeter wave pHEMT technologies

	PP25-21	PP15-50/51	PP10-10/11
Gate length	0.25 μ m	0.15 μ m	0.1 μ m
Operating Frequency	Up to 20GHz	Up to 30 GHz	Up to 90GHz
Max Drain Bias	8V	6V	4V
Max Id ($V_g=0.5V$)	490 mA/mm	630 mA/mm	760 mA/mm
IDSS ($V_g=0V$)	340 mA/mm	470 mA/mm	520 mA/mm
Max Gm	410 mS/mm	460 mS/mm	725 mS/mm
V_{to}	-1.15 V	-1.35 V	-0.95 V
V_{on} (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 (2x75 μ m)	1100 mW/mm @ 8V, 10GHz	870 mW/mm @ 6V, 29GHz	860 mW/mm @ 4V, 29GHz (2x50 μ m)

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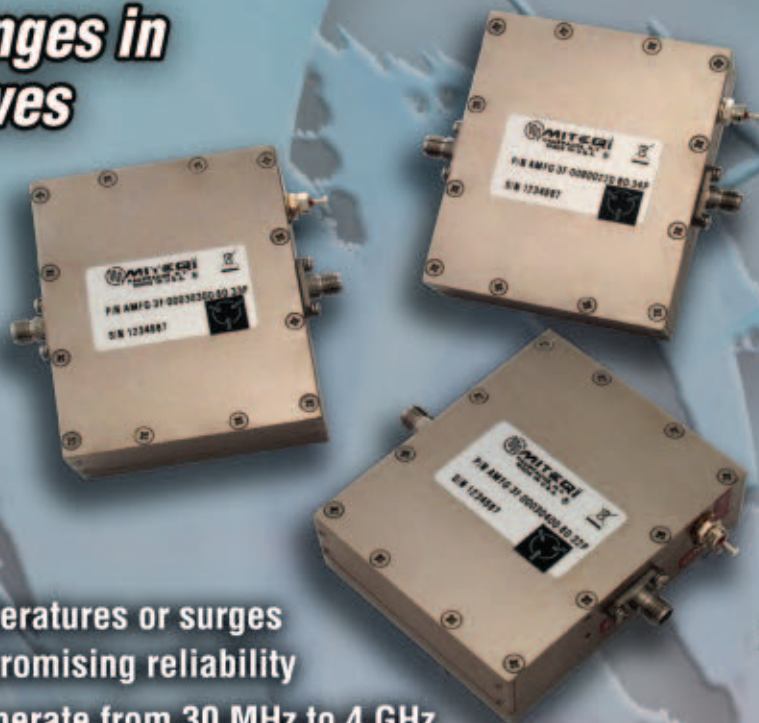


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MODEL NUMBER	FREQUENCY RANGE (GHz)	GAIN (dB, Min.)	GAIN FLATNESS (±dB, Max.)	NOISE FIGURE (dB, Max.)	VSWR IN/OUT	P1dB (dBm, Min.)	Psat (dBm, Min.)	NOMINAL PEAK CURRENT @ 30V (mA)
AMFG-3F-00030100-60-33P	0.03-1	42	1.5	6	2:2	34	36	750*
AMFG-3F-00030300-60-33P	0.03-3	40	2	6	2:2.2	33	35.5	750*
AMFG-3F-00030400-60-32P	0.03-4	40	2	6	2:2	32	35	750*
AMFG-3F-00040250-60-33P	0.04-2.5	40	2	6	2:2.2	33	35.5	670
AMFG-3F-00050100-50-34P	0.5-1	40	1.5	5	1.8:1.8	34	37	750*
AMFG-3F-00230025-30-37P	0.23-0.25	50	1	3	1.5:2	37	40	250*
AMFG-3F-00500350-60-32P	0.5-0.35	40	1.75	6	2:2.2	33	35	600*
AMFG-3F-00700380-60-35P	0.7-3.8	40	2	6	2.5:2.5	35	39	1500
AMFG-3F-00800220-60-35P	0.8-2.2	40	1.5	6	2:2	35	38	900*
AMFG-2F-01000300-60-35P	1-3	40	2	6	2:2.2	35	39	1500
AMFG-2F-01000200-60-38P	1-2	35	2	6	2:2	36	37	1500

Notes: Psat is defined as the output power where a minimum of 3 dB gain compression takes place.

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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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Eric Higham, Strategy Analytics

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Explores the evolution of the Doherty power amplifier through its first seventy-five years and explains how this architecture has adapted, and is being utilized to realize today's advanced power amplifier stages for wireless systems

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90 **Compact Microstrip Lowpass Filter with Wide Stopband and High Attenuation**

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Features a compact microstrip lowpass filter with a 3 dB cutoff frequency of 2.07 GHz that has been designed, fabricated and measured

Microwave Journal (USPS 396-250) (ISSN 0192-6225) is published monthly by Horizon House Publications Inc., 685 Canton St., Norwood, MA 02062. Periodicals postage paid at Norwood, MA 02062 and additional mailing offices.

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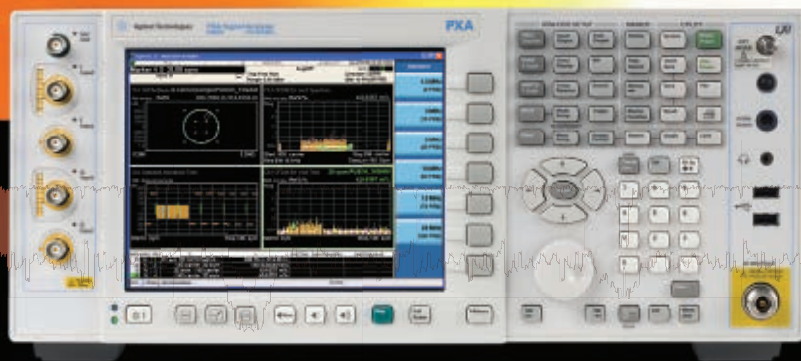
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Features

100 Integrated SAW Broadband Antenna for WLAN/WiMAX

I-Tseng Tang, National University of Tainan

Details a compact integrated SAW antenna with broadband performance designed and fabricated on a piezoelectric substrate, using photolithography and evaporation techniques

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Maury Microwave

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Synergy Microwave Corp. (Research GmbH)

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February Survey

"How do you determine load impedance?"

Harmonic Load Pull [84 votes] (13%)

Non-linear Device Models [33 votes] (5%)

S-parameters [75 votes] (11%)

X-parameters [14 votes] (2%)

Cripps Method [461 votes] (69%)

Executive Interview



Ulrich Rohde, Founder and Chairman of Synergy Microwave, talks about his life in microwave engineering, the importance of phase noise and his company's work in advancing the state-of-the-art in oscillator technology.

White Papers

Improving Measurement Accuracy for High Frequency RF Connectors

Ronnie Rice, RF Industries

High Temperature, High Power RF Life Testing of GaN on SiC RF Power Transistors

Brian Barr and Dan Burkhard, M/A-COM Technology Solutions
Presented by: Richardson RFPD

Solutions for Testing Very High Throughput 802.11ac Signals

White Paper, Agilent Technologies

Voice and SMS in LTE

White Paper, Rohde & Schwarz

The Advantages of Outsourcing your RF/Microwave Assembly to an Onshore Contractor

White Paper, SemiGen

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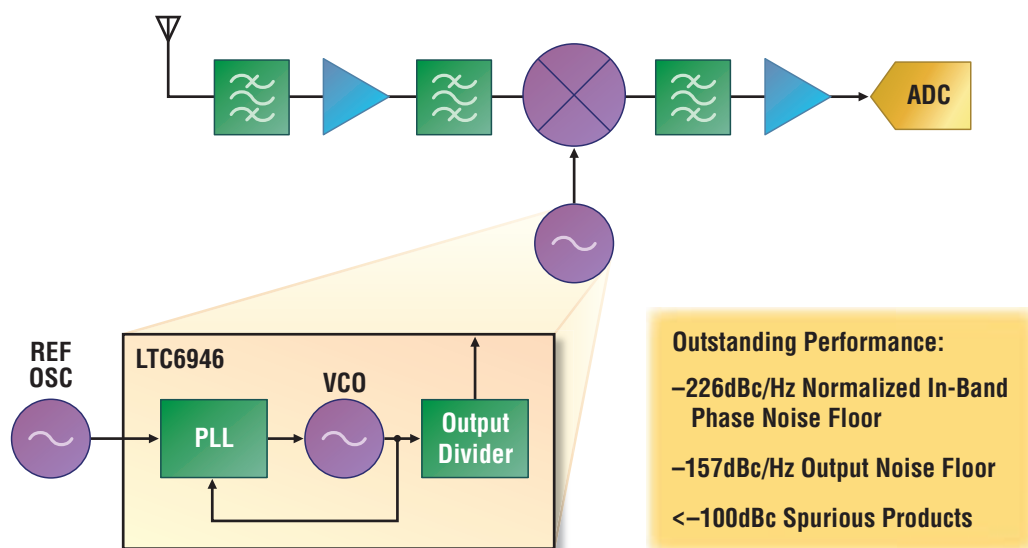
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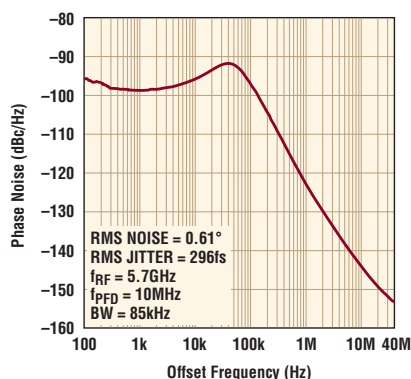
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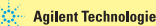


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COVER FEATURE
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Architecture and Amplifier Device Developments in CATV Networks

What began as a solution to poor over-the-air reception of television signals in the 1940s has evolved dramatically, in terms of content, reach and importance. CATV networks no longer focus solely on delivering TV broadcasts. Worldwide, the cable network infrastructure has been adapted to carry multiple services, adding Internet connectivity and voice telephony to traditional TV services. In addition, many countries are in the process of upgrading to digital broadcasting, as television services migrate away from analog broadcasts. The United States completed the analog to digital transition in 2009, with only a few “low power” television stations still allowed to broadcast analog content. The transition to digital broadcasting makes additional bandwidth available, and service providers are using this bandwidth to provide a whole host of additional services, such as video-on-demand, telephony, faster broadband data rates and enhancements, such as high-definition and 3D broadcasting.

As consumers continue to adopt these new services, bandwidth demand is increasing quickly, to the point where some in the industry suggest the need for doubling the bandwidth capability every two years. Cable operators are increasingly competing with traditional telecom carriers, as both fight for the lucrative bundle of “triple-play” services (voice, video and data). With no existing video networks,

some of the telecom carriers are turning to the high bandwidth capability of multi-wavelength or multiplexed fiber networks to deliver their services to customers. Traditional cable operators are responding with Hybrid Fiber Coaxial (HFC) networks, with the fiber portion pushing deeper into the network. The challenge for either type of operator is to provide a range of diverse, high-bandwidth capabilities and services that keep pace with customer demand without investing too heavily or too quickly in capital-intensive infrastructure.

ARCHITECTURE

The video signal in a traditional CATV HFC network (see **Figure 1**), originates at a Multiple Service Operator’s (MSO) headend. This facility receives television programming through “over the air” transmission or landlines for local channels and satellite transmission for national channels. The antennas and electronics in the headend receive, process and insert any additional programming required by local governing agencies or the cable operator. The resulting channel lineup is then distributed to the customers of the CATV provider.

In the HFC network, video channels leave the headend as optical signals on a fiber trans-

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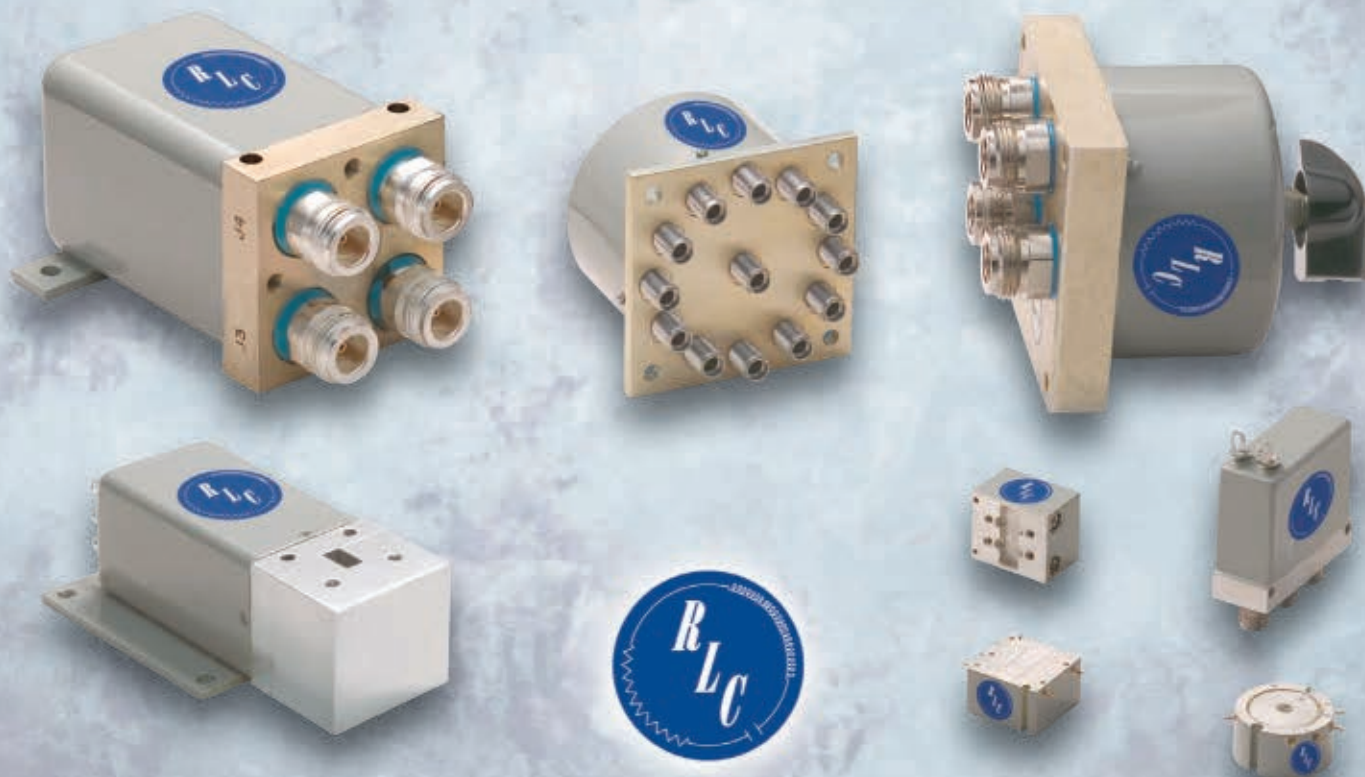
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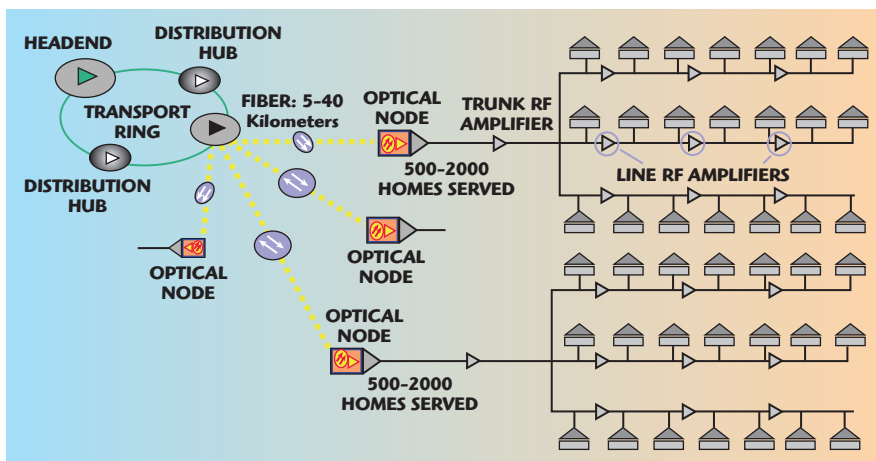
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▲ Fig. 1 HFC network topology.

port network. As the diagram illustrates, this signal splits a number of times until it reaches an optical node that typically serves between 50 and 2000 premises. This optical node contains electronics to convert the signal from the optical domain to the electrical domain for further transport on a coaxial network.

From here, the signal will likely undergo additional splits, until it reaches a consumer's premises. Once the optical signal is converted to the electrical domain, coaxial cables transport it to customer premises. Splitting the signal, as well as the loss of the coaxial transport cable, increases the loss of the transport network significantly. To offset this loss, a variety of amplifiers (system or trunk amplifiers, line extenders, drop amplifiers, etc.) are inserted to offset the path and splitting loss experienced in the CATV infrastructure. Typically, each node will have one system or trunk amplifier prior to a splitter or tap. After the signal splits, the subsequent run into a neighborhood typically incorporates three line extender amplifiers to compensate for signal loss. A single optical node may serve anywhere from 50 to 2000 homes, with the actual number varying based on region, bandwidth requirements and geography. The number of homes passed per optical node is trending downward as bandwidth intensive applications, primarily centered on video, proliferate. Many current estimates place the number of homes passed per optical node below 500. While some older networks still operate at lower frequencies, this "forward" or "downstream" path is being

rapidly upgraded to cover roughly 50 to 1000 MHz of bandwidth. There is also ongoing discussion in the industry about the need to increase the highest frequency of operation in response to the desire for new services and channels.

With its roots in improving reception of over-the-air analog broadcast signals, it is not surprising that initial CATV networks were one-way. As operators have added new services such as Internet connectivity, voice telephony and video on demand, the networks have evolved to accommodate the two-way nature of these communications. The return path, also known as upstream transmission, is a segment of the CATV frequency band that has been set aside to accommodate the required interactivity. The frequency allocation for the return path depends on the region and color-encoding scheme in use. In North America, Korea, Taiwan, Japan, the Philippines and parts of South America, the National Television System Committee (NTSC) developed the original analog encoding scheme and these systems use a 5 to 42 MHz return path with 6 MHz channels. The rest of the world use Phase Alternate Line (PAL) or Séquentiel Couleur à Mémoire (SECAM) encoding for their original analog CATV networks. These analog schemes use 5 to 65 MHz as the frequency range for the return path with 8 MHz channels.

RECENT DEVELOPMENTS

This is an industry that, until recently, had not seen a tremendous amount of innovation in the preceding 60 years. A large part of the rea-



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CHANGING THE STANDARDS

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son for this is the enormity of the “physical plant,” the actual hardware of the networks. The National Cable and Telecommunications Association estimates operators in the U.S. spent slightly more than \$157 billion dollars on CATV infrastructure since 2000. Even with this massive outlay of capital, it was becoming increasingly difficult to justify investment to increase network bandwidth incrementally or offer some additional analog channels. The conversion to digital channels

and the tremendous surge in demand for video content and faster broadband speeds is changing this situation quickly.

Much of the world has either completed or is well down the path for conversion of their analog television stations to digital. The benefits are enormous. In the U.S., with the new standards for digital transmission, an existing 6 MHz analog TV channel provides a 19.39 Mbps data rate for digital signals. This channel can be

sub-divided into many, lower data rate “standard” definition channels or the operator can offer a smaller number of HDTV or 3D channels.

Operators are supporting this CATV network upgrade because they are finding ways to generate new revenue streams. Consumers are embracing video and operators have responded with more (and higher quality) on-demand movies, faster (and more expensive) Internet packages based on DOCSIS 3.0 standards and more diverse channel offerings. The increased number of channels not only allows MSOs to broaden their channel offering, it also allows them to tailor their offerings and increase advertiser revenue with the concept of Switched Digital Video (SDV).

In a traditional CATV network, all subscribers have all channels passing their premises. Pay channels and other subscription services are filtered out, so that a subscriber only receives what they pay for. Despite a large offering of television channels, studies report that 80 percent of the viewers, in a given area, are watching the same twenty shows. The other channels are consuming bandwidth without much usage. SDV takes a more selective approach by offering the most popular channels on a system-wide basis. The logistics for these channels remain the same: to view one, the set top box (STB) or tuner selects that frequency from the network-wide channel stream. If you select one of the channels not contained in this grouping, the logistics change. In this case, the consumer's STB sends a signal to the access system in the headend, requesting that channel. Operators feel tailoring offerings to groups, whether they are regional, ethnic, same interest, etc., will be attractive to advertisers looking to increase payback on advertising spending. Many of the large MSOs are deploying SDV networks on varying scales. Comcast is already deploying these networks in certain areas and it feels it can re-coup enough bandwidth to offer an additional 150 HDTV channels.

AMPLIFIER DEVICE DEVELOPMENTS

Figure 2 shows a typical example of a line extender system amplifier. This network-level device contains a forward and reverse amplifier path and both of these paths typically con-

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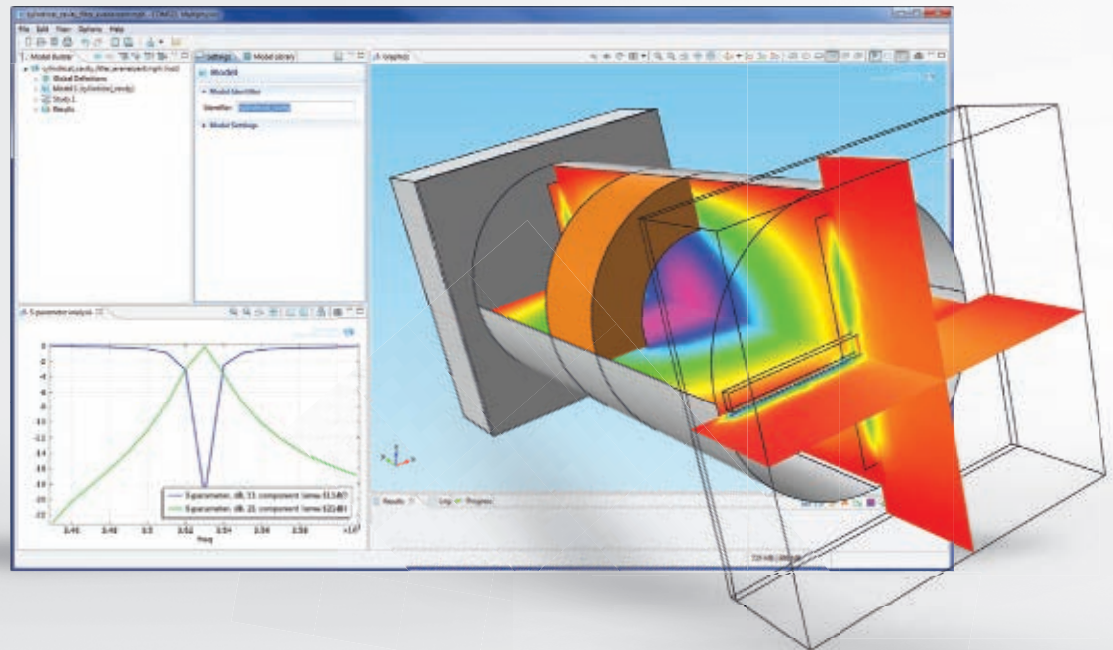


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tain a number of passive elements like equalizers, attenuator pads, baluns and duplexers. These system-level amplifiers will have different names and performance specifications depending on where they are located in the network architecture, but they all must perform bidirectional amplification of signals with little added distortion. To support the network evolution, the semiconductors used in the amplifier building blocks are also undergoing rapid change.

Befitting the sixty year heritage, the early amplifiers were constructed with discrete silicon bipolar junction transistors (BJT). These amplifiers incorporated all the tuning, active and passive elements, using hybrid manufacturing techniques, into what the industry refers to as "hybrids." In early deployments with a limited number of analog channels, the performance of hybrids incorporating silicon BJTs easily met the network requirements.

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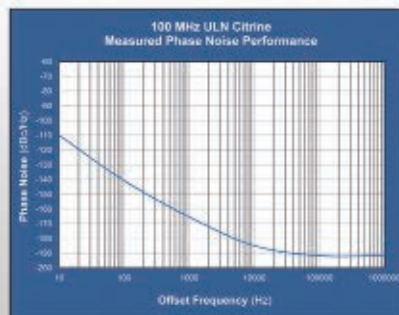


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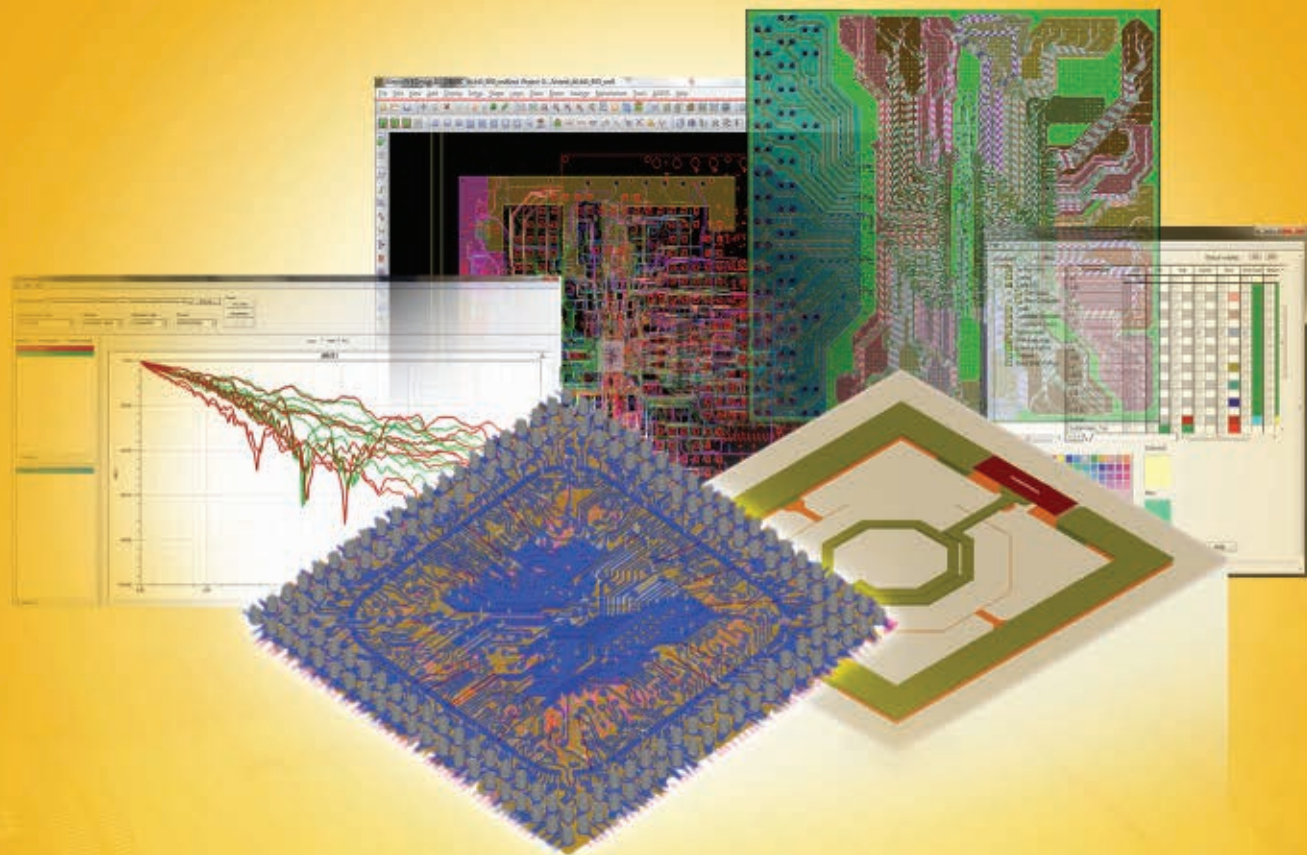


▲ Fig. 2 Line extender amplifier (courtesy of tonercable.com).

tal building blocks for the array of system-level amplifiers used in an HFC network, now use either silicon bipolar or GaAs technology. Over the past decade, GaAs has been supplanting silicon bipolar technology for networks where operators are seeking to offer advanced services and applications. The conversion from analog to digital broadcasting typically provides the opportunity to operate at a higher frequency and broader bandwidth, in addition to more stringent performance requirements. These new requirements favor GaAs parts fabricated using a PHEMT process that can provide better linearity and efficiency performance.

With the analog to digital conversion largely complete in the U.S. and Western Europe, much of that infrastructure has adopted GaAs as a preferred technology. The counterpoint to this trend is evident in the emerging Asian economies of China and India. In these countries, the conversion to digital broadcasting is at a much earlier stage and the cost pressure is severe. Strategy Analytics estimates silicon-based hybrid amplifiers still make up a substantial portion of the CATV infrastructure amplifiers used in this region, but we anticipate strong growth from GaAs devices as network requirements evolve.

As network performance requirements evolve and GaAs performance improves, designers are using more GaAs-based MMIC amplifiers as the building blocks for network amplifiers. Even though GaAs MMIC amplifiers offer the size and repeatability benefits of a wafer scale process, the highest system power amplification



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requirements, closer to the headend are still using hybrid amplifiers. Use of a hybrid versus MMIC gain block varies somewhat, according to the requirement and equipment manufacturer's preference. Research suggests that typical penetration of hybrids is approximately 80 percent in system amplifiers located after the optical node in HFC networks and approximately 75 percent in line extenders used to compensate for splitter and line loss of the signal.

Conversely, as the signal gets closer to the customer premises, the power output and price decrease while the quantity increases. The final amplifier in the HFC network architecture is typically called a "drop amplifier." This represents the last amplification stage before a signal enters a customer's premises and is just about exclusively a MMIC design. The power output trend for this amplifier is actually increasing. As network services have increased, the set top boxes have

become more sophisticated and complex. The addition of multiple tuners, hard drives for DVR functionality and multiple input and output ports for associated electronics have all increased the RF signal loss in the set top box. This increasing power output and stringent linearity requirements look likely to allow GaAs to maintain an edge over SiGe for this function.

Figure 3 shows the latest Strategy Analytics estimate of how MMICs will capture market share from hybrid technology in CATV infrastructure. The trend of GaAs becoming a dominant technology for CATV infrastructure is even more apparent when looking at the latest Strategy Analytics forecasts for market revenue segmented by semiconductor technology. **Figure 4** shows that we anticipate that the GaAs content in system-level amplifiers, whether in hybrid or MMIC configuration, will increase from slightly more than 50 percent in 2010 to more than 80 percent in 2015.

GaN IN CATV AMPLIFIER BUILDING BLOCKS

Probably the most interesting semiconductor development in the CATV market segment is the rapid adoption of GaN technology for amplifiers. The defense industry has long championed the benefits of GaN technology, specifically the ability to deliver high power at high frequencies and to withstand high temperatures. This performance stems largely from the GaN's wide bandgap (3.4 eV), high breakdown voltage, high power density and high gain at microwave frequencies. Until recently, however, the technology has struggled to gain a foothold in commercial market applications.

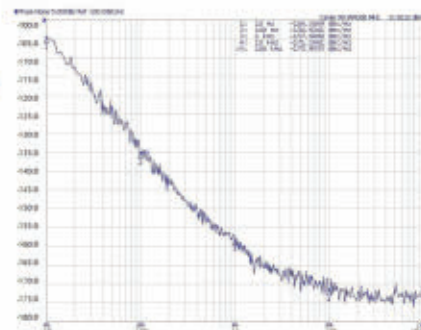
Within the last couple of years, CATV infrastructure applications have emerged as the leading commercial market for GaN-based RF components. This market application has blossomed as devices that are genuinely competitive with silicon and GaAs technology are being developed. GaN performance advantages are providing system benefits in a couple of ways.

For high power system applications, GaN-based amplifiers match the performance of incumbent GaAs components with lower power consumption. Device manufacturers

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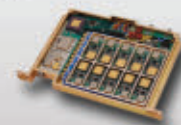
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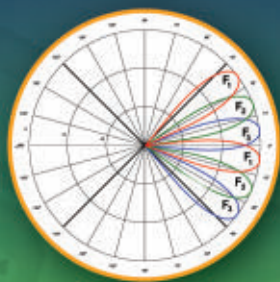
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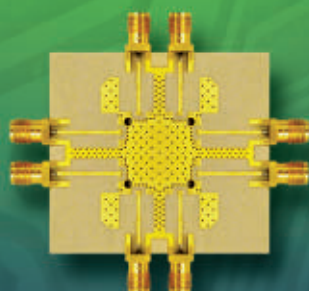


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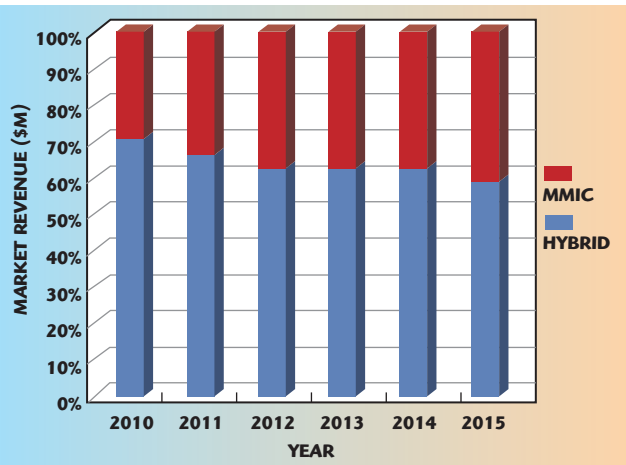
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claim an energy savings of up to 25 percent. This benefit is finding wide acceptance among operators because they can reduce their operating expenses, which represent an increasingly significant fraction of the overall cost of running a network. These GaN-enabled networks are being positioned as “green” because of their reduced energy consumption. This appears to be the most prevalent reason cited by operators for the use of GaN devices.

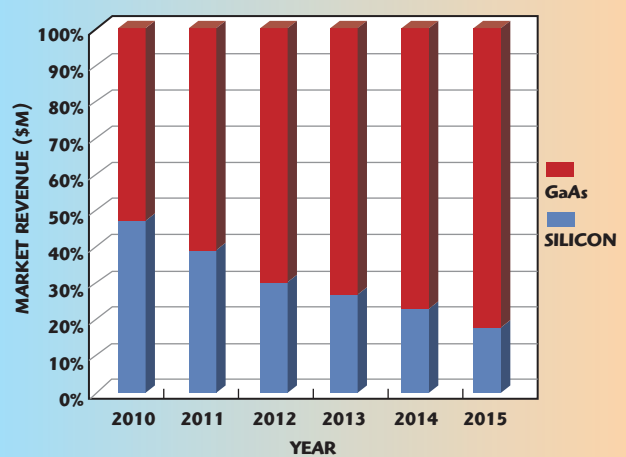
The second differentiating feature that is increasing GaN amplifier adoption in CATV networks is the higher output power and better distortion performance of the technology. The ability to use fewer RF amplifiers in the HFC network was actually the first benefit equipment providers touted to CATV operators. Initially, this approach did not meet with much acceptance because operators were reluctant to use an unproven technology and re-configuring the network layout meant “truck rolls” and additional costs. However, as operators embrace the “green” benefit of lower operating costs, the usage history is being established and operators are using the superior output power capability of GaN to increase the spacing between amplifiers in new “greenfield” applications.

There are still challenges for even wider adoption of GaN, however, with

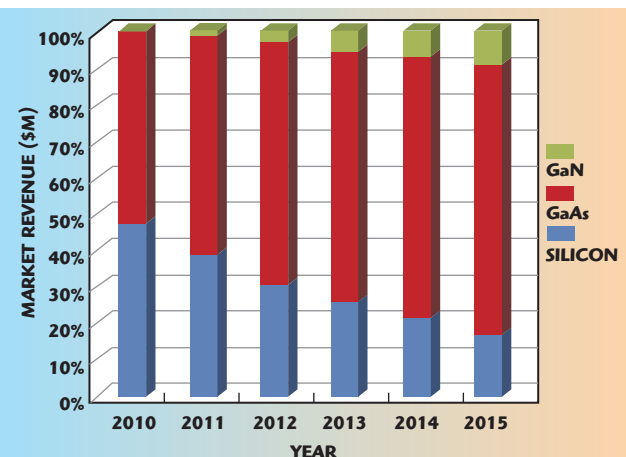
the largest being cost. Strategy Analytics believes that GaN products are currently selling with a price premium of 15 to 30 percent over competing GaAs technologies. To date, the performance advantages and system cost savings make this an acceptable premium for the CATV industry. The bigger issue may be that opponents of



▲ Fig. 3 Amplifier building block topology.



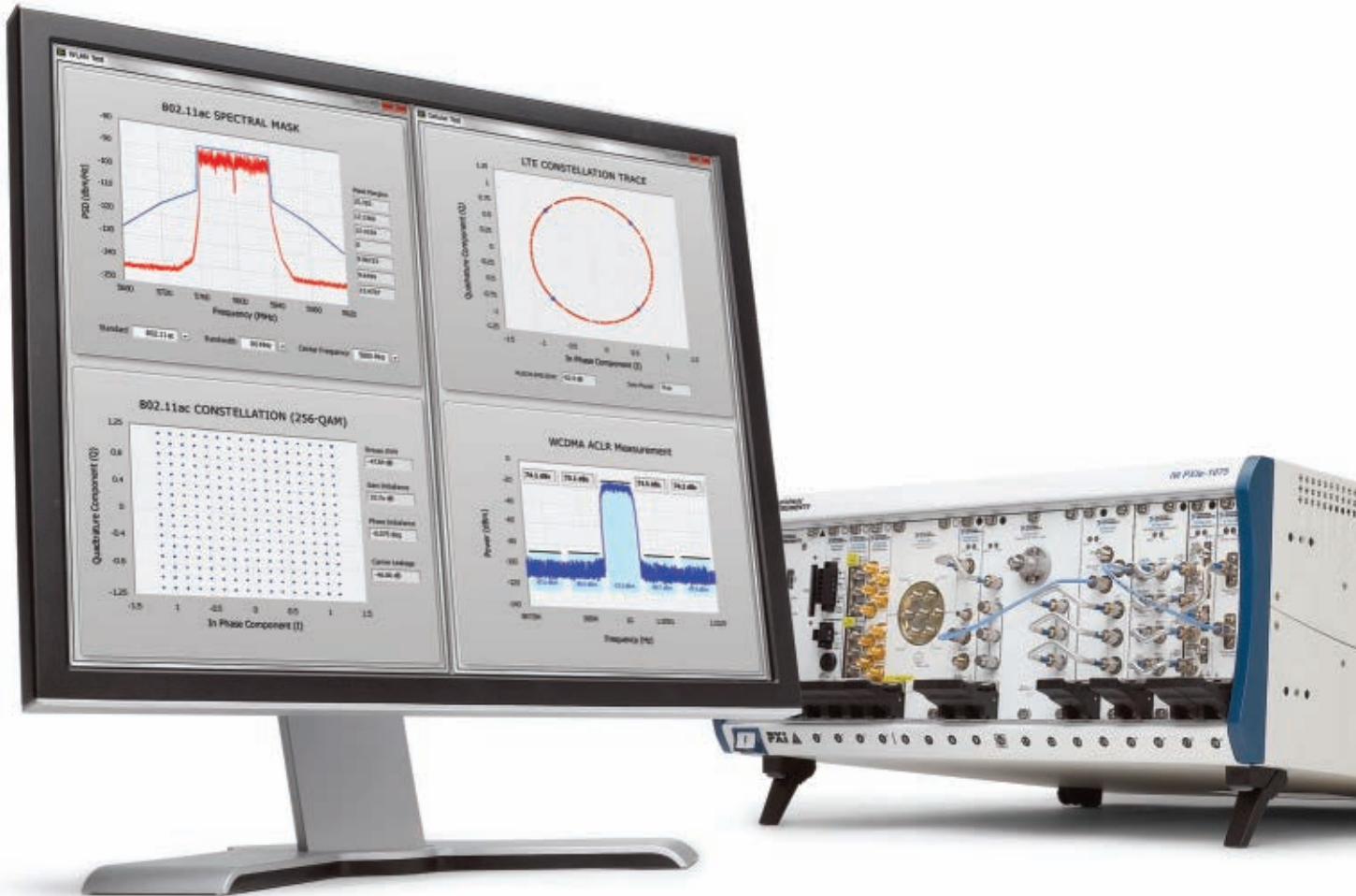
▲ Fig. 4 Amplifier building block technology.



▲ Fig. 5 Amplifier building block technology (including GaN).

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Cover Feature

GaN claim this price premium does not reflect the true cost differential and is not sustainable.

A big cost element is the lack of suitable native GaN substrates on which to grow lattice-matched, defect-free epilayers analogous to GaAs or silicon transistor fabrication. In the absence of production-scale, single-crystal GaN wafers, manufacturers must instead use foreign host materials such as sapphire, SiC or silicon. SiC has been the material of choice for RF applications,

thanks to its relatively close lattice match to GaN and its excellent thermal conductivity properties. While material and process improvements have helped with the quality of SiC wafers, it remains a difficult and expensive material to produce.

Recently, high-resistivity silicon has become a viable alternative to SiC for certain GaN applications. Although the lattice match with GaN and the thermal properties are not as good as SiC, silicon does provide the

potential for lower cost devices. There are GaN-on-Si devices for other market applications and development activity for RF applications, but the vast majority of devices currently used in CATV applications are GaN-on-SiC. With pricing pressure as the driver, it will be interesting to see how the two processing methods evolve.

GaN activity for CATV applications is substantial, as recent announcements illustrate. RFMD began pre-production shipments of GaN-based CATV hybrid amplifiers at the end of 2009. They anticipate revenue of \$4 to \$5 million from GaN-based amplifiers for CATV applications in 2012 and they expect this will double in 2013. These applications typically consist of power doubler devices that use GaAs PHEMT drivers and GaN HEMT output stages. Nitronex has revealed shipments of more than 200,000 GaN amplifiers to a U.S.-based CATV amplifier supplier and, in August 2011, Anadigics announced that they had incorporated GaN into their surface-mount CATV line amplifier portfolio.

Figure 5 revisits the CATV amplifier market revenue segmentation, with GaN added. As the chart shows, Strategy Analytics estimates shipments of GaN-based amplifiers began in 2010 and they will capture market share very quickly. We forecast the market value will grow with a Compound Average Annual Growth Rate (CAAGR) in excess of 150 percent to reach nearly \$25 million in revenue by 2015.

CONCLUSION

This is an exciting time in the CATV industry for consumers, operators, equipment suppliers and device manufacturers. An industry that had seen little change in its first 60 years is undergoing a dramatic upgrade in capability, in response to the explosion of video consumption. Services like digital TV, HDTV, 3D TV, video-on-demand, pay per view and targeted programming are being embraced by consumers. The bandwidth and technology requirements to meet these consumer demands are driving new network architectures and compound semiconductor technologies, most notably GaN, are enabling these new architectures. ■



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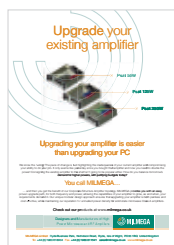
1994

In 1994, the MILMEGA design team turned its experience gained on solid state radar transmitters to the problem of replacing travelling wave tube amplifiers, at lower microwave frequencies, with a solid state equivalent.

Our first 1 to 2GHz product was conceived and, with it, the concept of the corporate structure amplifier (CSA) was introduced to the EMC test community. The building blocks were then laid for the quality, reliability and ownership benefits that the CSA architecture would translate, to for MILMEGA's future customer community. Our competition believed it to be a costly and inflexible method of amplifier implementation. It would take 10 to 15 years before they too began to adopt this flexible architecture with customer benefits.



Series 2000 Upgradeable amplifiers



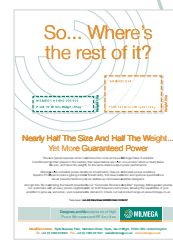
2000

In 2000, MILMEGA introduced the concept of the amplifier power and frequency upgrade to the EMC and wireless communication test communities. Based on the modular architecture of the MILMEGA product, the upgrade philosophy allowed

cost effective power upgrades within the same chassis facilitating re-use of chassis components and minimising waste in an era before it was compulsory to do so. The concept was very simply put at the time as enabling the customer's capability to grow, cost effectively, as their test requirements grew and the budget became available. With the ability to grow a 100W amplifier to 200W by simply adding 100W (and for the cost of 100W), customer's were given the opportunity to engage in future capability planning, with the comfort that MILMEGA would grow their current assets in partnership. Our competition believed power upgrades had no future and, taking a short term revenue based view, believed that MILMEGA would regret offering upgrades to its customer community. It would take 8 years before they too began to offer the concept of an upgrade but none with the elegance of the MILMEGA solution.



Dual Band



2003

In 2003, following input from users within the automotive EMC market, MILMEGA developed the dual band concept. It's fundamental goal was to ensure that customer's paid only for the power they required and not

the power competitive product forced on them through ineffective power architecture choice. While competitors seemed obsessed with demonstrating how clever they were technically, MILMEGA's obsession was with providing quality product, effectively targeted at customer's test requirements and their limited budgets. The dual band concept was simple – two independent amplifiers, each covering its own specific frequency band, switched at the appropriate point in a test cycle. The upper frequency band amplifier had its power tailored by the fact that the gain of test antennae increased with frequency, requiring less amplifier power to be applied at these higher frequencies. When first introduced the concept delivered up to a \$150,000 saving when compared against competitor solutions. The customer community loved it. The competitor community hated it, some even writing application notes as to why dual band amplifiers would never catch on. Nine years later those application notes have been withdrawn and competitors have their own dual band offerings. One or two have even borrowed and modified our slogan from our early adverts.



...others follow

5 Year Warranty introduced

1st commercial SiC Amplifier introduced



2005

In 2005, MILMEGA introduced a concept to the customer community, which has never been formally matched by our competitors – despite them having 7 years to catch up. It was the fully expensed, 5 year warranty. All MILMEGA

customers benefit from the reliability and quality pedigree inherent in all our products. Our customer service levels reflect the customer focus mindset that drives our operations. It was our belief that our customers should bear no additional costs if a MILMEGA amplifier failed within 5 years of ownership – no shipping costs, no labour costs, no component costs. So, in 2005, we introduced our simple 5 year warranty – no slippery caveats, no additional service contracts / insurance to purchase, just a plain and simple promise that in the first 5 years of ownership, if you have a problem, you pay no costs of repair. Our competitors called it financial madness, we called it customer service. Seven years on the competition are still shaking their collective heads (service revenue is valuable to them) and have made no effort to match our unique quality statement. Our 5 year warranty remains unique and, as a quality statement, it is unrivalled.

5



2008

Since early 2002 MILMEGA were experimenting with prototype versions of wide band gap power devices, driven by a keen understanding that these devices, when mature, would change the design landscape of amplifier design. Our focus was on the use of this technology in

multi-octave band commercial amplifiers and not the narrow band application that the technology was derived for. IN 2008, after significant research and development, MILMEGA introduced the first commercially available multi-octave band Silicon Carbide, 1000W amplifier – operating over the 200MHz to 1000MHz band. It was up a third smaller than competitive product. In 2011 we introduced a GaN 80MHz to 1000MHz product. The 1000W product is up to 3 times smaller than rival product and does not require the additional overhead of an air-conditioned room to operate in. With 10 years experience in designing with wide band gap devices, we remain well placed to build on the exciting future opportunities of this technology. Our competitors have yet to match this significant design and market achievement.



2011

In 2011 we introduced our new 80MHz to 1000MHz, 1000W concept. Building on our modular concept from 1994 and our discussions with the EMC community it was a triumph of the extraordinary over the ordinary.

Maximising asset use, extreme portability, the absence of a requirement for expensive support infrastructure, modular to its core and our unique (still unique after 7 years) 5 year warranty. It summarises our journey since 1994 – customer focussed, application efficient and a willingness to take technology risks rather than stand still. We remain the benchmark that competitors look to and subsequently emulate.

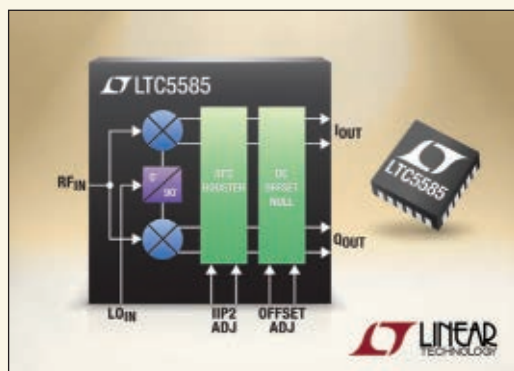


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I/Q Demodulator Eases Bandwidth Constraints

Zero-IF receivers are not new; they have been around for some time and are prominently used in cell phone handsets. However their use in high performance receivers, such as those in wireless base stations, has had limited success. This is due primarily to their limited dynamic range and that they are less understood. A new wide bandwidth zero-IF I/Q demodulator helps to relieve the dynamic range and bandwidth shortcomings for main as well as digital pre-distortion (DPD) receivers and enables 4G base stations to cost effectively address the ever-increasing bandwidth needs of mobile access. This feature covers how to optimize performance by minimizing the IM2 non-linearity and DC offset that reduce the dynamic range of zero-IF receivers, thus offering a viable alternative to an otherwise challenging design.

PUSHING EVER WIDER BANDWIDTH

Until recently, most base stations needed to only deal with a 20 MHz wide channel bandwidth, typically allocated to various wireless carriers. Associated with this 20 MHz channel is a companion 100 MHz bandwidth DPD receiver to measure intermodulation distortion spurs up to fifth-order for effective distortion cancellations. These requirements can generally be met effectively with high-IF (heterodyne) receivers. Nowadays though, such designs become much more challenging with industry trends pushing for base stations that support operation over the entire 60 MHz bands. Accomplishing this feat has significant cost saving implications for the entire wireless manufacturing, installation and deployment business model.

To accommodate the three times increase in bandwidth, the DPD receiver bandwidth has to increase from 100 to 300 MHz. In 75 MHz bands, the DPD bandwidth grows to a staggering 375 MHz. The design of receivers that can support this bandwidth is not trivial. Noise increases due

to the wider bandwidth, gain flatness becomes more difficult to achieve, and the required sampling rate of A/D converters increases dramatically. Furthermore, the cost of such higher bandwidth components is appreciably higher.

The modest bandwidth of a traditional high-IF receiver is no longer sufficient to support the 300 MHz or higher DPD signal with typically ± 0.5 dB gain flatness. The 300 MHz baseband bandwidth would require choosing an IF frequency of 150 MHz at a minimum. It is not trivial to find an A/D converter capable of a sampling rate upward of 600 Msps that is reasonably priced, even at 12-bit resolution. One may have to compromise and resort to a 10-bit converter.

NEW I/Q DEMODULATOR EASES BANDWIDTH CONSTRAINTS

Linear Technology's LTC5585 I/Q demodulator is designed to support direct conversion, thus allowing a receiver to demodulate the aforementioned 300 MHz wide RF signal directly to baseband (see the following link for I/Q demodulator theory of operation – www.mwjournal.com/IQtheory). The I and Q outputs are demodulated to a 150 MHz wide signal, only half the bandwidth of a high-IF receiver. In order to attain a passband gain flatness of ± 0.5 dB, the device's -3 dB corner must extend well above 500 MHz.

The LTC5585 supports this wide bandwidth with a tunable baseband output stage. The differential I and Q output ports have a $100\ \Omega$ pull-up to V_{CC} in parallel with a filter capacitance of about 6 pF (see **Figure 1**). This simple R-C network allows for the formation of off-chip lowpass or bandpass filter networks to remove high-level out-of-band blockers and equalization of gain roll-off the baseband amplifier chain that follows the demodulator. With a $100\ \Omega$ differential output

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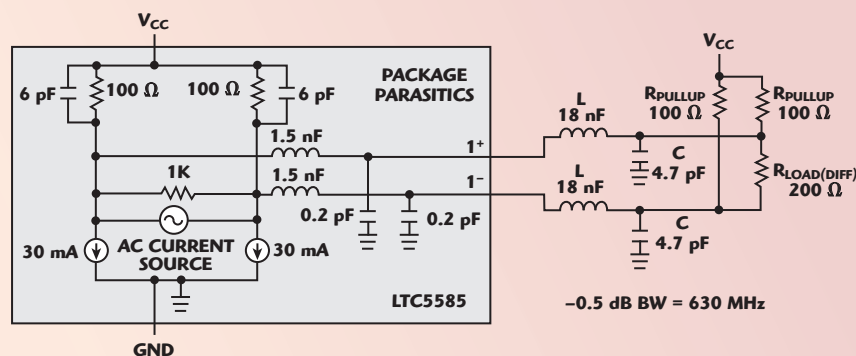
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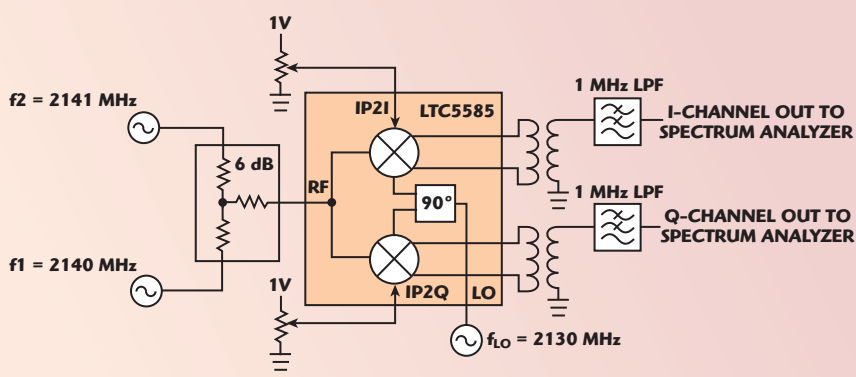
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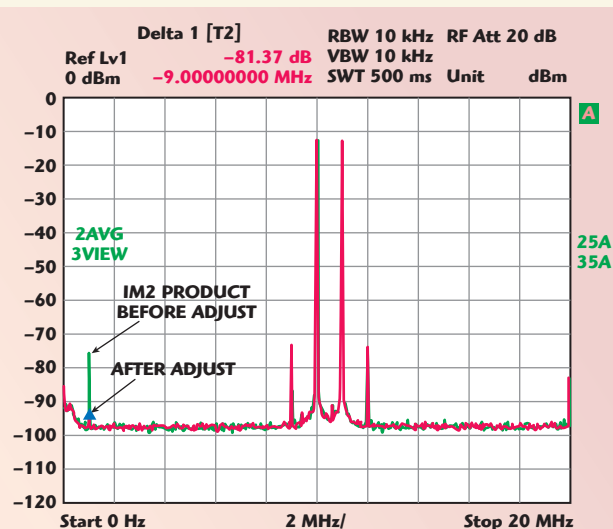
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▲ Fig. 1 Baseband output equivalent circuit for bandwidth extension with $L = 18$ nH and $C = 4.7$ pF.



▲ Fig. 3 Test set-up for IIP2 calibration with 1 MHz lowpass filters to select the IM2 component.



▲ Fig. 4 Output spectrum without lowpass.

loading resistance in addition to the external 100 Ω pull-up resistors, the -3 dB bandwidth reaches 840 MHz.

BASEBAND BANDWIDTH EXTENSION

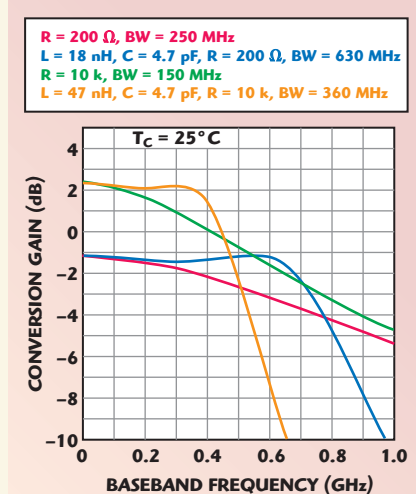
A single L-C filter section can be used to extend the bandwidth of the baseband output. Figure 1 shows the chip's baseband equivalent circuit with baseband bandwidth extension. With 200 Ω loading, the 0.5 dB bandwidth

can be extended from 250 to 630 MHz using a series inductance of 18 nH and a shunt capacitance of 4.7 pF. **Figure 2** shows the variety of output responses that are possible with different loading. One response is with differential loading resistances of 200 Ω and 10 kΩ. For 10 kΩ loading, the -0.5 dB bandwidth can be extended from 150 to 360 MHz using a series inductance of 47 nH and a

shunt capacitance of 4.7 pF.

SECOND-ORDER INTERMODULATION DISTORTION SPURS MATTER

In a direct conversion receiver, the second order intermodulation distortion products (IM2) fall directly in-band at the baseband frequencies. Take, for example, two equal power RF signals, f_1 and f_2 , spaced 1 MHz apart at 2140 and 2141 MHz, respectively, while the

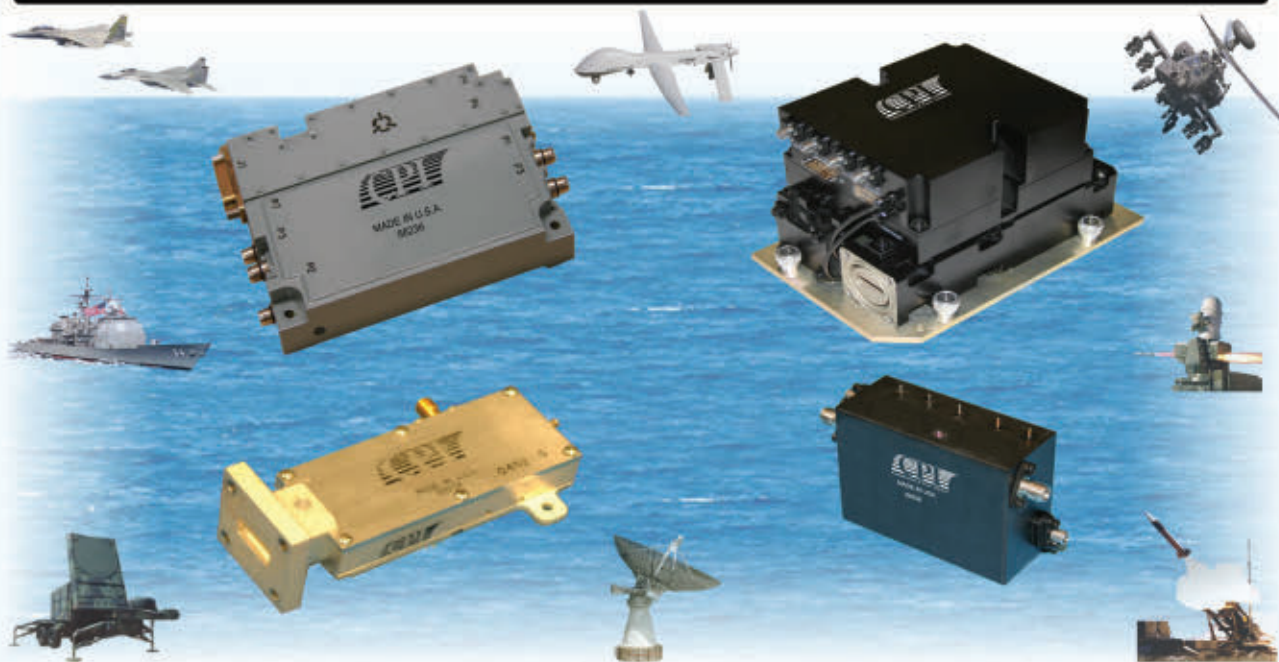


▲ Fig. 2 Conversion gain vs. baseband frequency with differential loading resistance and L-C bandwidth extension.

LO is spaced 10 MHz apart at 2130 MHz. The resultant IM2 spur would fall at $f_2 - f_1$, or 1 MHz. The LTC5585 has the unique ability to adjust for minimum IM2 spurs independently on the I and Q channels by using external control voltages. **Figure 3** shows a typical set-up for IIP2 measurement and calibration. The differential baseband outputs are combined using a balun and the 1 MHz IM2 difference frequency component is selected with a lowpass filter to prevent the strong main tones at 10 and 11 MHz from compressing the spectrum analyzer front end. Without the lowpass filter, 20 to 30 dB of attenuation and long averaged measurement times are necessary on the spectrum analyzer to attain a good measurement. As shown in the output spectrum of **Figure 4**, the IM2 component predictably falls in-band at 1 MHz. The plot also shows the IM2 product before and after adjustment, reducing the spur level by approximately 20 dB by adjusting the control voltages on the IP2I and IP2Q pins. This adjustment reduces the IM2 spur down to a level of -81.37 dBc.

With this IIP2 optimization capability, two possible strategies of IIP2 calibration may be considered. One can be a set-and-forget calibration step performed at the factory. In this case, a simple trim potentiometer for each adjustment pin suffices, as illustrated in Figure 3. Alternatively, an automatic, closed loop calibration algorithm can be implemented in the software which allows the equipment to be calibrated on a periodic basis. For DPD receivers that are already

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monitoring their transmitters' output, this is trivial as the transmitters can easily generate the two test tones. For main receivers, this calibration may involve additional hardware to loop back the two test tones to the receiver channel. In any event, these can all be performed during an off-line calibration cycle. Such an approach would take into account the actual operating environmental factors that may affect the base station's performance.

OPTIMIZING A/D CONVERTER DYNAMIC RANGE

A similar adjustment capability is also integrated into the chip to zero out the I and Q's DC output voltage. DC offset, a product arising from internal mismatch and self-mixing of the LO and RF input leakages, can diminish the ADC's dynamic range when the signal chain is DC coupled throughout. To illustrate, a modest 10 mV of output DC offset voltage, when passed through a 20 dB

gain stage, would result in 100 mV of DC offset at the input of the A/D converter. With 2 Vp-p input range of a 12-bit ADC, this amount of DC offset represents 205 LSBs of headroom reduction, or effectively reducing the ADC's dynamic range by 0.9 dB.

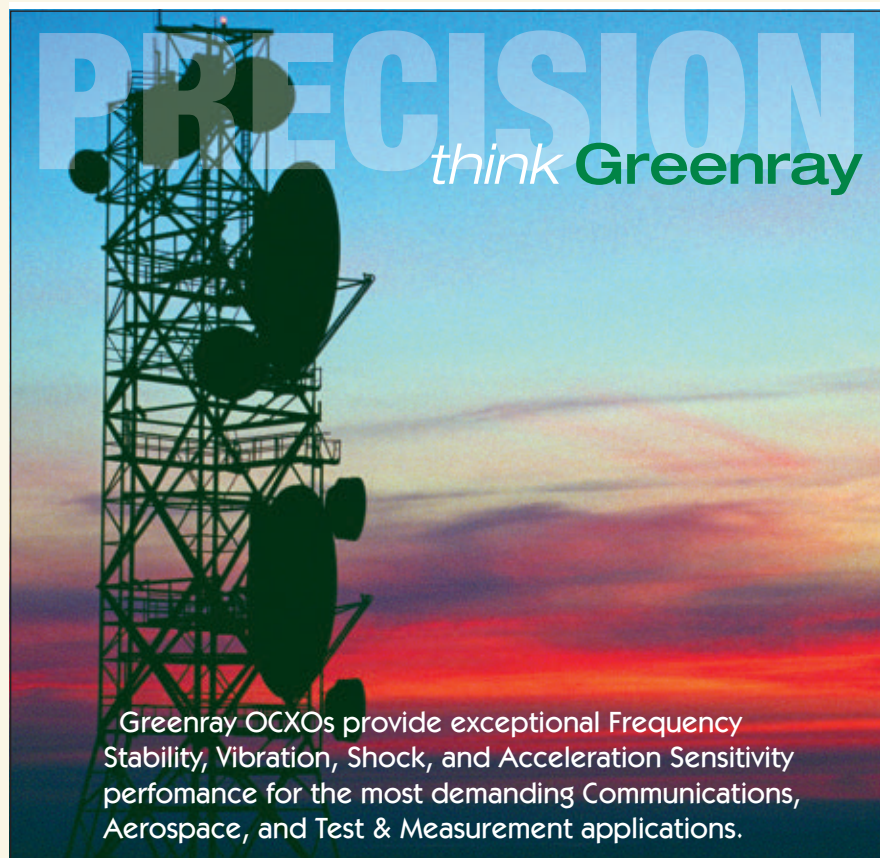
To minimize the leakage between the LO and RF inputs, care should be taken to isolate these two signals. In the PCB layout, separate these two signal traces from one another to prevent cross-coupling. The LO signal, even if there is measurable leakage to the RF port, will self-mix to form a DC offset term at the output. Fortunately the LO level is usually constant, so the DC offset voltage is also constant and can be easily canceled by the adjustment. More problematic is the RF input, which can vary over wide signal levels. Any signal leakage to the LO input would self-mix and produce a dynamic DC offset voltage as the signal varies. This will distort the demodulated signal. So keeping the leakage small will help to reduce the DC offset to a minimum.

POTENTIAL COST BENEFITS OF DIRECT CONVERSION RECEIVERS

A zero-IF receiver is particularly compelling due to its potential cost savings. As mentioned above, the RF signal demodulates to a low frequency baseband. At lower frequencies, the design of the filter becomes easier. Furthermore, zero-IF demodulation produces no image at the baseband, thus eliminating the need for a relatively expensive SAW filter. Perhaps most attractive of all is that the ADC sampling rate can be significantly reduced. In our example above, the 150 MHz I and Q baseband bandwidth can be effectively addressed with a dual 310 Msp ADC such as Linear Technology's LTC2258-14, without resorting to a much more expensive higher sampling rate ADC.

As the bandwidth and performance of wireless receivers increase, a new wideband quadrature demodulator offers an alternative approach that helps to address its architectural shortcomings and raises the level of receiver performance while driving a compelling cost metric.

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IF/RF MICROWAVE COMPONENTS

3G Power Amplifiers: Moving from GaAs to CMOS



ROBERT WAGNER, *Director of Marketing, Javelin Semiconductor, Austin, TX*

Several Austin, Texas companies were founded on the fundamental idea of applying mixed-signal CMOS technology to analog design challenges that traditionally used complicated and expensive semiconductor technology or discrete analog components. Repeatedly, once a viable CMOS solution was introduced, the market made a wholesale shift to the CMOS implementation. In the case of Javelin, the technical challenge was to

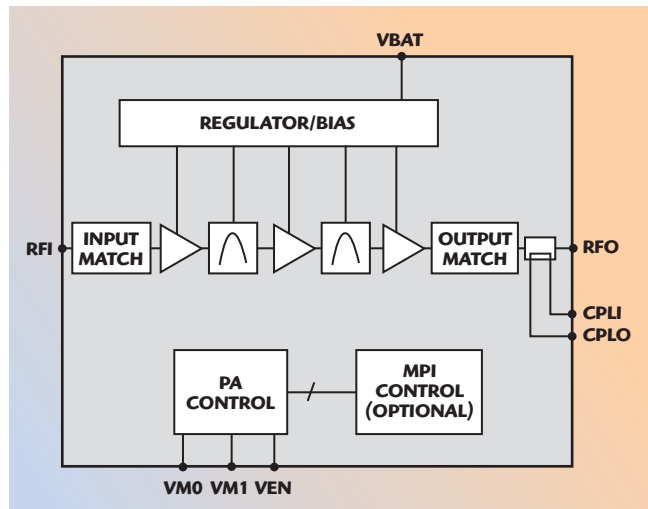
design a linear cellular power amplifier (PA) in standard CMOS technology when existing suppliers are using proprietary GaAs technology. Several companies had already invested millions of dollars and more than a decade of design effort attempting to develop a cellular PA in CMOS, but they were unable to meet stringent 3G performance requirements in a CMOS implementation. Therefore, Javelin was also faced with the business challenge of

proving the capabilities of CMOS for 3G applications and convincing a Tier I handset manufacturer to qualify a new PA supplier.

Javelin sees 3G as the entry point for CMOS to become a mainstream process technology for the cellular PA. The requirements for a 3G PA are very demanding in terms of performance (ef-

iciency, linearity and noise), reliability and also in having a high yielding, large capacity manufacturing supply chain. Javelin is the first company to produce a CMOS 3G PA that does not compromise any of these requirements. To break the GaAs PA monopoly in the 3G handset, Javelin developed an innovative mixed-signal architecture offering performance advantages while meeting or exceeding all stringent industry requirements. The innovative architecture provides an inherent bandpass response to minimize receive noise for 3G and other radios in the handset, while delivering excellent efficiency across the wide range of required output power levels. Because Javelin's PA is a 100 percent CMOS implementation, supply limitations are eliminated.

Javelin's PA was modeled and designed to meet the output power and linearity requirements of the 3GPP UMTS standards. The PA has a bandpass architecture that includes an input matching network, tunable bandpass filtering between each amplifier stage and an output matching network (see **Figure 1**). The PA



▲ Fig. 1 JAV550X architecture.

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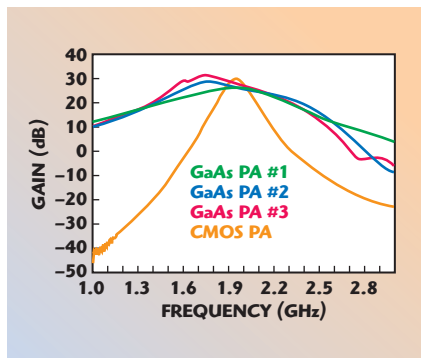
Broadband CW Power Applications

20 MHz - 1000 MHz	2.0 GHz - 6.0 GHz
20 MHz - 6000 MHz	2.5 GHz - 6.0 GHz
0.5 GHz - 2.5 GHz	6.0 GHz - 18.0 GHz

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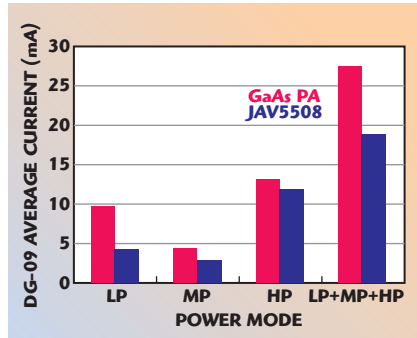




▲ Fig. 2 Bandpass filter response for various PAs.

also integrates complete circuitry for power regulation, PA bias and power control.

The integrated bandpass filtering can have a significant benefit in UMTS Band I (1920 to 1980 MHz transmit and 2100 MHz receive) applications, which is supported by the Band I PA. Typically, the transceiver transmit noise in Band I is filtered with a surface acoustic wave (SAW) filter between the transceiver RF output and PA RF input. With the bandpass filtering in this design, the SAW



▲ Fig. 3 Weighted average current in each mode according to the DG-09 average current definition.

filter can be removed, saving both cost and board area. The result is a bandpass response with low out-of-band skirts that reduces receiver noise (see **Figure 2**).

In the situation where transceiver noise is already low and a TX SAW is not required, the bandpass filtering provides additional margin for ease of implementation as well as manufacturing margin. Even with a low-noise transceiver and a traditional PA of any band, the duplexer (DPX) must maintain greater than 45 dB isolation

for acceptable receive sensitivity (desense). This level of isolation from the DPX is a challenge, and very careful PCB layout is required for the DPX and surrounding components. Javelin's PA reduces the DPX isolation requirement by the TX-to-RX gain difference. In this case, the DPX isolation requirement is reduced by more than 10 dB.

Also, particularly in smartphones, the bandpass filtering can provide benefits to overall performance. Smartphones contain multiple wireless interfaces, such as Wi-Fi, Bluetooth and GPS, which have low receive signal power levels. The bandpass filtering reduces interference with these other wireless interfaces and helps to lessen the RF design challenges within the smartphones.

Javelin offers a family of CMOS PAs covering the most popular UMTS bands including solutions for Band I (1920 to 1980 MHz), Band II (1850 to 1910 MHz), Band V (824 to 849 MHz) and Band VIII (880 to 915 MHz). Javelin's architecture ensures consistent performance by using a patented design with tunable filtering to optimize performance and maximize manufacturing yield. The result is a highly manufacturable, high yielding device that consistently meets stringent specifications. For example, the JAV5501 offers 26.5 dBm maximum linear output power in high power (HP) mode, 28.5 dB typical gain in HP mode, -42 dBc ACLR with ± 5 MHz offset, -148 dBm/Hz noise in RX band with 190 MHz offset and 1.5 percent typical error vector magnitude (EVM).

All of Javelin's PAs offer low average current with a direct connection to the battery. The JAV5505 and JAV5508 lead the industry with DG-09 average current below 19 mA, which is over 30 percent lower than competing devices. At specific low output power levels, PA current can be reduced by over 60 percent. The low average current is achieved using typical low power (LP, -47 to 6 dBm), medium power (MP, 6 to 15 dBm) and higher power (HP, 15 to 26 dBm) switch points, and without the additional cost and board area of a switch-mode power supply (SMPS) DC/DC converter to control the PA supply voltage. **Figure 3** shows the

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LNAs for Cellular Infrastructure, GPS, Broadband, ISM Band, and WLAN Applications

Part Number New Products	Application	Frequency Range (MHz)	Test Frequency (MHz)	Gain (dB)	NF (dB)	OIP3 (dBm)	OP _{1dB} (dBm)	V _{DD} (V) (Operating Range)	I _{DD} (mA) (Operating Range)	Package (mm)
SKY67101-396LF	Cellular Infrastructure	400–1200	900	17.5	0.57	34	19	4 (3.3–5.0)	54 (20–90)	DFN 8L 2 x 2 x 0.75
SKY67100-396LF	Cellular Infrastructure	1200–2300	1950	17.5	0.7	34	18.5	4 (3.3–5.0)	55 (20–90)	DFN 8L 2 x 2 x 0.75
SKY67102-396LF	Cellular Infrastructure	2000–3000	2600	17.2	0.8	34	15	4 (3.3–5.0)	50 (20–90)	DFN 8L 2 x 2 x 0.75
SKY67001-396LF	Cellular Infrastructure	700–1000	900	17.5	0.6	40.5	21	5 (3.3–5.0)	100 (50–120)	DFN 8L 2 x 2 x 0.75
SKY67002-396LF	Cellular Infrastructure	1600–2100	1950	17.5	0.65	39.5	20	5 (3.3–5.0)	95 (50–120)	DFN 8L 2 x 2 x 0.75
SKY67003-396LF	Cellular Infrastructure	2000–3000	2600	17.5	0.88	39	19.7	5 (3.3–5.0)	100 (50–120)	DFN 8L 2 x 2 x 0.75
SKY67105-306LF	Cellular Infrastructure	600–1100	850	37	0.7	41	26	5 (3.5–5.0)	140 (120–155)	QFN 16L 4 x 4 x 0.90
SKY67106-306LF	Cellular Infrastructure	1500–3000	1950	35	0.65	37	24	5 (3.5–5.0)	100 (80–125)	QFN 16L 4 x 4 x 0.90
SKY67107-306LF	Cellular Infrastructure	2300–2800	2600	32	0.85	37.5	18.5	5 (3.5–5.0)	125 (50–145)	QFN 16L 4 x 4 x 0.90
SKY67012-396LF	General Purpose	300–600	450	16.5	0.85	24	14	3.3 (1.8–5.0)	15 (5–30)	DFN 8L 2 x 2 x 0.75
SKY67013-396LF	General Purpose	600–1500	900	14	0.85	26	15.5	3.3 (1.8–5.0)	15 (5–30)	DFN 8L 2 x 2 x 0.75
SKY67014-396LF	General Purpose	1500–3000	2450	13	0.95	26	15	3.3 (1.8–5.0)	15 (5–30)	DFN 8L 2 x 2 x 0.75
SKY65404-31	5.8 GHz WLAN and ISM Band	4900–5900	5800	13	1.2	20	9	3.3 (2.8–5.0)	11 (10–15)	DFN 6L 1.5 x 1.5 x 0.45
SKY65405-21	2.4 GHz WLAN and ISM Band	2400–2500	2450	15	1.1	24	15	3.3 (2.8–5.0)	12 (10–16)	DFN 6L 1.5 x 1.5 x 0.45

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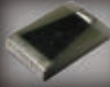
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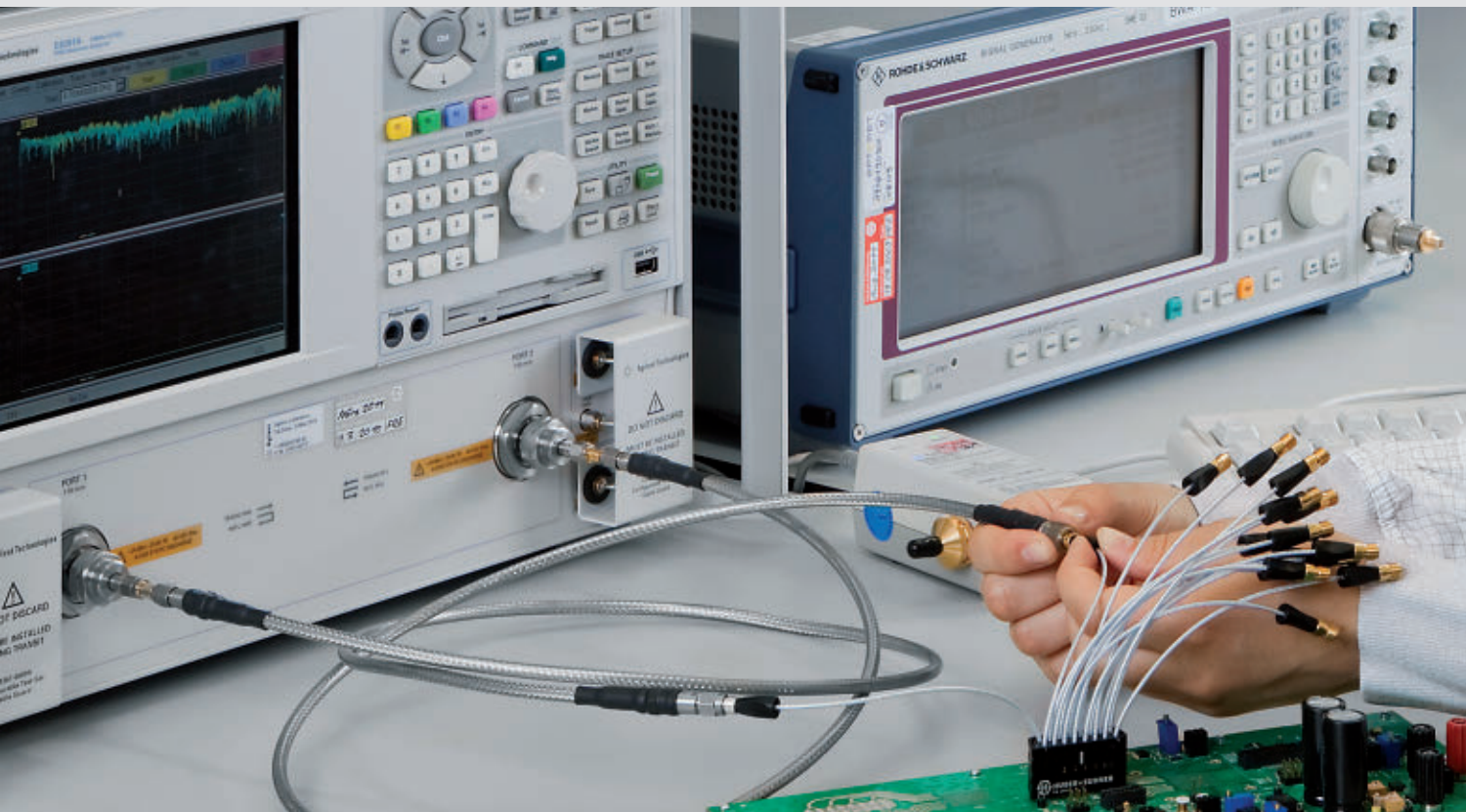
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Perspective

current levels that are the weighted average currents in each mode, according to the DG-09 average current definition.

Because the PA delivers significant power and is connected to the battery and the antenna, Tier I handset manufacturers require not only high performance, but also high quality and reliability. In Javelin's case, standard CMOS technology becomes a major benefit, because a monolithic CMOS approach leads to the highest manufacturing line yield and maximizes long term reliability in the field. Javelin's PA family utilizes the world's largest capacity process node of the CMOS supply chain combined with industry standard high-volume packaging technology to offer world-class quality and reliability, including a very high tolerance to electrostatic discharge (ESD) events. Javelin PAs are rated at 6 kV on RF pins and 3 kV on all other pins which is critical to manufacturing quality and reliability. Additionally, Javelin PAs can withstand driving full output power into a short circuit or open circuit without damage, which is critical to field quality and reliability.

The 3G smartphone market is an ideal starting point for a CMOS PA, as 3G is forecasted to be the largest segment of the mobile phone market over the next five years. Comparatively, the Long Term Evolution (LTE) market segment is currently small on a world-wide basis, but continues to experience rapid growth. Javelin's mixed-signal CMOS architecture is well suited for LTE. The transition to LTE will create additional PA design challenges while the higher peak to average ratios will require advanced architectures with more integrated intelligence and CMOS is well suited for this trend. As an example, the MIPI RF Front-End (RFFE) control interface, supported on Javelin PAs, is an industry standard digital communications interface which was defined to enable the integration of advanced features into the PA. In the future, this digital interface to the PA can be used for advanced power control and envelope tracking techniques. Thus, Javelin sees the CMOS PA trend continuing from 3G to LTE and beyond. ■



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MIMO... and All That Jazz



A preview of the MIMO OTA expert panels to speak at this year's CTIA Wireless conference in New Orleans.

To deliver higher data rates, greater coverage areas, and lower operational costs, 4G wireless technologies such as LTE and LTE-Advanced employ enhanced spectral efficiency through the use of MIMO antennas. In MIMO systems, a transmitter sends multiple spatial streams using multiple transmit antennas. These streams are transmitted over-the-air through a channel consisting of multiple paths, arriving at multiple receive antennas at different times. The receiver then decodes the received signal vectors into the original information.

Multiple antenna techniques include: 1.) "pre-coding" or multi-stream beamforming, whereby the same signal is emitted from each transmitter antenna with appropriate phase weighting in order to maximize the signal power at the receiver input 2.) "spatial multiplexing" whereby a high rate signal is split into multiple lower rate streams and each stream is transmitted through the channel at the same frequency and 3.) "diversity coding" whereby the signal is emitted from each transmit antenna with full or near orthogonal coding, exploiting the independent fading in the antenna links to enhance signal diversity.

Coding and signal processing are key elements in a successful implementation of MIMO. Every communication channel represents a major factor in the performance of a wireless system and therefore is the focus of much research. Because MIMO operates at an unprecedented level of complexity in order to exploit the channel space-time resources, a new level of understanding of the channel space-time characteristics is required to assess the potential performance of practical multi-antenna links. MIMO terminal performance is a combination of antenna characteristics, radio propagation conditions, RF, baseband hardware, and software, and therefore they need to be well understood through some form of

MIMO Over-the-Air (OTA) test system. The conventional way of testing the antenna characteristics and the signal processing performance separately does not assess the MIMO device performance realistically.

Last year, Microwave Journal teamed up with MIMO OTA test experts from ETS-Lindgren, Agilent Technologies, Spirent, and Elektrobit to present a two-hour panel session at CTIA Wireless 2011. The live forum and simultaneous webcast focused on the fundamentals of MIMO OTA testing as an accurate and cost-effective solution to validate complex MIMO device performance, providing an understanding of the core elements that facilitate systematic and repeatable measurements.

Last year's forum highlighted the technical features of the test system, including the chamber, software and instrumentation. The speakers presented information on cost-effective ways to perform MIMO OTA characterization using antenna pattern measurements, concepts and underlying assumptions behind MIMO OTA models and the importance of radio channel modeling and validation in MIMO OTA testing. An interactive panel discussion with the speakers allowed audience members to explore a range of related topics with these experts firsthand.

The CTIA Wireless 2011 MIMO Expert Forum Q&A session explored a range of topics. Moray Rumney (Agilent), Dr. Michael Foegelle (ETS-Lindgren), Doug Reed (Spirent Communications) and Jukka-Pekka Nuutinen (Elektrobit) took turns answering questions on OTA system calibration, validation through field mapping, the current situation on OTA standards and more. To see a sample of the CTIA Wireless 2011 MIMO panel discussion, go to mwjournal.com/CTIAW2011_MIMO_QandA.

MIMO

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Over-the-Air (OTA) Signal Challenges and Implications - Recommendation for LTE RAN

Protocols used by LTE networks to leverage MIMO technologies are significantly impacted by correlation and thus by the channel models under which they are tested or emulated. Over-the-Air testing with a Base Station Analyzer can determine how the MIMO Transmitters are functioning, map the downlink coverage or look for co-channel interference. This Forum provides an understanding of over-the-air, multi-path signal challenges and considerations for end-to-end testing.

Wednesday May 9, 2012
10:45 AM – 1:00 PM

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MIMO OTA Measurements – The Next Generation Platform for Wireless Testing

Extensive efforts are underway to standardize on a next generation platform for performance testing of wireless devices, taking into account LTE, A-GPS, uncertainty budgets and use of head/hand phantoms. This Forum provides an understanding of system performance and presents the core elements - such as the chamber, software and instrumentation - that facilitate systematic and repeatable measurements of MIMO devices.

Thursday May 10, 2012
11:45 AM – 2:00 PM

Sponsored by

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Elektrobit
Spirent Communications





Speaking of Beamforming and 8 Antenna MIMO support for TD-LTE.....

Interview with Madhusudhan Gurumurthy, Senior Applications Specialist for channel emulation products at Spirent Communications

Microwave Journal talks with Mr. Gurumurthy about TD-LTE deployments in China and across the Globe. Gurumurthy discusses TD-LTE MIMO requirements and explains how 8xn systems and beamforming techniques are currently being developed for networks targeting single-band spectrum for use in densely populated areas and how beamforming will require accurate per-user channel estimation in order to properly direct energy to a specific user device.

www.mwjjournal.com/Spirent_interview

CTIA WIRELESS 2012 PARTNER EVENT SERIES

Based on the success of last year's MIMO Expert Forum, Microwave Journal will once again feature a panel of speakers from ETS-Lindgren, Agilent, Elektrobit and Spirent Communications. In addition, the Journal is pleased to announce an all new technical session addressing OTA signal challenges for LTE featuring a second panel of industry measurement experts from An-

ritsu, Rohde & Schwarz, Azimuth and EMITE Ing.

Over-the-Air Signal Challenges and Implications: Recommendation for LTE RAN

Wednesday, May 9th (10:45 AM - 1:00 PM)

*Moderated by: David A. Sánchez-Hernández
CEO, EMITE Ing*

Sponsored by: Anritsu, Azimuth, Rohde & Schwarz and Electro Rent

Speakers from Anritsu, Rohde & Schwarz and Azimuth will discuss signal challenges for MIMO based LTE networks, base station analysis and characterization of the channel through field drive tests and software emulation. This forum will provide an overview of multi-path signal challenges, OTA testing and considerations for evaluating how well a MIMO transmitter is functioning. Topics include: how drive test software based on the full channel bandwidth can be applied to 4x2 and 2x2 MIMO systems to estimate MIMO functionality in the field, during network performance measurements, drive tests or in buildings.

MIMO OTA Measurements: The Next Generation Platform for Wireless Testing

Thursday, May 10th (11:45 AM - 2:00 PM)

*Moderated by: Mr. Bryan Saylor, President
and General Manager of ETS-Lindgren*

Sponsored by: Agilent Technologies, ETS-Lindgren, Elektrobit & Spirent Communications

Extensive efforts are underway to standardize on a next generation platform for performance testing of wireless devices, taking into account LTE, A-GPS, uncertainty budgets and use of head/hand phantoms. This Forum, featuring experts from Agilent, ETS-Lindgren, Elektrobit and Spirent Communications will provide an understanding of system performance and discuss how the core elements such as the measurement chamber, software and instrumentation are used to facilitate systematic and repeatable measurements of MIMO devices. The emphasis of this panel will be to look at the standards that are defining OTA test for the end-user device.





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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

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
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Lockheed Martin Team Completes On-Orbit Testing of First AEHF Satellite

Lockheed Martin recently announced the successful completion of on-orbit testing for the first Advanced Extremely High Frequency (AEHF) military communications space vehicle (SV-1). The AEHF system will provide vastly improved global, survivable, highly secure, protected communications for warfighters operating on ground, sea and air platforms. AEHF SV-1 was launched on August 14, 2010 aboard a United Launch Alliance Atlas V rocket and reached geosynchronous orbit on October 24, 2011 following successful execution of a work-around orbit-raising plan.

The satellite has now completed on-orbit testing that included establishing communications networks between combinations of EHF terminals at the backward compatible Milstar data rates as well as at the new AEHF extended data rates. On-orbit testing began with SV-1 then progressed with SV-1 networked with the Milstar constellation. Completion of this key milestone paves the way for the satellite to be turned over to the 14th Air Force at Vandenberg Air Force Base, Calif.



Source: Lockheed Martin

"I am extremely proud of the team that raised SV-1 to geosynchronous orbit and successfully demonstrated its on-orbit performance," said Lockheed Martin's Global Communications Systems vice president and general manager, Kevin Bilger. "Their ingenuity, perseverance and dedication to the mission enabled this critical national asset to stand ready to provide our warfighters around the globe with unprecedented new protected communications capabilities."

One AEHF satellite provides greater total capacity than the entire Milstar constellation currently on-orbit. Individual user data rates will be five times improved, providing transmission of tactical military communications, such as real-time video, battlefield maps and targeting data. In addition to its tactical mission, AEHF also will provide the critical survivable, protected, and endurable communica-

tions to the National Command Authority, including presidential conferencing in all levels of conflict.

The AEHF team includes the U.S. Air Force Military Satellite Communications Systems Directorate at the Space and Missile Systems Center, Los Angeles Air Force Base, Calif. Lockheed Martin Space Systems Co., Sunnyvale, Calif., is the AEHF prime contractor, space and ground segments provider as well as system integrator, with Northrop Grumman Aerospace Systems, Redondo Beach, Calif., as the payload provider.

Raytheon's U.S. Air Force Satellite Terminal Achieves Two Critical Milestones

Raytheon Co.'s U.S. Air Force satellite terminal system that provides protected communications to warfighters has received a successful Milestone C decision and subsequent production award. The Minuteman Minimum Essential Emergency Communications Network Program Upgrade (MMPU) is Raytheon's first Advanced Extremely High Frequency (AEHF) terminal for the Air Force to enter into the production phase. In another achievement, it became the company's third AEHF terminal to interoperate with the on-orbit AEHF satellite, joining the U.S. Army's Secure Mobile Anti-Jam Reliable Transportable Terminal (SMART-T) and the U.S. Navy Multi-band Terminal (NMT).

The first AEHF satellite, launched in August 2010, recently began an extensive set of operational tests. In this testing, MMPU, SMART-T and NMT demonstrated interoperable communications using the AEHF satellite's eXtended Data Rate (XDR) waveform, moving data more than five times faster than previous EHF systems. MMPU adds essential nuclear command and control capabilities to the Raytheon AEHF terminal product line established by SMART-T and NMT.

"Our success on MMPU reflects our three-decade commitment to our EHF/AEHF terminal product line," said Scott Whatmough, vice president of integrated communication systems for Raytheon's Network Centric Systems business.

"We are delivering the most powerful, the most secure communications to the armed forces, giving them more mission flexibility and significantly increased capacity to provide protected voice, data and video communications," added Whatmough.

Raytheon is projected to deliver 67 MMPU AEHF terminals, including spares, to the U.S. Air Force. The MMPU AEHF systems incorporate Raytheon's XDR wave-

"We are delivering the most powerful, the most secure communications to the armed forces..."

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form hardware and software, including new cryptographic algorithms for protecting national command and control (NC2) networks, a complex technological breakthrough in protected communications. XDR and the cryptographic algorithms provide increased bandwidth, speed and significantly improved security within the NC2 communications architecture.

Northrop Grumman Awarded Contract for Integration of Battlefield Airborne Communications Node on Global Hawks

The U.S. Air Force has awarded Northrop Grumman Corp. a \$47.2 million contract for the purchase and integration of two more Battlefield Airborne Communications Node (BACN) payloads on two existing Block 20 Global Hawk aircraft. BACN is a high-altitude, airborne communications and information gateway system that maintains operational communications support 24 hours a day, seven days a week. The persistent connectivity that BACN provides improves situational awareness and enables better coordination between forward-edge warfighters and commanders. BACN bridges and extends voice communications and battlespace awareness information from numerous sources using a suite of computers and

radio systems. After the BACN payloads have been integrated on the Block 20 Global Hawks, the aircraft will be designated as USAF EQ-4B unmanned systems, providing long endurance and high persistence gateway capabilities.

"The addition of two more BACN systems on Global Hawks will decisively enhance the required 24/7 gateway capability," said Claude Hashem, vice president of the network communications systems business at Northrop Grumman's Information Systems sector. "The EQ-4B unmanned systems will continue to provide long endurance and unsurpassed communications persistence to our warfighters."

Northrop Grumman is the prime contractor for the development, fielding and maintenance of the BACN system and the RQ-4 Global Hawk aircraft. The company was awarded the first BACN contract in April 2005 by the Air Force Electronic Systems Center, Hanscom Air Force Base, Massachusetts. The Global Hawk program is managed by the Air Force Aerospace Systems Center, Wright-Patterson Air Force Base, OH.

"The addition of two more BACN systems on Global Hawks will decisively enhance the required 24/7 gateway capability."

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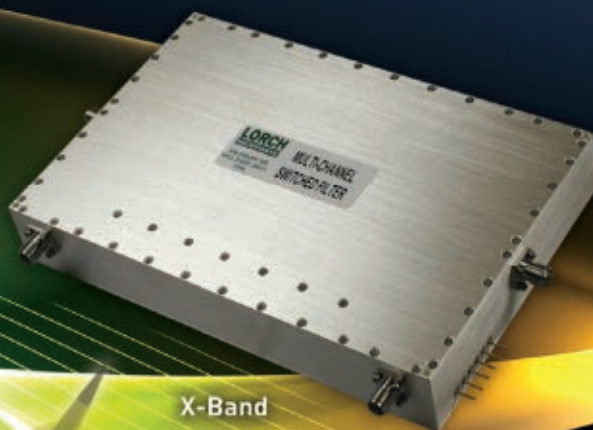
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Surrey NanoSystems Secures £4.5 M to Commercialize Semiconductor Fabrication

Surrey NanoSystems has raised third round funding of £4.5 million for developing silicon-friendly nanomaterials growth processes. The funds will be used to commercialize innovations in materials to support the continued scaling of integrated circuits. These include an advanced dielectric thin film for insulation applications, and a process for growing carbon-based interconnections or 'vias'. Progress in both of these back-end-of-line semiconductor fabrication areas is critical if manufacturers are to continue silicon's evolution to next-generation geometry sizes, operating speeds and power conservation.

The third-round funding is being provided by New Wave Ventures in conjunction with Parkwalk Advisors, and further investments from Surrey NanoSystems' existing backers Octopus Ventures, IP Group PLC and the University of Surrey.

"The new funding will be used to take our proven technology to the next stage – to demonstrate it at a scale compatible with the lithography and wafer sizes used in today's high volume semiconductor manufacture," said David Wong, CEO of Surrey NanoSystems. "We are cooperating with leading players in the semiconductor industry, and within the next two to three years we expect to be able to offer the technologies in forms suitable for commercial use."

Reducing leakage current is a critical requirement for the continued scaling of semiconductor devices. Surrey NanoSystems has developed a new class of high performance dielectric material for inter-layer or inter-metal insulation with an effective dielectric constant of less than 2.4. Another target application is a replacement material for the vertical connections that link the layers of an integrated circuit. Carbon nanotubes (CNT) can be structured to act as more efficient conductors, and Surrey NanoSystems' has developed a fabrication system and process that allows high density CNT structures to be grown at silicon-friendly processing temperatures of 350°C or less.



Source: Surrey NanoSystems

ITU Report Shows Accelerated Uptake for ICT Across Arab Region

Data from the International Telecommunication Union's ICT Adoption and Prospects in the Arab Region 2012 report reveals that, over the past five years, the number of mobile cellular subscriptions in the region has almost tripled, from 126 million in 2006, to nearly 350 million by the end of 2011. At the beginning of this year, regional mobile cellular penetration reached 97 per cent – ten per cent higher than global penetration.

However, the report into information and communication technology (ICT) warns that such figures can obscure wide disparities between the region's 'hyper-connected' economies and its less connected nations. For example, for every 100 people in Saudi Arabia, there are around 188 mobile phone subscriptions; in Djibouti, there are fewer than 20. More than 80 per cent of the population in Qatar uses the Internet, but the figure is below five per cent in Mauritania, Iraq and Somalia. Members of the Gulf Cooperation Council (GCC), with their higher incomes, have more than twice as many Internet users per 100 inhabitants as non-GCC countries.

"With the 'mobile miracle' we have brought the benefits of ICTs within reach of virtually all the world's people. It is now time to make the next step, and to ensure that everyone – wherever they live, and whatever their circumstances – has access to the benefits of broadband," said ITU Secretary-General Dr. Hamadoun Touré. "In the 21st century broadband networks must be considered basic infrastructure, just like roads, railways, water and power networks. Broadband is a powerful social and economic enabler, and will help accelerate progress towards the Millennium Development Goals, now just three years away."

"In the 21st century broadband networks must be considered basic infrastructure..."

Europe and India Sign Research and Innovation Declaration

The European Commission and the Indian Government have signed a Joint Declaration on Research and Innovation Cooperation. The Declaration provides an opportunity to step up relations between Europe and India towards an 'Indo-European Research and Innovation Partnership'.

Research and innovation are key pillars for creating sustainable growth and new jobs as part of the Indian 'Decade of Innovation' and the 'Europe 2020' strategy and the 'Innovation Union Flagship Initiative'. The Declaration will further strengthen the existing cooperation under the umbrella of the EU-India S&T Cooperation Agreement signed in 2001. It will also move cooperation up a gear to-



“Research and innovation are proven investments in growth and jobs...”

the synergies between India, the EU and its Member States.

Máire Geoghegan-Quinn, the European Commissioner for Research, Innovation and Science, said: “This joint declaration will boost an Indo-European alliance for research and innovation. We have great potential to make our joint research efforts more effective, in order to promote the innovation needed to tackle societal challenges we all face, such as food security and climate change. Research and innovation are also proven investments in growth and jobs in this difficult period for the global economy.”

wards building an ‘Indo-European Research and Innovation Partnership’ by: improving the scale, scope and impact of cooperation actions, focussing on common societal challenges, and building on

£2.5 M Investment to Grow UK Space Technology Industry

Twenty-two British companies are to share £2.5 million of UK government support to enable them to develop commercial products and services using space technology or space-derived data. The grant funding – from the UK Space Agency, the Technology Strategy Board

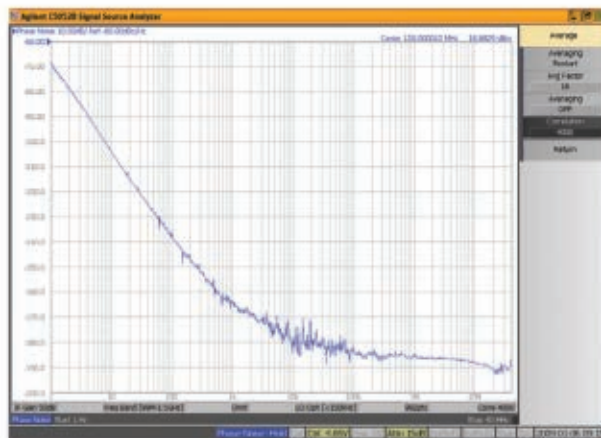
(TSB), and the South East England Development Agency (SEEDA) – will support fast-track research and development projects, each lasting between 6 and 9 months.

Fourteen of the twenty-two companies offered funding are small or medium sized enterprises (SME) while fifteen of them plan to use facilities available at the International Space Innovation Centre at Harwell and Guildford. The investment forms part of the UK Space Agency’s National Space Technology Programme (NSTP), which will see government investment of £10 million to help UK industry exploit growth opportunities in the space sector and improve the UK’s space technology capabilities.

The grant funding has been awarded following the companies’ success in the fast-track part of the ‘Space for Growth’ competition for collaborative R&D funding. The results of the other part of the competition, which will see grant funding of up to £2 million awarded to each of a small number of ‘flagship’ R&D projects, are likely to be announced in April 2012.

Dr. David Williams, chief executive of the UK Space Agency, said: “The UK space industry is one of the fastest growing sectors in the country, contributing £7.5 billion annually to the UK economy. The National Space Technology Programme will help us further this success by providing an opportunity for promising UK space technologies and applications to be developed to meet their full commercial potential and for businesses to explore collaborations with other sectors to establish services in new markets.”

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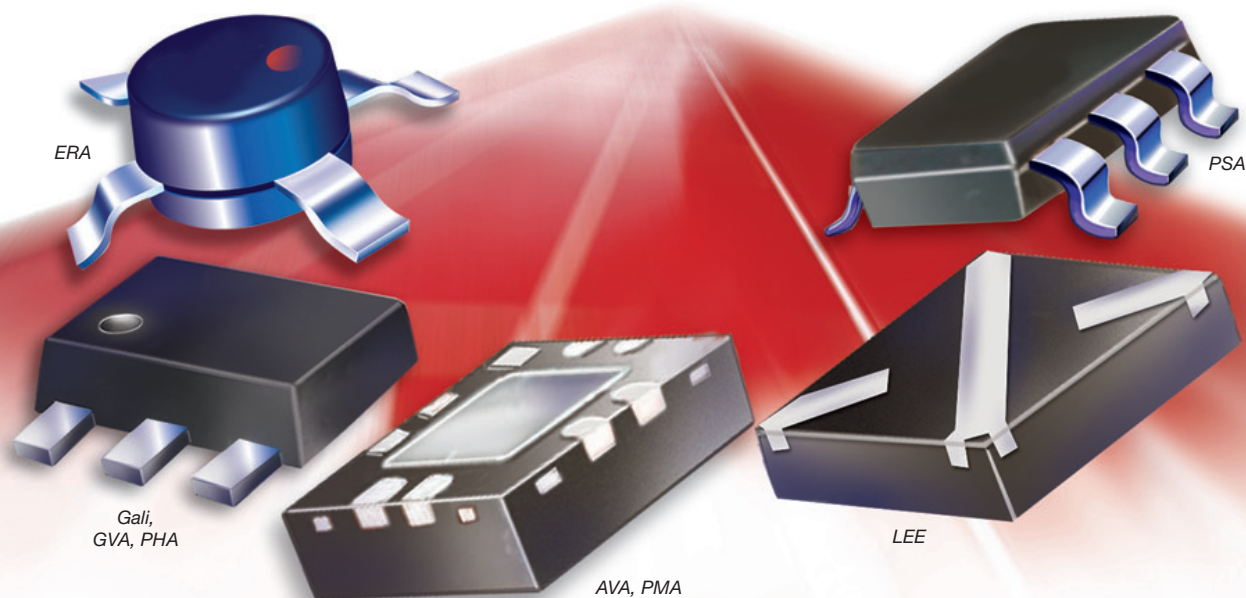
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Fast Growing Brazilian Operators Look Ahead to LTE Auctions

Brazil reached almost 250 million mobile connections by year-end 2011, according to Wireless intelligence data, accounting for over a third of total connections in the Americas region. It is now a larger market than Mexico, Argentina and Colombia combined. Brazilian connections grew almost 20 percent year-on-year, with all the market's major operators recording double-digit growth. 3G connections accounted for 17 percent of the Brazilian total at year-end, slightly ahead of the 15 percent regional average. Mobile penetration stands at 125 percent.

The market is led by Telefonica's Vivo, which had 72 million connections at the end of the year, giving it a 29 percent share, followed by Telecom Italia's TIM Brasil (64 million/26 percent), America Movil's Claro (60 million/25 percent) and Oi, the mobile arm of Brazil's fixed-line incumbent Telemar Norte Leste (45 million/18 percent). Although there are a number of smaller and regional operators in the market, these 'big four' account for 98 percent of the country's mobile subscriber base.

At Telefonica Group, the organic revenue contribution from its Latin American division increased by 5 percentage

...the organic revenue contribution from its Latin American division increased by 5 percentage points between Q3 2010 and Q3 2011...

points between Q3 2010 and Q3 2011, offsetting the declining contributions from its Spanish (-2.1pp) and European (-0.2pp) units. According to the operator, this was due in part to the "high rates of growth driven by a favorable economic context and acceleration in the adoption of new services" in Brazil. Tele-

fonica's Vivo added almost 3 million mobile net additions in Q3, up 72 percent year-on-year and 50 percent on the previous quarter. The operator has been pursuing the higher-value market segments and claims a 37 percent share of Brazil's contract-based mobile subscribers, and 43 percent in mobile broadband. This focus saw ARPU at Vivo rise 3 percent year-on-year to US\$13.21 in Q3.

The Brazilian regulator has been able to support growth in the market via several spectrum auctions in recent years. The most recent swathe – largely spectrum left over from previous tenders – was sold off in December 2011 and netted the government BRL 237.8 million (US \$132 million). TIM Brasil secured nine blocks of spectrum in the 1800 MHz band for BRL 109.3 million, with Oi acquiring four blocks in the same band for BRL 110.6 million. Sercomtel spent BRL 3 million on a single block of 1800 MHz spectrum, while Claro secured a block in the 800 MHz band for BRL 14.5 million.

Meanwhile, the government is gearing up to auction-off 4G-suitable spectrum later this year. Auctions for spectrum at 2.5 GHz (suitable for LTE) and 450 MHz are due to

begin this month, while 3.5 GHz fixed-wireless spectrum auctions are due to follow. Much sought-after 700 MHz spectrum could also be sold before year-end.

Semiconductor Industry Posts Revenues Despite 2011 Challenges

The Semiconductor Industry Association (SIA), representing U.S. leadership in semiconductor manufacturing and design, announced that worldwide semiconductor sales for 2011 reached a record \$299.5 billion, a year-on-year increase of 0.4 percent from the \$298.3 billion recorded in 2010. Worldwide semiconductor sales in December amounted to \$23.8 billion, a decrease of 5.5 percent from the month prior. Fourth quarter sales of \$71.5 billion represent a 7.7 percent decline from the immediate prior quarter and a 5.3 percent decrease over the same period in 2010. All monthly sales numbers represent a 3-month moving average.

"Between the natural disasters in Japan and Thailand and the overall impact of a weak global economy, 2011 presented a number of major challenges for the semiconductor industry. Despite these setbacks the industry showed resiliency and posted year-on-year growth with record-breaking revenues for 2011," said Brian Toohey, president, Semiconductor Industry Association. "The health of the industry is a direct reflection of the pervasiveness of semiconductor innovations and their applications in almost every aspect of modern society."

In 2011 the industry saw strong demand in several areas; specifically the optoelectronic, sensor and actuator and microprocessor markets showed solid year over year growth. Lamps and image sensors drove growth in the optoelectronic market to \$23.1 billion, a 6.4 percent increase over 2010. Optoelectronic applications bring energy efficiency and low cost in a wide range of products including mobile devices and cameras.

Sensors and actuators, currently the smallest semiconductor market segment, showed the highest year over year growth at 15.5 percent to \$8 billion in 2011. Sensor technology, which can be used to convert temperature, pressure or acceleration into electrical signals, is growing as an application in consumer electronics, medical devices and automotive systems to improve safety and efficiency. An area of continued growth for sensors is in the application of MEMS, or microelectromechanical systems, which are increasingly included in smartphones, tablets, digital cameras and numerous other consumer electronic products.

"Despite these setbacks the industry showed resiliency and posted year-on-year growth with record-breaking revenues for 2011."

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Commercial Market

In 2012 the industry is expected to experience further recovery, due to increased demand across a broad range of end market segments combined with the delayed sales impact from the supply chain disruptions in the second half of 2011. Additionally, several large semiconductor companies announced plans for new facilities and new R&D projects that will serve to fuel the industry's long-term growth expectations.

"This year our industry will invest billions in capital expenditures and in R&D, which will pay off both in the short and long term. In fact, reinvesting a large percentage of revenues is a hallmark of the industry. It is this combination of R&D investment, top engineering talent, high exports and cutting-edge advances, that have made the semiconductor industry a cornerstone of the innovation economy," continued Toohey.

Accessories Get Smarter as Smartphones Drive Revenues

Smartphones will drive \$20 billion in aftermarket accessory revenues in 2012, accounting for more than half of the \$36 billion that all aftermarket handset accessories will produce. By 2017, smartphone accessories will grow to \$38 billion in revenues, while feature phone accessory revenues decline to \$12 billion. "The increasing

penetration of smartphones is driving a more ubiquitous digital consumer who expects the data capabilities of the smartphone to be available in any device with which the smartphone interacts," says Michael Morgan, senior analyst, mobile devices.

Feature phone consumers will spend an average of \$28.17 on accessories per device, while smartphone owners will spend \$56.18 on accessories per device. The difference in spending is driven by a combination of consumers spending more per accessory and purchasing more accessories for smartphones as compared to feature phone owners.

Smart accessories do not represent a unique segment, but are the results of accessory OEMs adapting traditional accessory value propositions to a new data-centric usage paradigm. Consumers continue to use accessories as they always have, but increasing capabilities and expectations of consumers and their devices are changing the way accessories are designed. "To address this shift in consumer behavior, accessories must focus on delivering tighter integration with smartphone functionality and features offering a more intelligent accessory product or smart accessory," says Kevin Burden, vice president and practice director, mobile devices.

ABI Research's report, "Mobile Handset Accessories," focuses on key handset accessories and the market for these products, including in-depth analysis for both in-box as well as aftermarket handset accessories.

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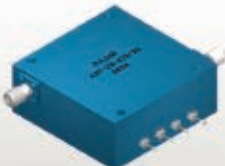
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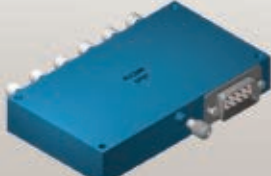
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AML056P4013	0.5 - 6.0	40	35	36	4	28V, 0.75A	22%	EAR99
AML056P4014	0.5 - 6.0	40	37	38	6	28V, 1.0A	20%	EAR99
AML056P4511	0.5 - 6.0	45	39	40	10	28V, 1.3A	25%	EAR99
AML056P4512	0.5 - 6.0	45	43	44	25	40V, 2.7A	23%	EAR99
AML13P5013	1.0 - 3.0	50	46	47	50	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

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INDUSTRY NEWS

Agilent Technologies Inc. announced that **Accelicon Technologies'** is now part of Agilent. The two companies had announced an acquisition agreement on December 1, 2011. Financial details were not disclosed. Agilent's newly acquired solutions from Accelicon include MBP for device-level extraction and model generation, MQA for device-level model validation and AMA for advanced model analysis, including layout effects. Accelicon was founded in 2002 by noted industry veteran Dr. Xisheng Zhang, who has now joined Agilent along with former Accelicon CEO Tim K. Smith. The majority of the former Accelicon employees are located in Beijing; they are also now part of Agilent.

Huawei has joined the **Wireless Gigabit (WiGig) Alliance** Board of Directors in a move that emphasizes the significant industry momentum now backing the world's most important short-range wireless standard. Huawei joins an impressive list of members representing the industry's top chipmakers and consumer electronics manufacturers from around the world. News of the increasing industry support comes on the heels of the WiGig Alliance's announcement in December that it has completed all necessary components to define the first ever multi-gigabit wireless docking specification. It has also recently hosted the first ever interoperability test event, and received ITU-R recognition.

Advantech Wireless, a Canadian-based manufacturer of Satellite, RF Equipment and Microwave equipment and **Smartrove**, the newest data offload company based in the silicon valley in the United States, have successfully deployed a large microwave network in the island of Bermuda. This alliance allows the Bermuda police department to reach the farthest corners of the island wirelessly and improve law and order by having a 24x7 video surveillance system operate over carrier grade equipment from Advantech Wireless and Smartrove.

Hesse & Knipps Inc. recently opened a West Coast Demo and Applications Laboratory to provide enhanced applications and field support to customers throughout the western region. The Hesse & Knipps Demo and Applications Lab is located at the company's manufacturer rep — Chalmers Technologies — in Anaheim, CA.

Qosmotec announced that it would support **Azimuth's** portfolio of real world test solutions with the Qosmotec Propagation Effects Replicator (QPER) software. With QPER, Azimuth's customers will have access to a powerful application that creates virtual environments, which can then be recreated with the dynamic RF fading capability available with the Azimuth ACE MX MIMO Channel Emulator. Azimuth's solutions include the ACE MX MIMO Channel Emulation platform, Azimuth's Field-to-Lab (FTL) Solution and Azimuth's RPM Real World Performance Measurement solution.

Maxim Integrated Products Inc. announced it has made a strategic investment in **Scintera Networks Inc.**, a leading provider of adaptive signal processing solutions for wireless communications. The partnership will enable rapid deployment of power-efficient small cell base stations with form factors and system cost points attractive to cellular infrastructure OEMs and network operators.

Anritsu Co. and **ETS-Lindgren** announced the Anritsu MT8820C RF Tester has been selected by ETS-Lindgren as an approved test solution for 2G to 4G/LTE/MIMO Over-the-Air (OTA) testing. As part of the selection, support for the MT8820C has been integrated into the CTIA-compliant ETS-Lindgren EMQuest™ EMQ-100 Antenna Measurement Software. Currently available to user equipment (UE) developers and manufacturers, it is an accurate and flexible turnkey solution to characterize and validate designs in accordance with industry standards.

Giga-tronics announced that it has successfully renewed its AS9100 certification, an upgrade of its ISO 9001 Quality Management System. Giga-tronics is now certified as fully capable to be a provider of products and services that meet the most stringent aerospace and defense industry quality system requirements.

TriQuint Semiconductor Inc. announced that its Foundry Services division is supporting start-up **Sarda Technologies** to bring a new line of high-efficiency DC-DC converter switches to the global marketplace. Sarda, a 'cleantech' company based in Durham, North Carolina (USA), plans to offer cost-saving solutions for increasing efficiency and reducing component size in smartphones, mobile PCs and similar applications.

Skyworks Solutions announced that it is ramping global positioning system (GPS) and global navigation satellite system (GNSS) solutions for **Samsung Electronics Co. Ltd.** The company's newest devices, which integrate a low-noise amplifier with filtering specifically designed for GPS/GNSS receiver applications, deliver industry-leading performance and are the smallest solutions in the market requiring no external components, allowing manufacturers an easy "plug and play" option.

CONTRACTS

Kratos Defense & Security Solutions Inc. announced that the **U.S. Air Force (USAF) Space and Missile Systems Center (SMC)** has awarded its **Integral Systems** subsidiary a \$15.69 million extension to its Command and Control System-Consolidated (CCS-C) contract. Under the terms of the contract extension Integral Systems will continue to provide the USAF and SMC with its EPOCH Integrated Product Suite to simplify operations by consolidating satellite ground systems.



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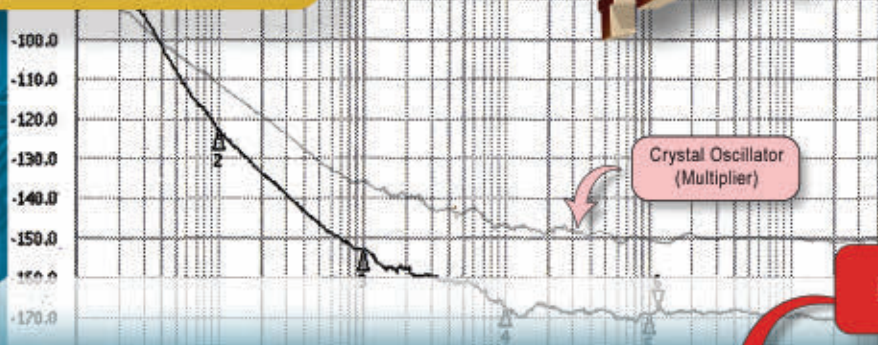
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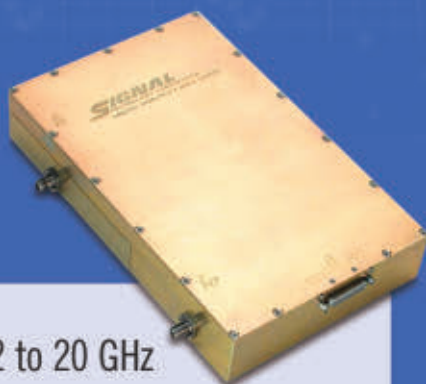
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Around the Circuit

ASC Signal Corp. has been awarded a \$1 million contract for the first three phases to build up to 100, 3.7 meter, X-Band antenna systems to support global government communications. These fixed, tracking antennas will communicate with the U.S. Department of Defense's Wideband Global Satcom constellation in the X-Band frequency. The WGS high-capacity satellite system is deployed across the Pacific, Indian and Atlantic Ocean regions and supports many military and government platforms.

NuWaves Engineering has been awarded a contract to design and manufacture prototype high efficiency switching power amplifiers for Earth Radar Observation Systems (HESPEROS) by NASA, as part of the government agency's efforts to pursue smaller and more affordable spacecraft. HESPEROS applies several innovative techniques to increase the efficiency and operational bandwidth of RF power amplifiers (PA) targeted for radar applications.

Auriga Microwave announced that it has received two Small Business Innovative Research Phase I contracts. The company earned its second Air Force SBIR (Air Force AF112-150 20 GHz Radiation Hardened Solid State Power Amplifier for Satellite Communications Downlinks) and first NASA SBIR (NASA O1.05 High-power X- and Ka-Band Gallium Nitride Amplifiers with Exceptional Efficiency).

PERSONNEL

Microwave Journal announces the hiring of staff editor **Laura Casasanto**. Prior to this role, Casasanto spent five years writing and editing SAP-focused content at Wellesley Information Services. She has a bachelor's degree in English Writing/Communications and Rhetoric from the University of Massachusetts Dartmouth and lives in Waltham, MA. Casasanto is replacing Kerri Germani and will be handling PR submissions. You can reach her via email at lcasanto@mwjournal.com.



▲ Jeffrey Grudzien

Rogers Corp. announced the appointment of **Jeffrey Grudzien** as vice president of its Advanced Circuit Materials Division, replacing Michael Bessette, who is retiring after 37 years with the company. Grudzien joined Rogers in 2000 and has served as vice president of global sales & marketing for the past four years. Previously he served as director of Asia sales, corporate director of marketing, and marketing director for the High Performance Foams division of Rogers Corp. In his new role, Grudzien will be responsible for managing the performance, strategic direction and growth of Rogers' Advanced Circuit Materials business, and guiding the division's commercial and technology development of next gen high frequency materials.

AR RF/Microwave Instrumentation announced the appointment of **Joseph J. Diesso** to the position of vice president Marketing. Jim Maginn, president of AR/RF Microwave Instrumentation states that with his new promotion, Diesso will be putting additional focus on new

RFMD.

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APPLICATIONS

- Broadcast
- General purpose broadband amplifiers
- Cellular wireless infrastructure
- High power radars
- Public mobile radio
- Aerospace & Defense
- Industrial/scientific/medical

FEATURES

- High power density > 6W/mm
- Advanced 0.5µm GaN HEMT process
- 48V bias operation
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Unmatched Power Transistors

Freq Range (GHz)	P3dB at 900MHz (W)	Linear Gain at 900MHz (dB)	Drain Eff. at 900MHz (%)	P3dB at 2.1GHz (W)	Linear Gain at 2.1GHz (dB)	Drain Eff. at 2.1GHz (%)	V _D (V)	I _{DD} (mA)	Package	Part Number
DC to 3.5	50	20	65	45	14	65	48	130	Ceramic 360 Bolt Down	RF3931
DC to 3.5	76	21	68	74	14	66	48	220	Ceramic 360 Bolt Down	RF3932
DC to 3.5	90	21	75	90	13.5	65	48	300	Ceramic 360 Bolt Down	RF3933
DC to 3.5	145	21	75	140	13	60	48	440	Ceramic 360 Bolt Down	RF3934

Note: Also available in die form



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Around the Circuit



▲ Joseph J. Diesso

product development and forming strategic business alliances. Diesso joined AR in April 2010 as marketing manager and has over 30 years of experience in the marketing and sales of RF/microwave devices, components and assemblies. He held the positions of vice president of business development and vice president of programs during his employment with Stellex Electronics before joining AR.



▲ Fred Gilligan

Massachusetts Bay Technologies

named **Fred Gilligan** as director of engineering. Gilligan has been recognized as a leader in the RF/microwave industry and has a proven track record in improving processes and product design. His background includes being the former VP of Operations at Micrometrics and VP of Engineering at Aeroflex-Metelics. Gilligan is engaged with all facets of the business and with over 40 years of diode manufacturing experience, brings a wealth of knowledge to every aspect of business operations.

Constant Wave Inc. announced that **Anthony Peccolo** and **Stephen Witt**, two electronics industry executives, have joined the company. Peccolo brings to Constant Wave extensive experience in the test and measurement industry and specific expertise focused on marketing and sales. Peccolo joins Constant Wave from Agilent Technologies where he was a North American sales manager of a team responsible for successfully generating more than \$200 million in revenue annually. Witt joins Constant Wave with extensive leadership experience and vast knowledge in the test and measurement industry.

RF Micro Devices Inc. announced the retirement of **Bob Van Buskirk**, corporate vice president of RFMD's Compound Semiconductor Group (CSG). Bob Van Buskirk has been a member of the RFMD executive staff since 2007. He joined RFMD with the acquisition of Sirenza Microdevices, where he had been president and CEO. He led the integration of Sirenza and was instrumental in the formation of CSG and RFMD's Multi-Market Products Group (MPG).

REP APPOINTMENTS

MegaPhase announced that **Cain-Sweet Co.** and **Protea Electronics** have been added to the MegaPhase Sales Team. Cain-Sweet Co. will bring over 27 years of comprehensive technical background in products and solutions that include RF/microwave components to support the Wireless Communications and Aerospace Markets.

Modelithics Inc. announced its partnership with **SJ Technology Ltd.** for sales and service representation for the United Kingdom. Modelithics' CEO, and the managing director for SJ Technologies, John Kitchen, have signed a comprehensive agreement designed to fully support Modelithics in the United Kingdom markets for RF and microwave simulation models as well as custom and special order microwave characterization and modeling services.



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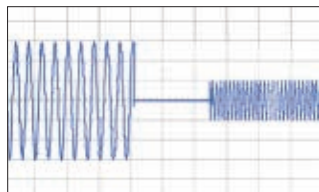
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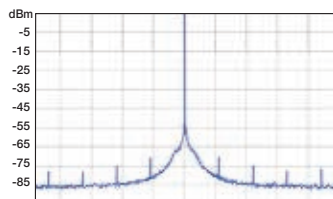
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IF/RF MICROWAVE COMPONENTS

Being Seventy-Five Still Young: The Doherty Power Amplifier

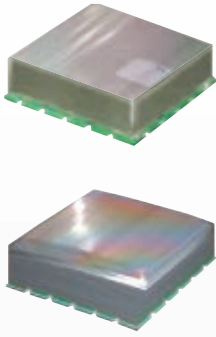
In this article, the evolution of the Doherty Power Amplifier (DPA) through its first seventy-five years is presented. The aim is to explain why this architecture is still used to realize very advanced power amplifier stages for wireless systems. To this purpose, a review of the DPA principle of operation, together with a benchmark of the state of the art results, realization methods and fields of application, is reported.

The idea behind the power amplifier architecture, which nowadays is identified as the Doherty Power Amplifier (DPA), was proposed to the world by W.H. Doherty many decades ago. The original paper, entitled “A New High Efficiency Power Amplifier for Modulated Waves” was published in September 1936.¹ Thus, the DPA has just celebrated its first seventy-five years of age.

The last sentence of that old paper was: “The new amplifier is believed to offer a most logical and practical solution to the problem of efficient operation of high power transmitters.” The prediction expressed by W.H. Doherty with these few words came true. In fact, even though actual systems are extremely different with respect to the first broadcasting transmitters, in terms of active device technologies, required power levels and adopted modulation schemes, the DPA seems to remain the best candidate to realize power amplifiers (PA) for modern and future generations of wireless systems.

In fact, the increasing complexity of modulation schemes, used to achieve higher and higher data rates, creates the need for PAs able to manage signals with a large time-varying envelope. The resulting peak-to-average power ratio (PAPR) of the involved signals critically affects the average efficiency achievable with traditional PAs. As schematically reported in **Figure 1**, such high values of PAPR imply a large back-off operating condition, dramatically reducing the average efficiency levels attained by using traditional PA solutions. In order to stress this effect, it is useful to refer to an ideal Class B PA, delivering an efficiency of 78.6 percent at its maximum output power, while only 25 percent at 10 dB of back-off. Therefore, when dealing with an amplitude modulated signal, it is more practical to refer

R. GIOFRÈ, L. PIAZZON,
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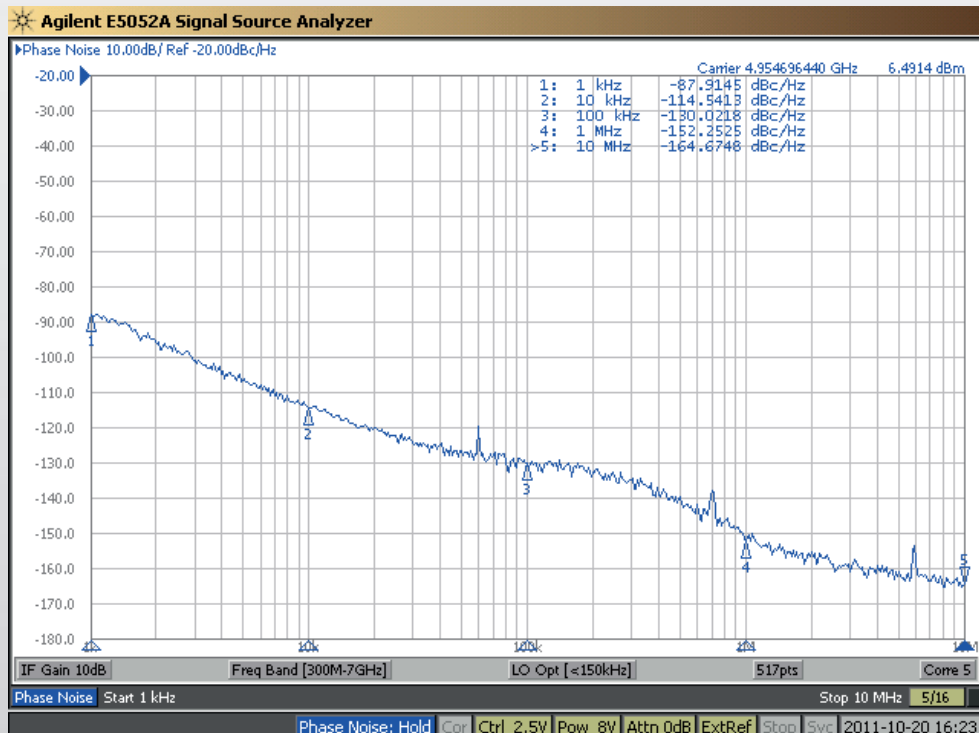
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DTA1-1860A	1-18	10	-80
DTA1-1870A		100	-70
DTA1-1880A		1000	-80
DTA182660A	18-26	10	-80
DTA182670A		100	-70
DTA182680A		1000	-80
DTA264060A	26-40	10	-80
DTA264070A		100	-70
DTA264080A		1000	-80
DTA184060A	18-40	10	-80
DTA184070A		100	-70
DTA184080A		1000	-80

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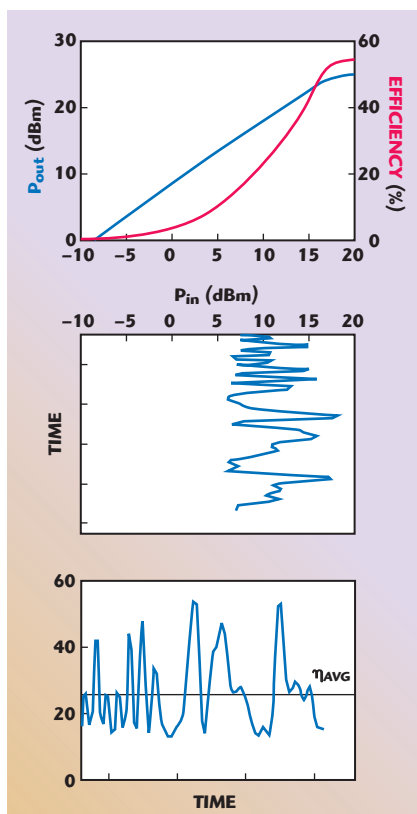
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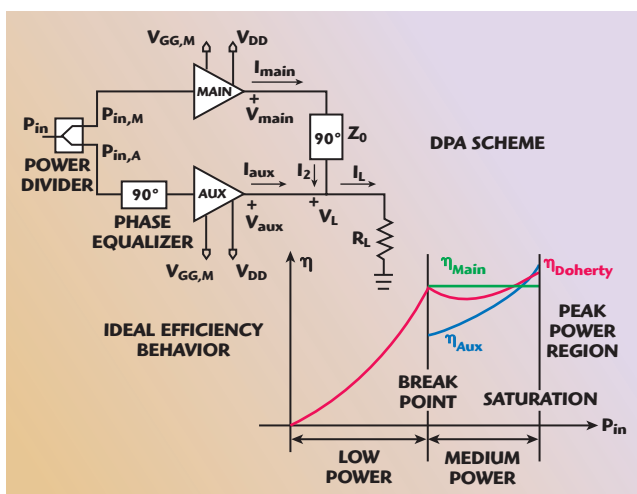
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Special Report

to the average efficiency, which is defined as the ratio of the average output power to the average supply DC power. Clearly the average efficiency depends on both the PA instantaneous efficiency and the probability density function (PDF) of the signal. Therefore, to obtain high average efficiency when time-varying envelope signals are used, the PA should work at the highest efficiency level in a wide range of its output power.



▲ Fig. 1 Average efficiency using traditional PA.



▲ Fig. 2 Typical DPA efficiency behavior vs. output power.

This kind of requirement represents the main feature of the DPA architecture, whose theoretical efficiency behavior is shown in **Figure 2**. The region with almost constant efficiency identifies the DPA output back-off (OBO) range, and it is usually fixed according to the PAPR of the signal to be amplified.

DPA APPROACHES

A typical DPA is composed of two active devices, namely main and auxiliary, an impedance inverter network (IIN), a phase compensation network (PCN) and an uneven input power splitter (IPS). The DPA is based on the idea to modulate the load of the main device, in order to force it to operate at its maximum efficiency condition for a pre-determined range of input power levels. Such an action is performed by exploiting the active load concept, by using the auxiliary device and exploiting the IIN properties. According to this solution, a suitable current supplied by the auxiliary amplifier in the output load dynamically modulates the load seen by the main device coherently with the input power levels.

In the first DPA implementation,¹ both devices were biased in Class B condition (hereafter referred to as B-B DPA). However, the B-B configuration implies the critical issue to maintain the auxiliary off along the entire low-power region, which solution was left to "one of the many practical solutions," as indicated in the original Doherty paper. Consequently, it becomes mandatory to complicate the hardware implementation using

a switching circuitry to control the on-off auxiliary condition. In order to avoid such criticisms, a proper Class C bias condition for the auxiliary device has been adopted. However, in this case, the input power splitter dimensioning becomes a further critical design key aspect.²¹

Finally, a pure Class B bias condition for the main de-

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SSHPS 1.2-1.4-4000	1200-1400 MHz	200 Watts	4000 Watts	0.7 dB	60 dB	1.6:1	4 μ sec	4.5 x 3.5 x 1.0 inches
SSHPS 2.7-2.9-1000	2.7-2.9 GHz	100 Watts	1000 Watts	0.8 dB	40 dB	1.7:1	4 μ sec	3.5 x 3.5 x 1.0 inches
SSHPS 2.9-3.1-1000	2.9-3.1 GHz	100 Watts	1000 Watts	0.8 dB	40 dB	1.8:1	4 μ sec	3.5 x 3.5 x 1.0 inches
SSHPS 2.7-3.5-1000	2.7-3.5 GHz	50 Watts	1000 Watts	0.9 dB	40 dB	2.0:1	4 μ sec	3.5 x 3.5 x 1.0 inches
SSHPS 0.020-1.000-200	20-1000 MHz	200 Watts	1500 Watts	0.7 dB	25 dB	2.0:1	5 μ sec	3.0 x 3.0 x 1.0 inches
SSHPS 0.225-0.450-400	225-450 MHz	400 Watts	2000 Watts	0.7 dB	40 dB	2.0:1	5 μ sec	3.0 x 3.0 x 1.0 inches
SSHPS 1.0-2.5-200	1000-2500 MHz	200 Watts	1000 Watts	0.9 dB	25 dB	1.5:1	4 μ sec	4.0 x 6.0 x 1.3 inches

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- Higher Power Levels
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SSHPS 1.03-1.09-5000 Typical Data

- Operation from 1030-1090 MHz
- Peak Power Handling of 5000 Watts
- Insertion Loss = 0.4 dB nominal
- Isolation = 58 dB typical
- Operation into an Infinite VSWR
- -40C to +70C Operation
- Internal BIT
- < 5 μ Sec Switching Speed
- Return Loss, All Ports = -14 dB nominal
- 4.5" wide x 3.5" long x 1.0" high
- All switches High Power Tested & ESS Screened



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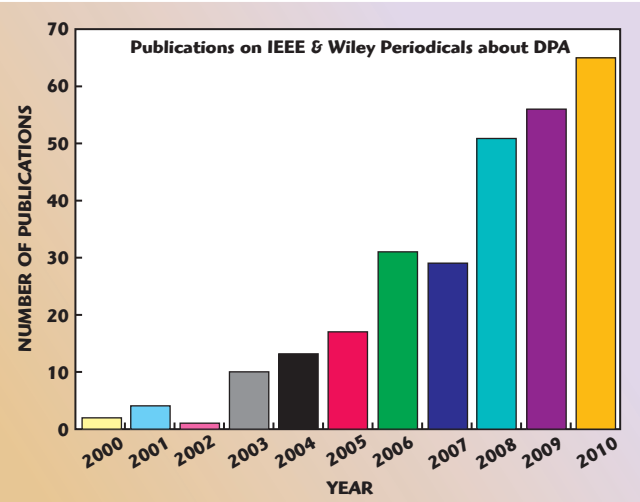


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▲ Fig. 3 DPA publications vs. years.

vice does not seem to be advisable, due to the large cross-over distortion. To avoid this further drawback, a Class AB bias condition for the main device is preferred, resulting in a small reduction of the efficiency as compared to a pure Class B, but with a significant improvement in the overall linearity.

Nowadays, the actual DPAs employ Class AB (Main) and Class C (auxiliary) bias conditions (hereafter referred to as AB-C DPA). Consequently, the characteristics and values of each DPA elements have to be carefully dimensioned and designed since they are strictly related to each other.

Thanks to the huge work done by the scientific community, several innovations regarding the DPA have been introduced and validated, mostly devoted to finding advanced design methodologies to increase the achievable DPA performances. As an example, the existing theoretical gap between the B-B DPA and the AB-C DPA has been filled.¹⁶ In this article, the role of each elements used in a typical DPA architecture and how they have to be di-

TABLE I						
SELECTION OF PAPERS FROM DATABASE EXTRACT						
ID	Freq. (GHz)	Pout@ sat (dBm)	η@sat (%)	Gain (dB)	Technology	MMIC/Hybrid
[2]	7	38	46	7	GaN	M
[3]	10	30	47	6,5	GaAs	M
[4]	20	23	32	8	GaAs	M
[5]	2,1	38	76	10	GaN	H
[6]	2,5	54	63	11	GaN	H
[7]	2,14	43	47	11	GaN	H
[8]	2,14	39	51	6	GaN	H
[9]	2,5	47	54	10	GaN	H
[10]	1,9	27	65	12	GaAs	H
[11]	2,14	34,7	54	3,5	GaN	H
[12]	2,14	35	54,7	4	GaN	H
[13]	9,6	31	48	6	GaAs	M
[14]	2,14	37	58	9	GaN	H
[15]	3,5	51	37	7,5	GaN	H
[16]	2,14	36	70	7,5	GaN	H
[17]	2,6	52,5	65,6	15	GaN	H
[18]	5,5	31	30	8,4	SiGe	H
[19]	1,3	35	50	11	GaAs	H
[20]	2,1	47	45	10,5	AlGaN/GaN	M

mensioned, considering their mutual dependence, has been highlighted and clarified.

BENCHMARK OF THE STATE OF THE ART

Figure 3 shows the number of scientific papers focused on the DPA architecture over the years, from 2000 to 2010. From it, it is possible to have an idea on the increasing attention to the DPA architecture in the last few years. In fact,



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NV2640P10M	26.5-40	10	5-19	-105	-15	2.5	700	WR-28
NV3350P10M	33-50	10	4-16	-103	-15	2.5	700	WR-22
NV4060P10M	40-60	15	5-19	-102	-15	2.5	900	WR-19
NV5075P10M	50-75	15	4-15	-99	-15	3	900	WR-15
NV6090P0M	60-90	0	5-19	-98	-15	6	850	WR-12
NV75110P10M	75-110	10	4-13	-96	-15	4.5	1200	WR-10

*Values are Typical

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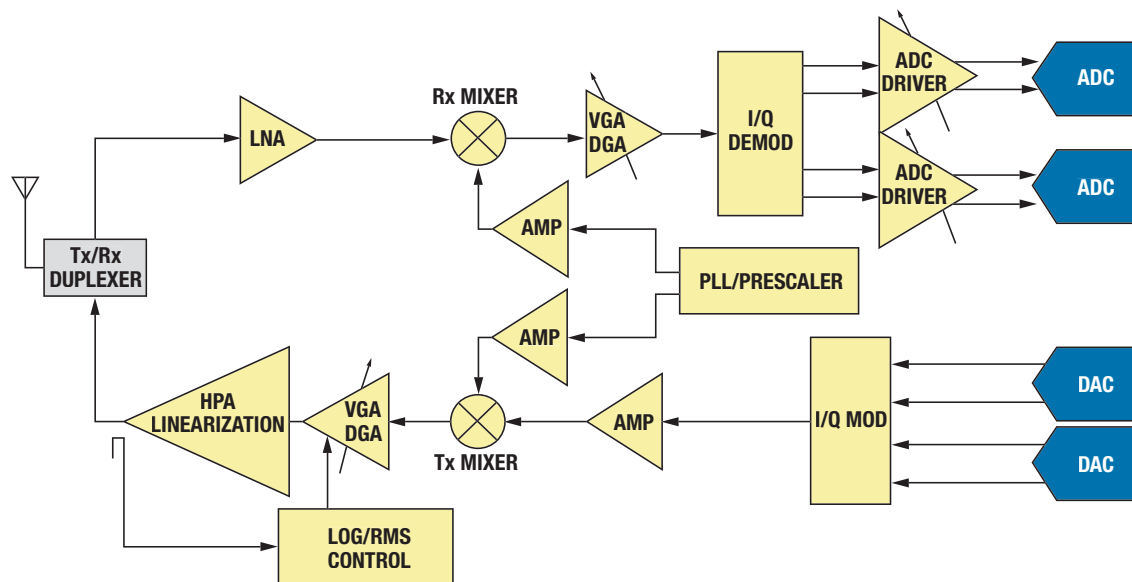


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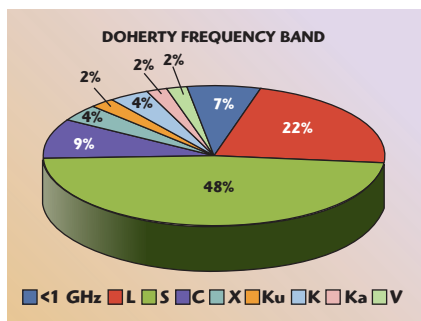
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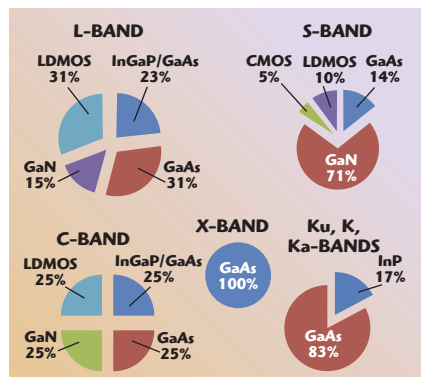


Design resources

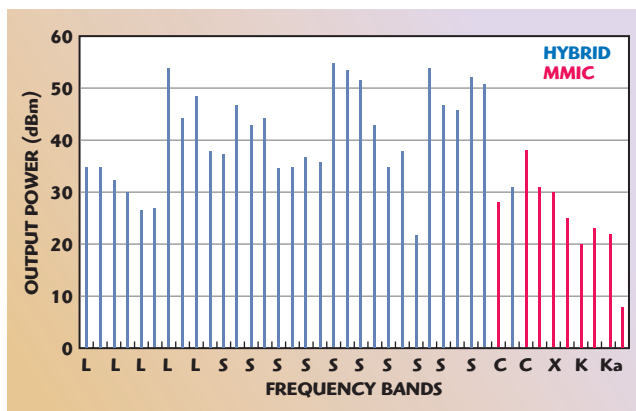
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▲ Fig. 4 Frequency applications for DPAs.



▲ Fig. 5 Active device technologies for DPAs.



▲ Fig. 6 Hybrid vs. MMIC DPA realizations.

in 2000, only a few papers have been published on DPA, while in 2010, 65 scientific papers have been published by journals edited by IEEE and Wiley.

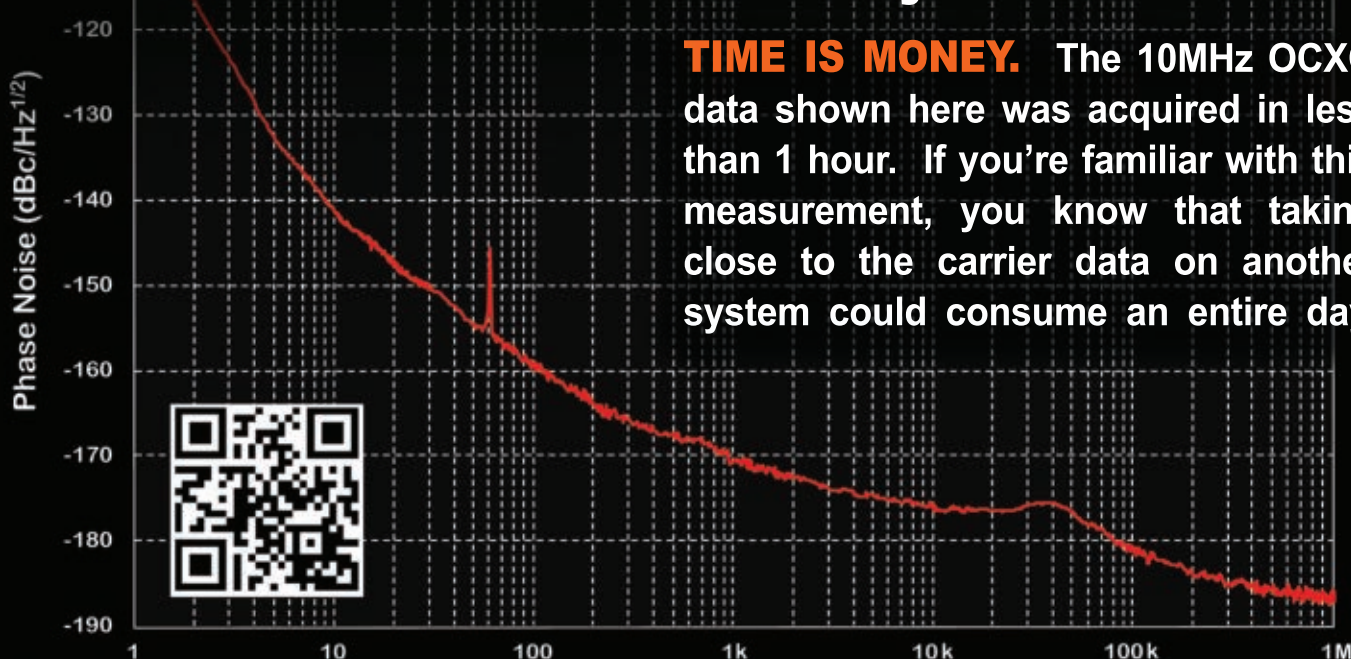
In order to benchmark the DPA architecture, an extensive database with more than 50 scientific papers has been created. However, to avoid exceeding the article maximum length, it was possible to report only a selection²⁻²⁰ (see **Table 1**). From the collected data, it is evident that the DPA architecture is usually adopted in

telecommunication systems for both handsets and base station terminals. In particular, it is frequently employed in UMTS and WiMAX systems and, with minor rate, in WiFi, WLAN, WiBro and LTE applications. This observation is also confirmed by **Figure 4**, where the numbers of realizations found in literature are classified as a function of their frequency band. As can be noted, almost 50 percent of DPA realizations are in S-Band (2 to 4 GHz), where the most important wireless systems are located.

Figure 5 shows the active device technologies used to design DPAs for each frequency band. As can be observed, in S-Band, almost the totality of DPAs is realized using GaN technology and, as will be highlighted later, in hybrid form. In fact, thanks to

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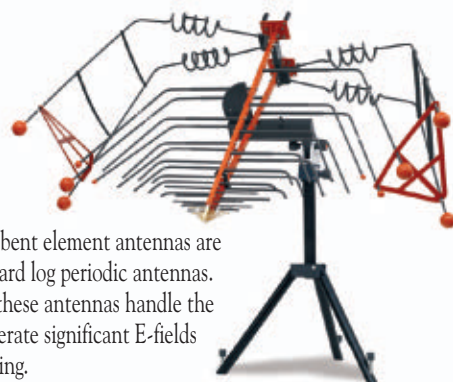
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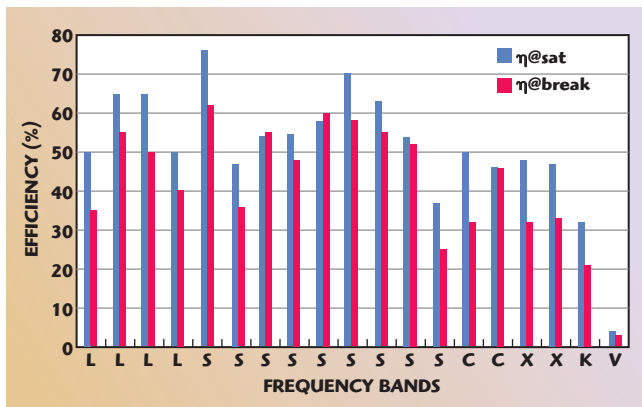
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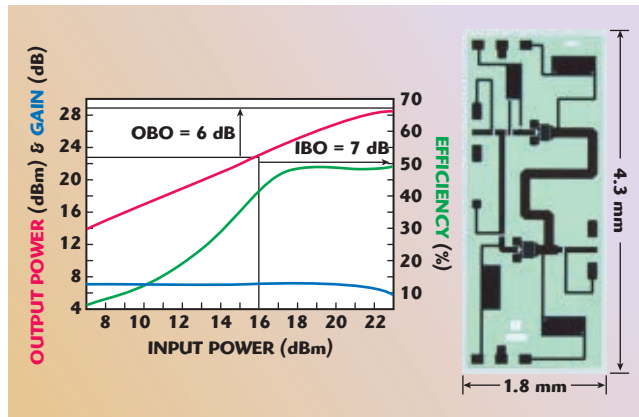


▲ Fig. 7 Efficiency levels of DPA realizations.

the high power capability of GaN devices and the fast prototyping offered by the hybrid structure, it is much easier to reach high power level together with a simpler circuit layout.

Figure 6 shows the output power levels achieved by DPAs realizations as a function of frequency bands, while distinguishing between MMIC and hybrid forms. As stated before, the hybrid form is almost always used up to S-Band while, for upper frequencies, MMIC technology is preferred. Moreover, a considerable number of realizations achieved output power levels higher than 50 dBm.

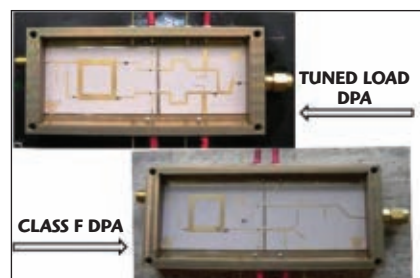
Considering the key feature of a DPA, **Figure 7** shows the achieved efficiency levels corresponding to both satu-



▲ Fig. 8 MMIC DPA for X-Band application.

ration and break point conditions, as a function of frequency bands. It is important to emphasize that the break point represents the power level at which the auxiliary amplifier is turned on.

Typically, and for all the realizations reported, the break point is located



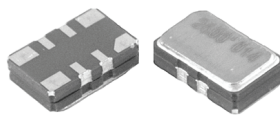
▲ Fig. 9 S-Band hybrid DPAs using GaN technology.

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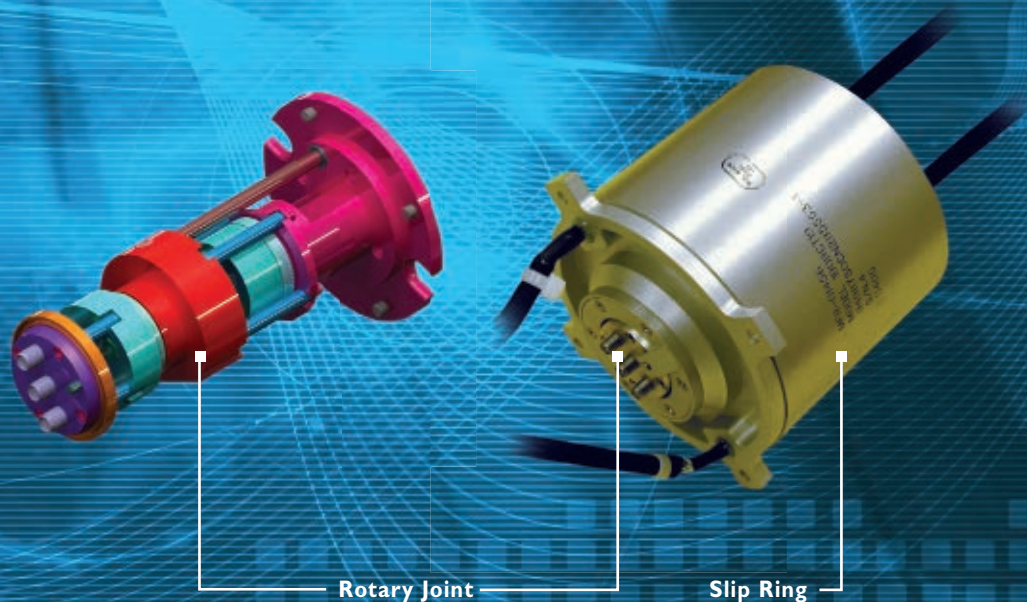
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at 6 dB of OBO. As can be noted, with respect to a traditional single ended PA, the DPA architecture assures high efficiency also in back-off, that is a fundamental characteristic for systems that deal with time varying envelope signals.

As an example of MMIC DPA, **Figure 8** shows a photo and the corresponding experimental results of a GaAs MMIC DPA realized for X-Band application. Analogously, **Figure 9**

shows the photos of two DPAs for S-Band applications, using GaN technology realized in hybrid form. The first DPA has been designed assuring a tuned load harmonic configuration for both main and auxiliary devices.¹⁶ For the other one, with the aim to further increase the efficiency level achieved by the DPA at the break point, a Class F harmonic configuration has been adopted for the main device.¹² Regarding the design of the auxiliary

amplifier, also in this case, a TL configuration has still been considered to optimize its performance. In fact, due to the Class C biasing condition, the adoption of other different HT strategies (including the Class F one) would result in a detrimental effect for the auxiliary device performance.¹² Both are designed using a GaN HEMT (1 mm of gate periphery) as the active device to operate at 2.14 GHz, assuring an almost constant efficiency over the usual OBO range of 6 dB.

A comparison of the obtained experimental results from the two DPAs is shown in **Figure 10**. As can be noted, the expected (roughly) 15 percent improvement in output power and drain efficiency, when using a Class F configuration with respect to its TL counterpart, has been experimentally demonstrated.¹² On the other hand, one of the main drawbacks of the DPA architecture is related to its intrinsic lower power gain, with respect to the nominal value assured by the main amplifier alone. **Figure 11** shows the gain level achieved by the realizations included in our database as a function of frequency bands.

As can be noted, few realizations have a gain higher than 15 dB, despite the low frequency band and the use of active devices with high available gain levels. Typically, the realizations with higher gain include a driver to increase this feature, with a consequent



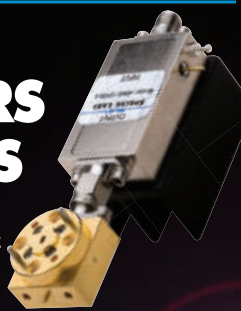
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Low-Noise Amplifiers						
RF Freq (GHz)	N. F. (dB)	Gain (dB)(min/typ)	P-1dB (dBm)(min/typ)	VSWR in/out(yp)	Bias mA/VDC	Model
2 - 20	2.5 max	28/30	+10/+12	3:1/1.5:1	175 mA/+8 to 12	SL1118-30-2
18 - 30	2.5 typ/3.4 max	30/32	+12	2.2:1/2:1	145 mA/+8 to 12	SL2412-30-3
26.5 - 40	2.4 typ/3 max	30/37	-10	2:1	175mA/+8 to 12	SLKa-30-3
33 - 50	3.5 typ/4 max	15/18-20	-3	2.5:1	50 mA/+8 to 12	SLQ-15-4W
50 - 75	4 typ/5 max	15/18	-5	3:1	50 mA/+8 to 11	SLV-20-4
75 - 110	4.5 typ/5.5 max	15/18	-10	2.5:1	50 mA/+8 to 11	SLW-15-5

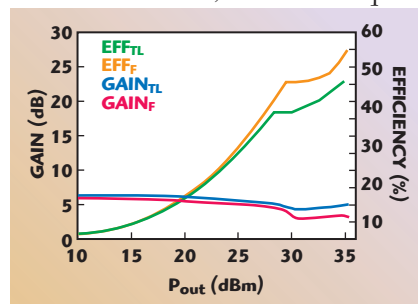
Power Amplifiers						
RF Freq (GHz)	P-1dB (dBm) (typ)	Gain (dB) (min)	VSWR in/out (typ)	Bias mA/VDC	Model	
13 - 18	+37/36 min	35/37 typ	2:1 max	2850 mA/+10	SP155-35-37	
20.2 - 21.2	+32	43	2:1	1520 mA/+9 to 12	SP211-43-33W	
25 - 30	+34/33 min	20/23 typ	3:1/2:1	2400 mA/+9 to 10	SP285-20-33	
26.5 - 40	+29	30/32 typ	2:1 max	2400 mA/+8 to 12	SPKa-32-29	
39 - 44	+31/29 min	26/33 typ	2:1	2200 mA/+9 to 12	SP435-33-31	
50 - 66	+17	40/45 typ	2:1	500 mA/+8 to 12	SP5816-28-20W	
77 - 82	+14	15/18 typ	3:1	150 mA/+10	SP805-15-10	
92 - 96	+19/18 min	28/30 typ	3:1/2.5:1	750 mA/+8 to 11	SP944-30-23	
75 - 110	+14 Psat	15 typ	3:1	250 mA/+8 to 12	SPW-15-14	

Active Multipliers						
RF Freq Input (GHz)	Input Pwr (dBm)	RF Freq Output (GHz)	Output Pwr min/typ (dBm)	Spur/Har (dBc) max	Bias mA/VDC	Model
13.5 - 20	+17	26.5 - 40	+23/+25	-15	1050 mA/+8 to 12	AKa-2XW-23
8.25 - 12.5	+12 - 18	33 - 50	+15/+18	-15	550 mA/+7 to 15	AQ-4X-18
10 - 15	+17	40 - 60	+4/+8	-15	400 mA/+8 to 12	AU-4XW
10 - 15	+15	60 - 90	+3/+5	-15	300 mA/+8 to 12	AE-6XW
7.66 - 8	+12 - 15	92 - 96	+13	-15	450 mA/+8 to 12	A944-12XW-10

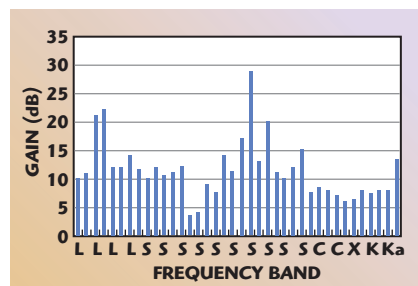


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▲ Fig. 10 F-DPA and TL-DPA performance.



▲ Fig. 11 Gain levels of DPA realizations.

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reduction of the overall efficiency level. Generally speaking, while comparing the DPA gain with the one achievable through a standard PA, designed by using the same active devices, a drop of about 4 to 6 dB is observed. This decrease can be ascribed to both the Class C bias condition of the auxiliary amplifier and the uneven input power splitter. The former is needed to assure the automatic turning on condition at the break point, while

the latter is necessary to guarantee the correct dynamic evolution, from the break point to saturation.²¹

In terms of efficiency, this effect could be a problem when, for instance, the DPA has to be integrated in a transmitter chain. In fact, in those cases, a driver stage could be necessary to assure the requested gain level. These driver stages are usually designed to operate as linear systems, so their efficiency is typically

very low. Therefore, the efficiency of the overall chain is similar to the one of the DPA if, and only if, its gain is very high. For this reason, in high frequency applications, where the active devices for power applications usually have an available gain lower than 15 dB, a gain drop of about 4 to 6 dB for the power stage becomes unacceptable. For practical uses, new ideas to overcome the gain problem are under investigation. For instance, it has been demonstrated that the adoption of different drain bias voltages for the main and auxiliary device could be useful to increase the gain of the overall DPA.⁷ In this case, to demonstrate the reliability of the proposed design methodology, two different DPAs have been designed: one with the same bias voltages for main and auxiliary devices (DPA1), and a second one (DPA2) that uses different drain bias voltages according to the guidelines derived previously.⁷

For the design, an LDMOS device, provided by Freescale Semiconductor, has been used and the operating frequency of 2.14 GHz has been assumed. **Figure 12** shows the comparison between the performance obtained from both prototypes. As can be noted, both DPAs reach the same saturated output power level (43 dBm), with a quite similar efficiency behavior. However, it can be noted that an increase of roughly 2 dB in power gain has been obtained with DPA2. For both DPAs, the efficiency is higher than 40 percent with an OBO of 6 dB.

Another drawback of the standard DPA architecture becomes evident when the PAPR of the signal to be amplified is larger than 8 to 9 dB. In fact, referring to **Figure 13** where the efficiency behaviors of DPAs with different OBOs are plotted; in the case of OBO = 12 dB, the achievable average efficiency



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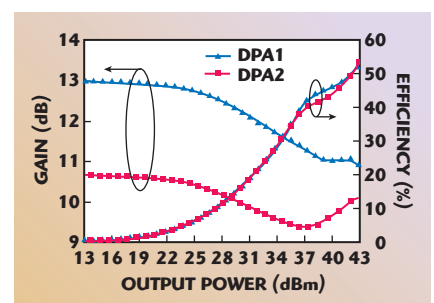




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▲ Fig. 12 F-DPA and TL-DPA performance.

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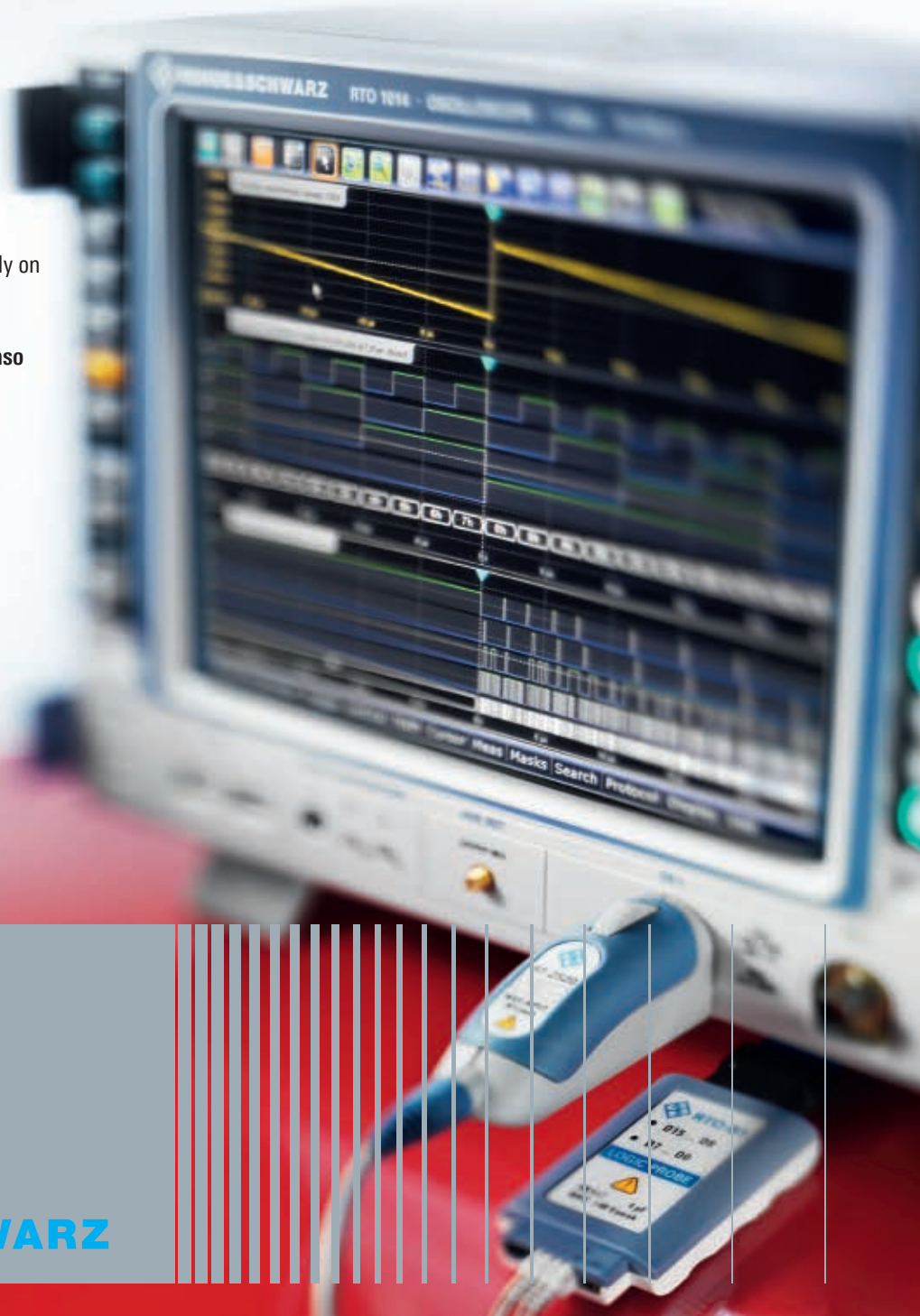
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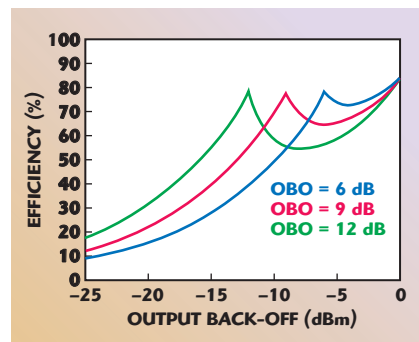


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is dramatically reduced. Therefore, new solutions to overcome this further drawback are also under study, as the multi-stage or n-stage, sometimes also named multi-way DPA.²²

Finally, looking at the DPA topology, it is possible to note that it is intrinsically based on many narrow band components, like the IIN, the IPS and the PCN. This aspect restricts the DPA potentialities as the best solution for power stage in modern com-

munication systems. In fact, one of the goals of the new systems is to simultaneously operate with more communication standards (such as UMTS, WiMAX, WiFi, etc.). Since each standard has its frequency band, transmitters with multi-band frequency capability become mandatory. Thus, ideas to alleviate such weakness are needed. A possible solution has been reported⁸ where the design of a dual-band DPA is demonstrated.



▲ Fig. 13 Efficiency behavior of DPAs with different OBO.

CONCLUSION

In this article, the evolution of the DPA through its first seventy-five years has been presented. The reasons why this architecture is still popular to realize power amplifier stages for wireless systems have been highlighted. A review of the DPA principle of operation, together with a benchmark of state of the art realization methods and fields of application has been reported. ■

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ZHL-5W-1	5-500	44	+39.5	+40.5	4.0	+49	25	3.3	995	970	
ZHL-5W-2G+	800-2000	45	+37.0	+38.0	8.0	+44	24	2.0	995	945	
ZHL-10W-2G	800-2000	43	+40.0	+41.0	7.0	+50	24	5.0	1295	1220	
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• ZHL-20W-13+	20-1000	50	+41.0	+43.0	3.5	+50	24	2.8	1395	1320	
ZHL-30W-252+	700-2500	50	+44.0	+46.0	5.5	+52	28	6.3	2995	2920	
ZHL-30W-262+	2300-2550	50	+43.0	+45.0	7.0	+50	28	4.3	1995	1920	
• ZHL-50W-52	50-500	50	+46.0	+48.0	6.0	+55	24	9.3	1395	1320	
• ZHL-100W-52	50-500	50	+47.0	+48.5	6.5	+57	24	10.5	1995	1920	
• ZHL-100W-GAN+	20-500	42	+49.0	+50.0	7.0	+60	30	9.5	2395	2320	
ZVE-3W-183+	5900-18000	35	+34.0	+35.0	5.5	+44	15	2.2	1295	1220	
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Compact Microstrip Lowpass Filter with Wide Stopband and High Attenuation

A compact microstrip lowpass filter using radial stub resonators is developed. This filter is composed of two radial stub resonators that are asymmetrically connected to each other by a stepped impedance structure. This structure results in a very high rejection and wide stopband. The proposed filter with a 3 dB cutoff frequency of 2.07 GHz has been designed, fabricated and measured. Measurement and simulation results are in good agreement.

Microstrip lowpass filters with compact size and high performance find many applications in communication systems for suppressing unwanted signals. These filters appear in various shapes such as a shunt open-stub at the feed point of the center fed coupled-line hairpin resonator, which is used to design a compact lowpass filter with very wide stopband¹ and stepped impedance hairpin resonators² that present wide stopband and high selectivity. A filter has been proposed using a stepped impedance resonator with the assistance of open stubs and short-end coupled lines.³ The stopband characteristics of this filter have improved but it has low selectivity. Another shape is used to obtain compact size and low insertion loss, utilizing a symmetrically loaded radial shape.⁴ A novel compact Koch shaped electromagnetic bandgap microstrip lowpass filter with wide stopband has been presented.⁵

Radial stubs have been used to achieve a wide stopband operation and deep rejection through zero point generation.⁶ Both symmetrically loaded resonant patches and meander transmission lines have been used to achieve

compact size and wide stopband.⁷ The design of a lowpass filter is based on a defected ground structure and stepped impedance shunt stubs⁸ for suppressing harmonics. A multisection lowpass filter is presented⁹ where each section is composed of a transmission line and an interdigital capacitor. It has been demonstrated that the passband performance of a microstrip stepped-impedance lowpass filter can be improved by constructing the low impedance sections with fractal shapes, such as Koch and Sierpinski fractal shapes,¹⁰ but the transition band of this structure is not sharp. Because of the short comings of the mentioned structures, in this article, a lowpass filter, using radial stub resonators that are asymmetrically connected through a stepped impedance structure, is presented that improves the width and attenuation of the stopband.

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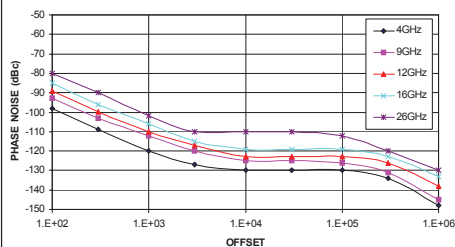
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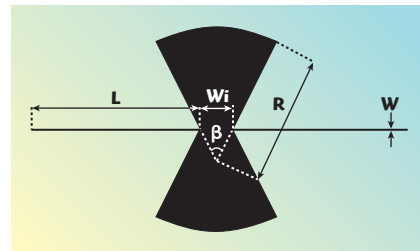
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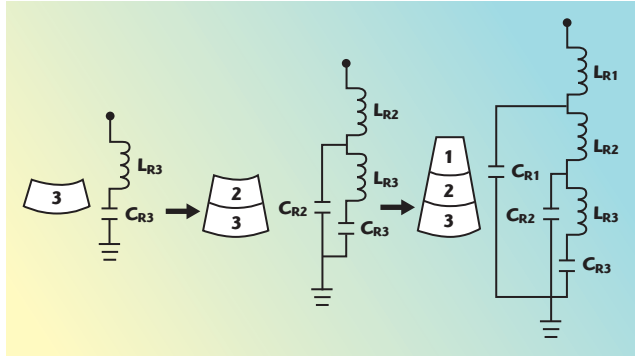
Technical Feature

DESIGN OF THE PROPOSED FILTER STRUCTURE

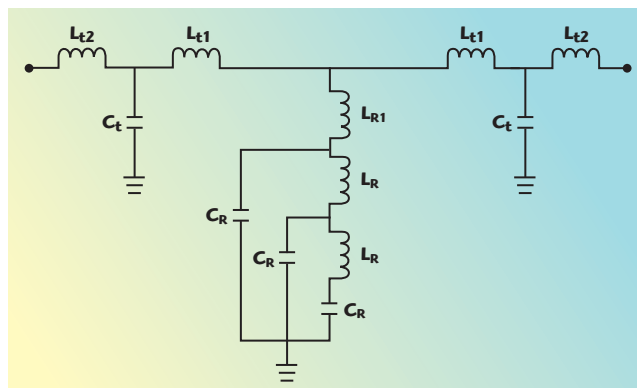
The layout of the proposed resonator is shown in **Figure 1**. This resonator is composed of a transmission line loaded with radial stubs. The dimensions of the resonator are $L = 7.65$ mm, $W = 0.1$ mm, $R = 4.7$ mm, $W_i = 1.6$ mm and $\beta = 54^\circ$. **Figure 2** represents a new LC model for a radial stub. This



▲ Fig. 1 Layout of the proposed resonator.



▲ Fig. 2 LC equivalent circuit of the radial stub.

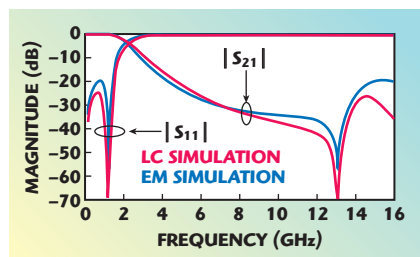


▲ Fig. 3 LC equivalent circuit of the proposed resonator.

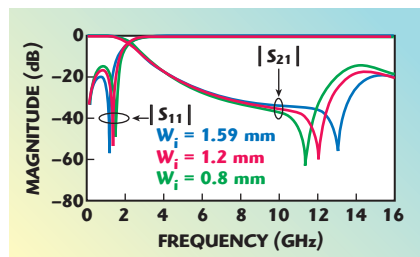
model is achieved by considering each radial stub to be made of three smaller radial stubs that are connected to each other, thus by modeling each small stub and then connecting these models to each other, the final model is obtained. The LC model of the radial stub resonator is shown in **Figure 3**. In this model, the central transmission line is described by L_{t1} and L_{t2} as series inductance and C_t as body capacitance, while $L_{R1} - L_{R3}$ and C_R represent the inductances and capacitances of the radial stub, respectively.

Figure 4 shows the EM and circuit simulation results of the proposed resonator. The value of the circuit elements that are used in the circuit simulation are: $L_{t1} = L_{t2} = 2.2$ nH, $L_R = L_{R1} = 37$ pH and $C_R = 0.8$ pF. These values are calculated by choosing proper initial values and then using tuning techniques in order to match the circuit and EM simulated results. As seen, the circuit and EM simulation results are in good agreement especially at the cut-off frequency. The differences of the responses in the higher frequencies are mostly because of the approximations in the modeling of transmission lines by LC elements and assuming them lossless.

After introducing the resonator, the effect of dimension variations on the response of the resonator is studied using the LC equivalent circuit to evaluate the importance of each part.



▲ Fig. 4 EM and circuit simulation of the proposed resonator.



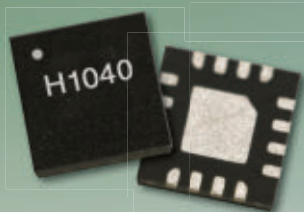
▲ Fig. 5 EM simulation of the proposed resonator as a function of W_i .

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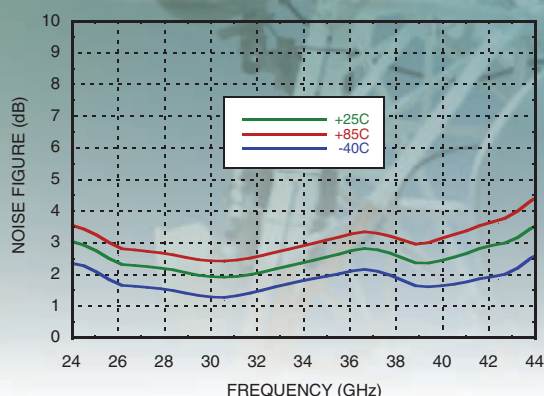
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6 - 17	Low Noise	18	25	1.7	14	+3.5V @ 80mA	LP3	HMC903LP3E
6 - 26.5	Low Noise	22	18	2.5	10	+3.5V @ 45mA	LC4	HMC963LC4
7 - 14	Low Noise	17	25	1.8	13	+3V @ 51mA	LC4	HMC564LC4
7.5 - 26.5	Low Noise	13	23	2.5	13	+3.5V @ 70mA	LC4	HMC962LC4
17 - 27	Low Noise	25	25	2.2	13	+4V @ 73mA	LC4	HMC751LC4
18 - 31	Low Noise	15	23	3.5	11	+3V @ 75mA	LC4	HMC519LC4
24 - 28	Low Noise	25	26	2.5	13	+3V @ 70mA	LC4	HMC752LC4 [1]
NEW! 24 - 43.5	Low Noise	22	25	2.5	15	+3V @ 70mA	LP3C	HMC1040LP3CE
28 - 36	Low Noise	21	24	2.8	12	+3V @ 82mA	LP4	HMC566LP4E
35 - 45	Low Noise	16	-	2	6	+4V @ 87mA	Chip	HMC-ALH376
57 - 65	Low Noise	21	-	4	12	+2.5V @ 64mA	Chip	HMC-ALH382 [1]
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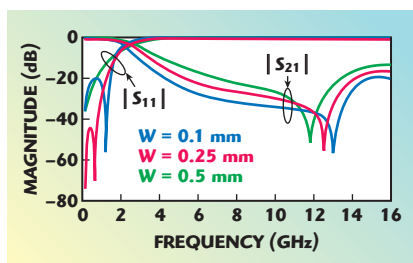
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Technical Feature

TABLE I VARIATION OF LC ELEMENTS AS A FUNCTION OF W_i , W AND R FOR THE PROPOSED RESONATOR						
Dimension (mm)	L_{R1} (nH)	L_R (nH)	C_R (pF)	L_{t1} (nH)	L_{t2} (nH)	C_t (pF)
$W_i = 1.59$	0.037	0.037	0.8	2.2	2.2	0.109
$W_i = 1.2$	0.041	0.041	0.77	2.6	2.6	0.109
$W_i = 0.8$	0.052	0.052	0.75	2.8	2.8	0.109
$W = 0.1$	0.037	0.037	0.8	2.2	2.2	0.109
$W = 0.25$	0.43	0.037	0.8	1.6	1.6	0.15
$W = 0.5$	0.051	0.037	0.8	1.3	1.3	0.18
$R = 4.7$	0.037	0.037	0.8	2.2	2.2	0.109
$R = 5.7$	0.053	0.053	0.97	2.2	2.2	0.109
$R = 6.7$	0.07	0.07	1.12	2.2	2.2	0.109

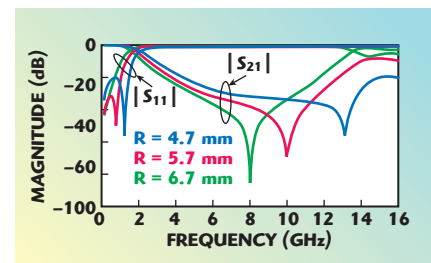


▲ Fig. 6 EM simulation of the proposed filter as a function of W .

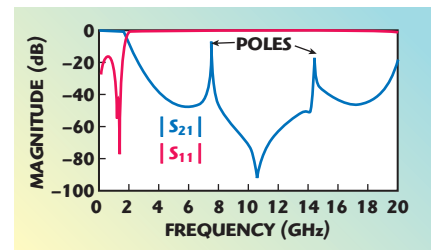
The first dimension to be studied is W . **Figure 5** shows the simulated results of the resonator as a function of W_i . From this figure, it is obvious that by decreasing the value of W_i from 1.59 to 0.8 mm, the transmission zero moves to lower frequencies. This is because this reduction causes an increase in the series inductance of the radial stubs, but decreases the value of the capacitance with respect to ground, according to the area reduction. **Table 1** shows the variation of LC parameters as a function of resonator dimensions.

From the table, it can be seen that the overall increase in the value of inductances overcomes the capacitance reduction and as a result, the transmission zero gets smaller. It should be mentioned that in each row of the table, only one of the resonator dimensions is going to be studied and the value of other dimensions are the same as values that were mentioned before.

The second effective dimension is W . Simulated results of the resonator as a function of W are shown in **Figure 6**. These results illustrate that increasing the value of W reduces the frequency of transmission zero and decreases the insertion loss in the stopband because the series induc-



▲ Fig. 7 EM simulation of the proposed filter as a function of R .



▲ Fig. 8 Response of two connected resonators.

tance of the transmission line (L_{t1} and L_{t2}) is reduced and the value of L_{R1} is increased according to the enhanced distance between the radial stubs. Values of the inductances and capacitances are presented in the middle rows of Table 1.

The third important dimension is R , which when increased, reduces the frequency of the transmission zero because this increases the values of both capacitance and inductance of the radial stubs as seen in the three last rows of the Table 1. Simulated results of the resonator as a function of R are presented in **Figure 7** and as seen, these results are as expected.

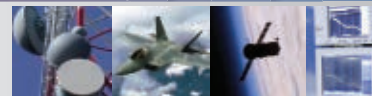
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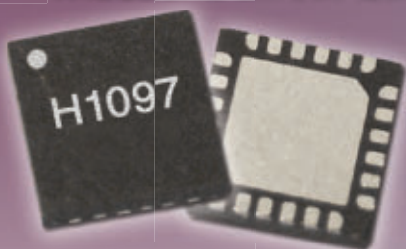
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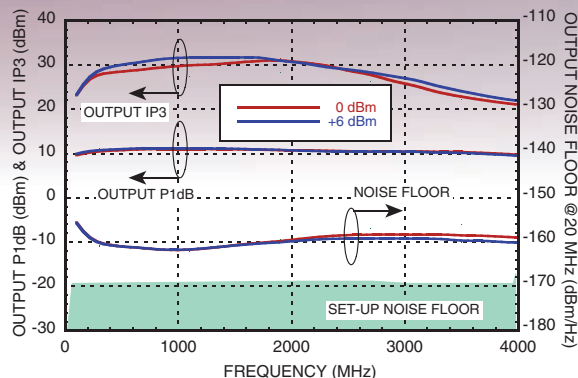
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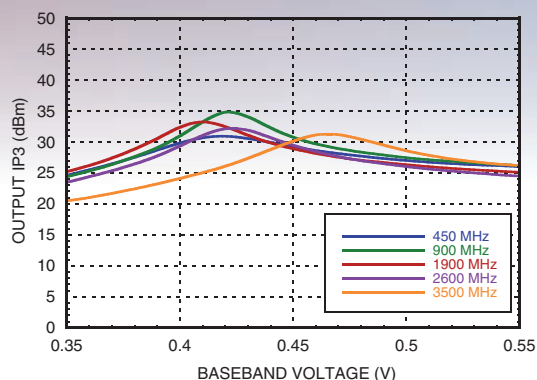
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0.05 - 2.7	Direct Quadrature with VGA	25 / 50	DC - 440	-159	+5V @ 120mA	HMC795LP5E
0.1 - 4.0	Direct Quadrature	23 / 42	DC - 700	-159	+5V @ 170mA	HMC497LP4E
NEW! 0.1 - 6.0	Direct Quadrature	30 / 40	DC - 700	-160	+5V @ 170mA	HMC1097LP4E
0.25 - 3.8	Direct Quadrature	14 / 38	DC - 250	-158	+3.3V @ 108mA	HMC495LP3E
0.45 - 4.0	Direct Quadrature	22 / 43	DC - 700	-165	+5V @ 168mA	HMC697LP4E
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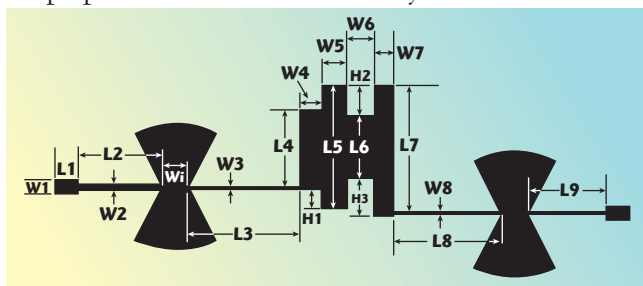
make the roll-off sharper, two units of the proposed resonator can be directly

connected to each other; but this causes two harmonics at 7.46 and 14.41 GHz, which are shown in **Figure 8**.

To solve this problem, the resonators are connected asymmetrically through a stepped impedance cell. This cell is a modified version of an H-shaped, stepped

impedance resonator that is tuned to present a wide suppressing range. The layout and photograph of this structure are shown in **Figures 9** and **10**, respectively. This method doubles the selectivity of the former geometry and suppresses the unwanted harmonics.

The correlative dimensions of the proposed filter are: $W_1 = 1.15$ mm, $W_2 = 0.45$ mm, $W_3 = W_8 = 0.1$ mm, $W_4 = W_7 = 1.17$ mm, $W_5 = W_6 = 2$ mm, $W_i = 1.6$ mm, $L_1 = 2$ mm, $L_2 = 6.8$ mm, $L_3 = 9$ mm, $L_4 = 6.33$ mm, $L_5 = 10$ mm, $L_6 = 5$ mm, $L_7 = 10.66$ mm, $L_8 = 8.7$ mm, $L_9 = 6.5$ mm, $H_1 = 1.8$ mm, $H_2 = 2.5$ mm, $H_3 = 3$ mm.



▲ Fig. 9 Filter layout.

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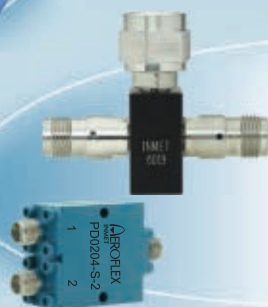
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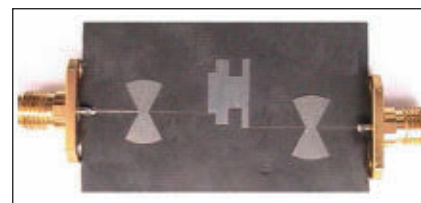
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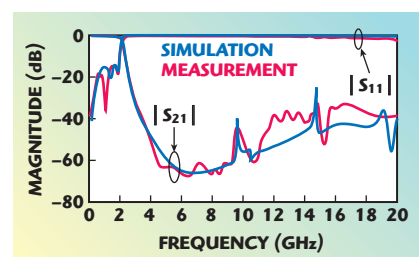
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SIMULATION AND MEASUREMENT

The simulation was accomplished using the EM-simulator (ADS) and the measurements were performed using the Agilent network analyzer N5230A. **Figure 11** shows the simulated and measured results of the filter. As seen, the 3 dB cutoff frequency occurs at 2.07 GHz and a reject-band is achieved from 2.67 up to 20.52 GHz with -24 dB attenuation. The advantage of the proposed filter over the conventional structures can be obtained through the comparison of the bandwidths. The values of improvement are 125, 80, 145, 80, 160, 30, 28 and 260 percent compared to the filters of references 2 to 5 and references 7 to 10, respectively. The attenuation from 3.39 to 14.58 GHz is more than -40 dB, which guarantees the high rejection operation. The insertion loss has a maximum value of



▲ Fig. 10 Photograph of the fabricated filter.



▲ Fig. 11 Simulated and measured results for the proposed filter.

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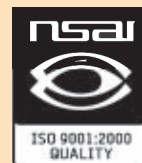
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0.2 dB from DC to 1.9 GHz, which indicates a very good passband performance and is better than most of the conventional structures. The return loss is better than 14.6 dB in the passband and is close to 0 dB in the stopband. The transition band is from 2.07 to 2.54 GHz with -3 to -20.12 dB, which is sharper than the filters of references 3 to 5, 7, 8 and 10, with improvements of 50, 25, 53, 40, 3 and 60 percent, respectively. The size of the proposed filter is 44.53 by 15.42 mm.

CONCLUSION

A compact microstrip lowpass filter is designed, fabricated and measured. The proposed structure is composed of two radial stub resonators and a stepped impedance cell. Simulation and measurement results indicate that the demonstrated filter achieves good performance in terms of high attenuation, very wide stopband and low insertion loss in the passband. This filter has also an acceptable selectivity. ■

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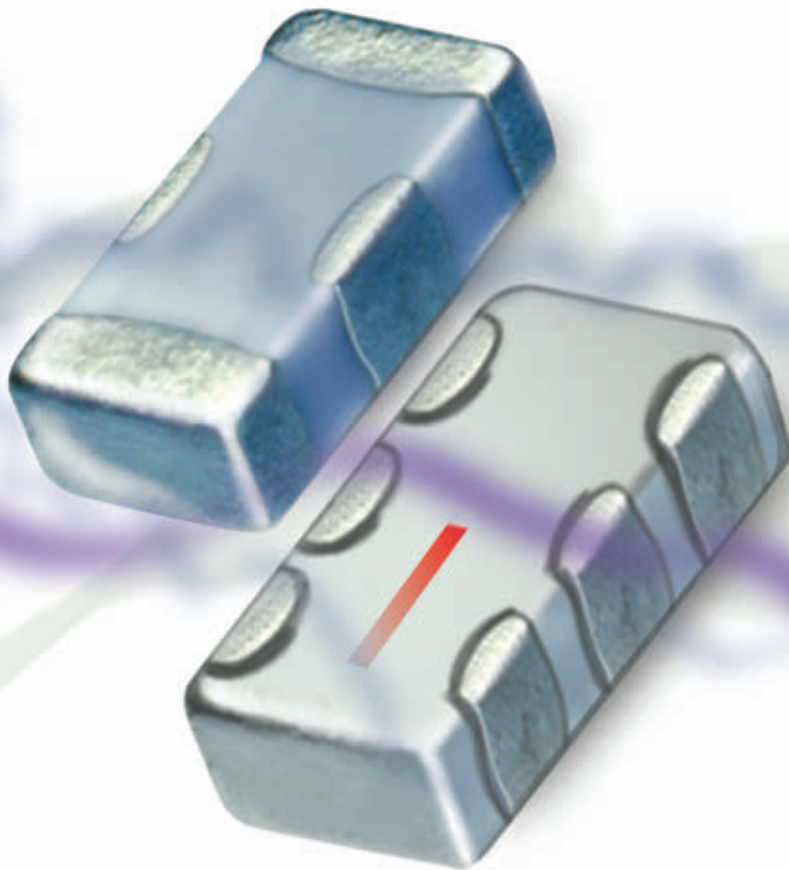
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A miniaturized, integrated broadband surface acoustic wave (SAW) antenna with a size of 8.4×6.8 mm is designed on a 0.5 mm thick, 128° -rotated Y-cut lithium niobate (LiNbO_3) piezoelectric substrate. The antenna is constructed using four cross-coupled half-wavelength square open-loop strips and two $16 \mu\text{m}$ width interdigital transducers (IDT) of 42 pairs. Photolithography and evaporation techniques are used to realize the designed pattern. The proposed antenna has a -10 dB bandwidth of 2.2 GHz (4.8 to 7 GHz) for WLAN/WiMAX bands applications. The gain and far-field radiation patterns of the proposed antenna are also developed in this study.

Broadband antennas have aroused high interest in recent years for application to multimode wireless communication systems. Because of low cost and process simplicity, printed monopole antennas are very popular candidates for these applications. One of the major challenges is the design of terminal antennas that are compact in size but have a wide impedance matched band. Many kinds of broadband antennas have been studied.¹⁻³ Most printed circuit boards (PCB), made of FR-4 which has a relative permittivity of approximately 4.4, could not be used to fabricate antennas with smaller sizes, and they could be difficult to integrate in radio frequency/microwave circuitry. SAW devices have been

widely fabricated and played an important role in wireless communication systems^{4,5} because the SAW devices had the advantages of low manufacturing cost, miniaturization, light-weight, easy realization, easy integration and better isolation between the radiating element and feeding network. The proposed broadband SAW antenna can be easily integrated with other circuit components to form a complete system. Details of the antenna design and performances are presented.

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AUM1001G-DTOK-3R5MBW	0.1 - 1.0	2.0	-	1.0	10	3.5MHz	-60	-20
DTG-0R5G2G-CD-1	0.5 - 2.0	2.5	0.1	2.0	10	DC - 9MHz	-60	-20
DTG-0R5G2R5G-CD-1	0.5 - 2.5	2.5	0.1	2.0	10	DC - 9MHz	-60	-20
DTG-2G6G-CD-1	2.0 - 6.0	2.0	0.1	2.5	+2 to +8	DC - 14MHz	-65	-45
DTG-6G18G-CD-1	6.0 - 18.0	2.5	0.1	4.0	10	DC - 10MHz	-60	-55
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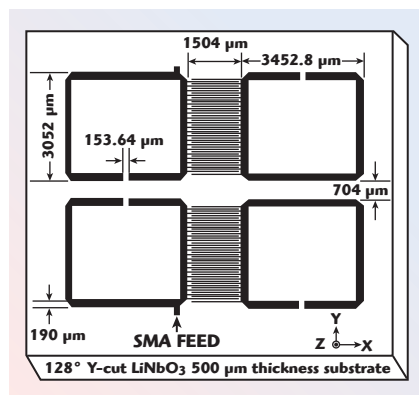
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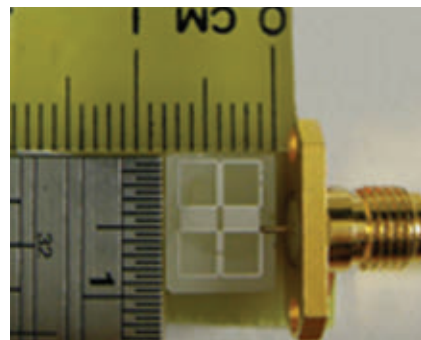


▲ Fig. 1 Geometry of the proposed SAW broadband antenna.

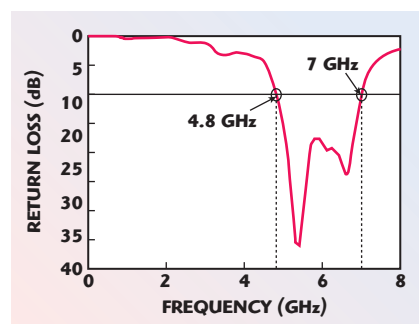
ANTENNA STRUCTURE AND DESIGN

Figure 1 shows the geometry of the proposed SAW broadband antenna for WLAN/WiMAX bands applications. This antenna is fabricated on a 128°-rotated Y-cut lithium niobate (LiNbO_3) piezoelectric substrate, with a thickness of 0.5 mm. A 50 Ω SMA connector was welded as the input. As shown, this antenna is composed of two parts, which are four cross-coupled half-wavelength square open-loop strips and two 16 μm width interdigital transducers (IDT) of 42 pairs. The IDTs consist of interleaved metal electrodes, which are used to launch and receive the waves, so that an electrical signal is converted to an acoustic wave and then back to an electrical signal. The IDTs not only are the lumped capacitors, but play the role of transducers. The half-wavelength square open-loop strip determines the resonant frequencies.

When the LiNbO_3 piezoelectric substrate is used to fabricate the microwave devices, Aluminum (Al) can be used to print the needed patterns of designed electrodes. The printed method did not need to use a FeCl_3 solution to etch the Cu plate from the surfaces of PCBs. Another important reason for us to use the photolithographic technology was that it was easy for mass production and integration. As the parameters showed, the designed antennas had a small size of 8.4×6.8 mm, which was much smaller than the monopole antennas fabricated on an FR4 substrate. The photograph of the fabricated SAW antenna under the optimal parameters is shown in **Figure 2**. Finally, the characteristics of fabricated antennas were



▲ Fig. 2 Photograph of the proposed SAW broadband antenna.



▲ Fig. 3 Measured return loss for the proposed SAW broadband antenna.

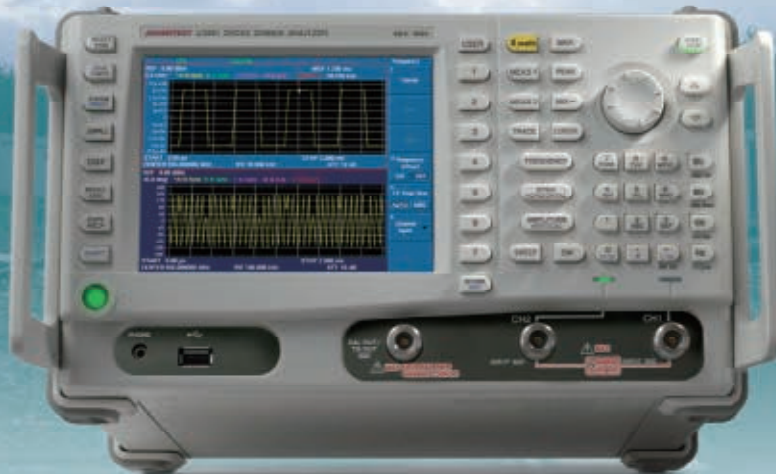
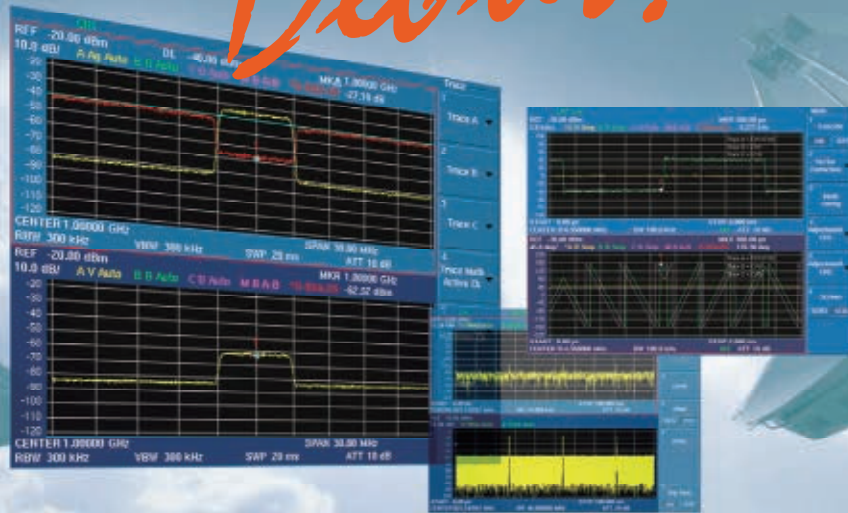
measured using a vector network analyzer and a far-field measurement system.

RESULTS AND DISCUSSIONS

The measurement of return losses is carried out with an HP8720C network analyzer. **Figure 3** shows the measured return losses of the proposed broadband SAW antenna. The -10 dB bandwidth for the measured return losses reaches 2.2 GHz (4.8 to 7 GHz), and can cover the 5.15 to 5.35 GHz and 5.725 to 5.825 GHz WLAN bands, as well as the 5.25 to 5.85 GHz WiMAX bands. The measured far-field radiation patterns of the integrated broadband SAW antenna in x-y, x-z and y-z plane at 5.4 and 6.6 GHz are depicted in **Figure 4**. The patterns are observed to be stable for operation at the two operating frequencies. In the xz-plane, the patterns are all nearly omni-directional, and in the xy-plane, as expected, are all very monopole-like.

Figure 5 shows the measured antenna gain. The antenna gain varies from approximately -11 to -7 dBi for frequencies over the entire band. According to S. Masaaki's **Figure 4**,⁶ the result shows that when the electrical length of the antenna is reduced, the antenna gain is also reduced. Although

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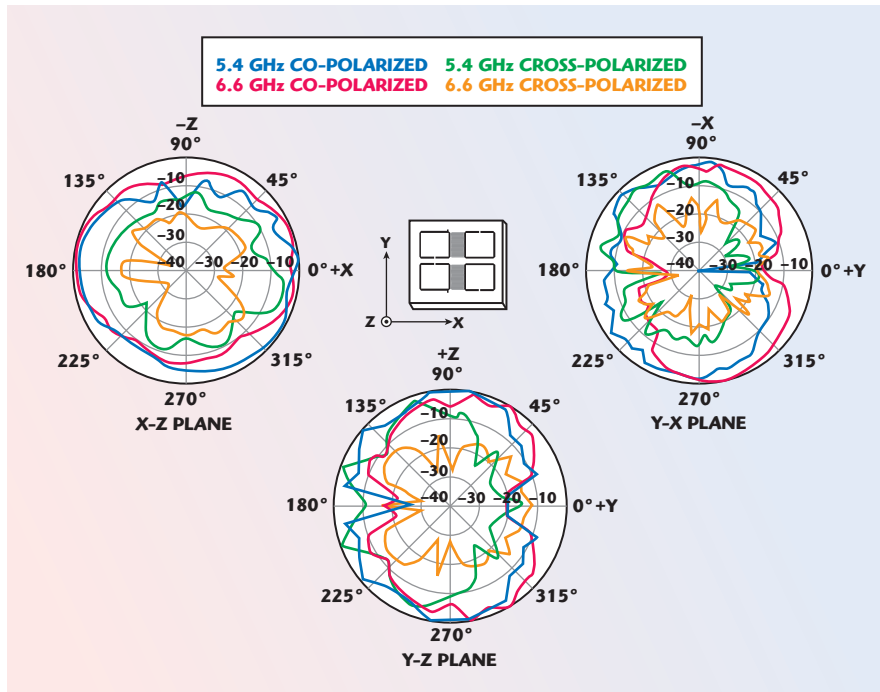
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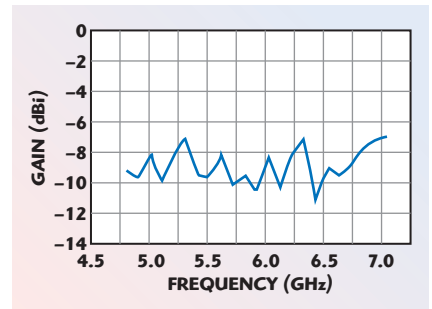


▲ Fig. 4 Measured radiation patterns of the proposed SAW broadband antenna at 5.4 and 6.6 GHz.

the antenna gain is not perfect, it can be integrated with the active components to increase the antenna gain.

CONCLUSION

A compact integrated SAW antenna with broadband performance is de-



▲ Fig. 5 Measured gain of the proposed SAW broadband antenna.

signed and fabricated on 128°-rotated Y-cut LiNbO₃ piezoelectric substrate, using photolithography and evaporation techniques. This antenna is composed of four cross-coupled half-wavelength square open-loop strips and two 16 μm width IDTs of 42 pairs. The proposed broadband SAW antenna can be designed to have a bandwidth of 2.2 GHz (4.8 to 7 GHz), good radiation performance and antenna gain varying from approximately -11 to -7 dBi for frequencies over the operating band, but is only 8.4 × 6.8 mm in size. This antenna is especially suited for WLAN/WiMAX applications in small-size signal receptions and handheld mobile devices. The proposed antenna is easy to fabricate and integrated with radio frequency/microwave circuitry for low manufacturing cost. ■

ACKNOWLEDGMENT

This research work was supported by the National Science Council of the Republic of China, under the grant number NSC 98-2221-E-024-016.

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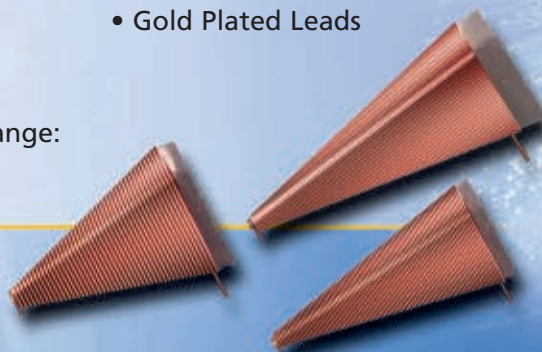
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The BILT/IVCAD pulsed characterization system is a joint development between AMCAD Engineering and Maury Microwave Corp. It consists of three parts: a mainframe, input and output pulsers, and IVCAD measurement and modeling characterization software.

Mainframe

The BILT mainframe is the backbone of the pulsed characterization system and includes five embedded DC power supplies, hardware synchronization/triggering to control external instruments, GPIB/LAN communication and internal calibration standards. The mainframe is designed to fit a standard 19" rack.

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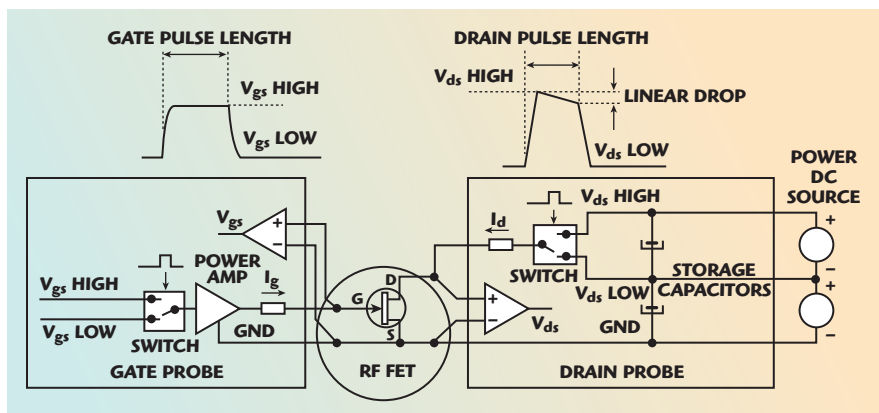
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▲ Fig. 1 Pulser block diagram.

Pulsers

Input and output pulsers (also referred to as probes or pulse heads) are available in four models. The AM211 has been specifically designed for pulsing the input (gate) of the transistor, while the AM221, AM222 and AM223 have been designed for pulsing the output (drain) of the transistor (see **Table 1**).

Each drain pulser is capable of independently controlling both quiescent and hot voltages, allowing for full flexibility in Pulsed IV configuration. This is achieved by using several separate DC sources, large storage capacitors, a pulse amplifier for the gate and extremely fast MOSFET switching for the drain as shown in **Figure 1**.

The embedded acquisition and measurement hardware contained within each pulser is actually comprised of two separate A/D converters; one used for low current measurements and the other for high current measurements. Each A/D converter has 16-bit measurement capability, resulting in both fast and accurate voltage and current measurements with a typical measurement accuracy of 0.1 percent. When comparing with an oscilloscope, the embedded measurement system offers the equivalent of 50 Msamples/s and 10 MHz bandwidth for pulse monitoring. Each

TABLE I

PULSER MODELS AND SPECIFICATIONS

	AM211	AM221	AM222	AM223
Max Voltage	± 15 V	250 V	120 V	-5/+15 V
Max Current (pulsed)	± 200 mA	10 A	30 A	± 200 mA
Max Current (DC)	200 mA	3 A	4 A	200 mA
Peak Power	3 W	2 kW	2 kW	3 W
Avg Power (pulsed)	3 W	50 W	50 W	3 W
Avg Power (DC)	3 W	80 W	80 W	3 W
Min Pulse Width	200 nS	200 nS	400 ns	200 nS
Max Pulse Width	1 ms/DC	1 ms/DC	1 ms/DC	1 ms/DC
Min Duty Cycle	0%	0%	0%	0%
Max Duty Cycle*	100%	100%	100%	100%

* The duty cycle must respect maximum stated average powers for each pulser

pulser is equipped with an electronic fuse for system protection. The fast-switching circuitry activates within 70 nS, thereby offering protection to the transistor, probes, components and test system.

IVCAD Measurement and Modeling Characterization Software

IVCAD is a comprehensive software suite that offers a wide array of measurement and modeling device characterization tools including: DC-IV and S-Parameters, Pulsed IV and Pulsed S-Parameters, Harmonic Load Pull, Compact Transistor Modeling, Behavioral Modeling, advanced visualization and data analysis and more.

With regard to GaN technology, the development of linear and non-linear models first stems from Pulsed IV and Pulsed S-Parameter measurements. Current-Voltage (IV) measurements are used to describe the rela-

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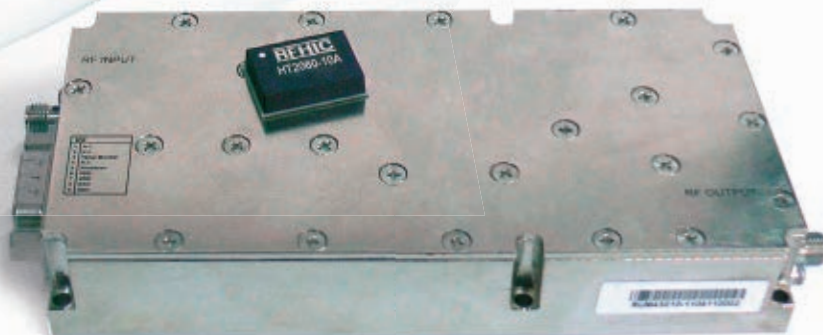


Go ahead and measure it; this is the actual size GaN Technology

&

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2-6GHz 10W Wideband Amp Comparison



RUM43010-10 5.12 x 2.52 x .84 (Inch)

Both of these parts cover the same 2-6GHz and generate the same 10W of power.

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Radar Application

Part Number	Frequency (MHz)	Power (W)	Gain (dB)	PAE (%)
RRC13050-10	1200 ~ 1400	50	30	50
RRC31050-10	2700 ~ 3500	50	25	45
RRC29050-10	2700 ~ 3100	50	25	50
RRC94030-10	9300 ~ 9500	20	15	35
RRY56025-L1	5400 ~ 5900	25	20	42

Wideband Application

Part Number	Frequency (MHz)	Power (W)	Gain (dB)	PAE (%)
HM0005-10A	20 ~ 520	10	30	50
HM0525-10A	500 ~ 2500	10	20	35
HM02060-10A	2000 ~ 6000	10	18	25
TG2000-10	20 ~ 2000	10	14	45
TG2000-03	200 ~ 2000	3	33	45

Telecom Application

Part Number	Frequency (MHz)	Power (W)	Gain (dB)	PAE (%)
HT0808-15A	869 ~ 894	10	35	55
HT2008-15A	2065 ~ 2080	10	33	55
HT0808-30A	869 ~ 894	20	28	45
HT2121-30A	2100 ~ 2170	20	33	45
RNC16010-10	1616 ~ 1626.5	10	25	53



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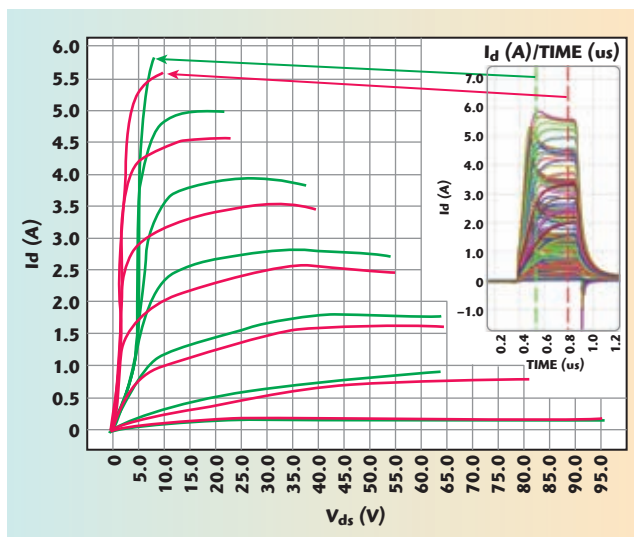


QPSK Modulators



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Product Feature



▲ Fig. 2 Example IV plot.

relationship between input and output currents and voltages. For a typical GaN field effect transistor (FET), characterization is achieved by measuring output currents as a function of output voltages for a set of input voltages. Because of self-heating and trapping phenomena, it is critical to pulse the voltages between quiescent and hot states thereby reducing average DC power and achieving quasi-isothermal performance. Pulse widths must be carefully selected in order to reach a steady state but not to the extent of self-heating; too short and undershoots/overshoots will invalidate the measured currents, too long and self-heating will lead to current degradation. IVCAD offers full flexibility on the pulse timing including pulse widths, pulse periods, duty cycles, delays and full synchronization and timing between gate and drain pulses. Enabling time domain measurements allows a user-defined number of IV acquisitions within each pulse and can be used to study the IV curves at user-selected traces within each pulse, including during the rise-time, overshoot, steady state and fall-time (see Figure 2).

S-Parameters are used to define the electrical behavior of an n-port device. With regards to two-port transistors, S-Parameters are used to quantify return loss, isolation and gain, and are essential in developing a transistor model. S-Parameters, however, are only valid under those specific conditions at which they were measured,

including bias and temperature. Because a transistor's performance changes as a function of bias (both DC and Pulsed quiescent and hot voltages), its S-Parameters must be recorded for each set of bias conditions. When adding a vector network analyzer (VNA) with pulsed capabilities, such as a PNA-X, to the setup, IVCAD can measure fully synchronized Pulsed IV and Pulsed S-Parameter measure-

ments, with complete flexibility on the measurement sequence and timing within each pulse.

Compact transistor modeling is achieved using Pulsed IV and Pulsed S-Parameter measurements to create linear, nonlinear and electro-thermal models. Pulsed S-Parameters are used to determine the transistor's extrinsic parasitic elements, from which intrinsic elements can be calculated. These elements are then used with the nonlinear modeling engine. Pulsed IV measurements are used to determine input and output current models, as well as gate-lag and drain-lag trapping effects. Synchronized Pulsed IV and Pulsed S-Parameters are used to determine one-dimensional input and output capacitance models C_{gd} and C_{gs} . Electro-thermal models are achieved by calculating the thermal resistances and capacitances through a controlled set of pulsed IV measurements, and are used to model the transistor's temperature dependence.

The BILT/IVCAD pulsed characterization system is the first to allow engineers and transistor designers to characterize and model GaN FETs by performing synchronized Pulsed IV and Pulsed S-Parameter measurements and developing Compact Transistor Models from the comfort of their labs.

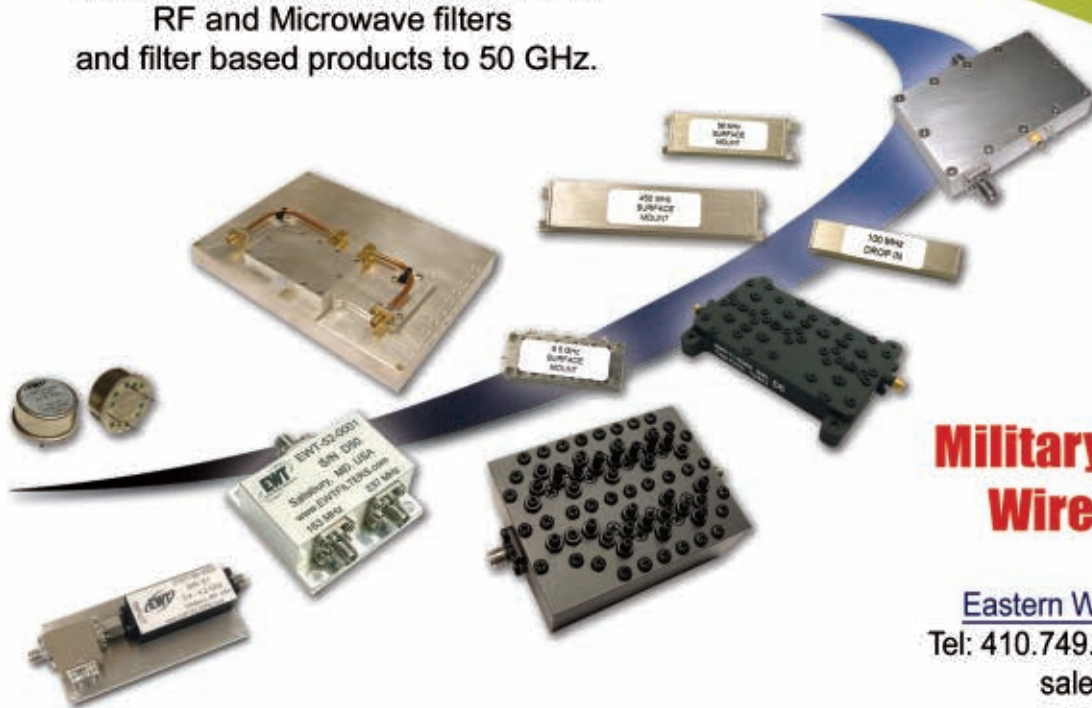
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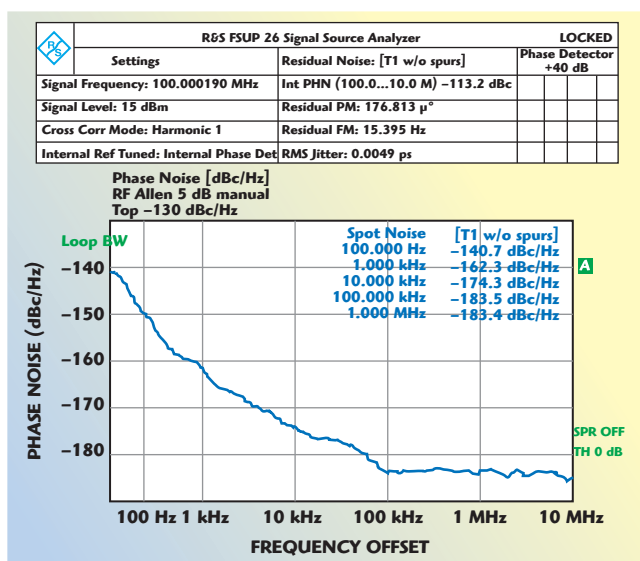
Over recent years the phase noise behavior of crystal based oscillators has been steadily improved, driven by new modulation-types up to 4096 QAM that require extremely low jitter sources. Also, ultra-low-noise sources improve the performance of radar systems and are particularly suited to instrumentation applications in bit-error-rate testers and in laboratory references.

Often companies select crystals that offer the best phase noise performance. However, such crystals can be expensive and unpredictable, and therefore unsuitable for mass-production. The ability to understand the quartz and oscillator behavior, combined with patented noise cancelling feedback technologies, allied to a quartz-supplier who has the capability to deliver constant performance, facilitates the design of small VCXOs with unique specifications and a good price-performance-ratio.

Synergy Microwave Research GmbH is able to meet these criteria with its LNXO-series that is available with some standard frequencies, packages and options with good phase noise performance, yet without the need for quartz-selection. As well as standard LNXOs, customized frequencies and other specifications such as increased output power are available on request.

PERFORMANCE AS STANDARD

A standard product is the LNXO100, which gives a 100 MHz signal with typically +10 dBm output power. Its phase noise performance is



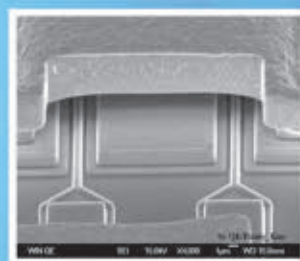
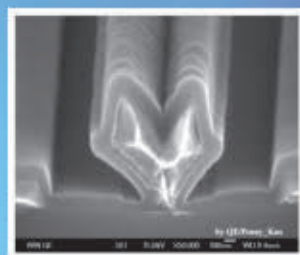
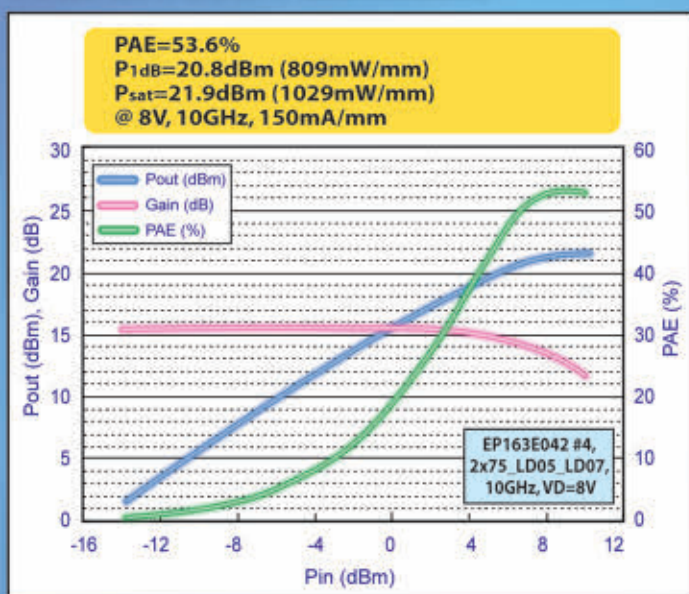
▲ Fig. 1 Example of a phase noise ratio test report.

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PP25-21 Power Performance



Comparison Table for 0.1 μ m, 0.15 μ m, 0.25 μ m and 0.5 μ m pHEMT

	PP10	PP15	PP25-21	PP50-11
V _{to} (V)	-0.9	-1.2	-1.2	-1.4
I _{dss} (mA/mm)	450	500	345	350
I _{dmax} (mA/mm)	720	650	460	480
GM (mS/mm)	750	495	380	310
VDG (V)	9	10	19.2	20
f _t (GHz)	130	85	65~72	32
F _{max} (GHz)	175	180	160	85
P _{1dB} (mW/mm)	533.25 (3.5V)	670 (5V)	809 (8V)	587 (8V)
P _{sat} (mW/mm)	764.3 (3.5V)	820 (5V)	1029 (8V)	851 (8V)
Gain (dB)	14.35	18.1	15.6	15.5
PAE (%)	53.57	55	53.6	53.5
Frequency	29 GHz	10 GHz	10 GHz	10 GHz

Product Feature

-140 dBc/Hz at 100 Hz (-140 typical), minimum -165 dBc/Hz at 1 KHz (-183 typical) and the noise floor is typically -185 dBc over the temperature range of -20° to +60°C. In reality, the performance is better than the typical data and on request the company will make a selection and guarantee the better performance, as illustrated in the phase noise test report shown in **Figure 1**. Harmonics below -35 dB guarantee a clean spectrum.

The frequency stability over temperature is $< \pm 0.2$ ppm and the VCXO ages at ± 0.3 ppm/year after 30 days of continuous operation. Frequencies can be electrically adjusted at ± 5 ppm with an external tuning voltage of 1 to 10 V. Also, the guaranteed jitter specification of 10 fs (typically 6 fs) gives the best performance for fast A/D-converter clocks.

SHOCK AND VIBRATION

Because of the use of shock-



▲ Fig. 2 The ULNS0100 is a connectorized version of the LNXO100.

resistant and vibration optimized quartz-holders and SC-cut crystals, the VCXOs are particularly suitable for military systems where excellent shock and vibration resistance are prerequisites. The LNXO100 is available in a standard 5-pin OCXO and in a connectorized package (**Figure 2** shows the ULNS0100, which is a connectorized version of the LNXO100), with an SMD-package soon to be available.

Another example is the LNXO125 that delivers a 125 MHz-signal with a minimum phase noise performance of -140 dBc/Hz at 100 Hz (-140 typically), minimum -160 dBc/Hz at 1 KHz (-183 typical) and a noise floor of typically -185 dBc over a temperature range of -20° to +60°C.

All packages offer a GPS-receiver option that synchronizes the LNXO-signal to a GPS signal, which gives the oscillator good long-term-stability combined with good phase noise performance. In addition, a built-in option for external locking to a long-term, stable signal, as a rubidium standard, will be available soon.

FUTURE DEVELOPMENTS

Currently 100 and 125 MHz VCXO versions are available and other frequencies are under development, while additional frequencies can be developed upon request from customers.

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Hybrid



Doherty
Combiner



5dB
Directional



20dB
Directional

3dB Hybrid Couplers

Part No	Size in Inches (mm)	Freq Band (MHz)	Power (W)	Return Loss (dB)	Insertion Loss (dB)	Amplitude Bal or Mean Coupling (dB)	Phase Bal (degree)	Isolation (dB)
X3C06A4-03S	0.56 x 0.35 (14.22 x 8.89)	410 - 860	275	20.8	0.20	± 0.60	± 4.0	20
		430 - 450	450	23.1	0.10	± 0.40	± 3.0	20
X3C07P1-03S	0.25 x 0.20 (6.35 x 5.08)	600 - 900	130	23.1	0.20	± 0.25	± 4.0	23
		695 - 805	130	24.9	0.17	± 0.17	± 2.0	25
		731 - 881	130	23.1	0.20	± 0.25	± 4.0	25
X3C09P1-03S	0.25 x 0.20 (6.35 x 5.08)	800 - 1000	90	23.1	0.22	± 0.25	± 4.0	23
		869 - 894	110	24.9	0.14	± 0.14	± 2.0	25
		925 - 960	110	24.9	0.14	± 0.14	± 2.0	25
X3C09P2-03S	0.25 x 0.20 (6.35 x 5.08)	800 - 1000	90	23.1	0.20	± 0.22	± 4.0	23
		869 - 894	110	24.9	0.12	± 0.14	± 2.0	25
		925 - 960	110	24.9	0.12	± 0.14	± 2.0	25
X3C19P1-03S	0.25 x 0.20 (6.35 x 5.08)	1400 - 1500	90	17.7	0.15	± 0.50	± 4.0	20
		1550 - 1710	90	23.1	0.22	± 0.22	± 3.0	23
		1700 - 2000	90	23.1	0.22	± 0.22	± 4.0	23
		1805 - 1880	110	24.9	0.12	± 0.10	± 2.0	25
		1930 - 1990	110	24.9	0.12	± 0.10	± 2.0	25
X3C19P2-03S	0.25 x 0.20 (6.35 x 5.08)	1700 - 2000	176	23.1	0.22	± 0.22	± 4.0	23
		1805 - 1880	176	24.9	0.12	± 0.10	± 2.0	25
		1930 - 1990	176	24.9	0.12	± 0.10	± 2.0	25
X3C21P1-03S	0.25 x 0.20 (6.35 x 5.08)	2000 - 2300	90	23.1	0.22	± 0.22	± 4.0	23
		2110 - 2170	110	24.9	0.12	± 0.10	± 2.0	25
		2300 - 2400	90	17.0	0.25	± 0.40	± 4.0	18
		1800 - 2200	90	22.1	0.17	± 0.22	± 3.0	23
X3C21P2-03S	0.25 x 0.20 (6.35 x 5.08)	2000 - 2300	172	23.1	0.22	± 0.22	± 4.0	23
		2110 - 2170	172	24.9	0.12	± 0.10	± 2.0	25
X3C26P1-03S	0.25 x 0.20 (6.35 x 5.08)	2300 - 2900	110	20.1	0.20	± 0.40	± 4.0	20
		2300 - 2500	110	23.1	0.18	± 0.20	± 4.0	26
		2500 - 2700	110	23.1	0.18	± 0.20	± 4.0	26

Doherty Combiners

Part No	Size in Inches (mm)	Freq Band (MHz)	Power (W)	Return Loss (dB)	Insertion Loss (dB)	Return Loss (dB)	Insertion Loss (dB)	Amplitude Imbalance (dB)	Phase Imbalance (degree)
				Max Power Condition		Low Power Condition			
X3DC07E2S	0.56 x 0.20 (14.22 x 5.08)	728 - 768	200	20.0	0.15	20	0.25	± 0.12	± 3.0
X3DC08E2S	0.56 x 0.20 (14.22 x 5.08)	869 - 894	200	20.0	0.15	20	0.25	± 0.12	± 3.0
X3DC09E2S	0.56 x 0.20 (14.22 x 5.08)	920 - 960	200	20.0	0.15	20	0.25	± 0.12	± 3.0
X3DC18E2S	0.56 x 0.20 (14.22 x 5.08)	1805 - 1880	200	20.0	0.15	20	0.20	± 0.12	± 3.0
X3DC19E2S	0.56 x 0.20 (14.22 x 5.08)	1930 - 1990	200	20.0	0.15	20	0.20	± 0.12	± 3.0
X3DC21E2S	0.56 x 0.20 (14.22 x 5.08)	2110 - 2170	200	20.0	0.15	20	0.20	± 0.12	± 3.0

Data current as of: March, 2012

5dB Directional Couplers

Part No	Size in Inches (mm)	Freq Band (MHz)	Power (W)	Return Loss (dB)	Insertion Loss (dB)	Amplitude Bal or Mean Coupling (dB)	Phase Balance (degree)	Directivity (dB)	Freq Sensitivity (dB)
X3C07P1-05S	0.25 x 0.20 (6.35 x 5.08)	600 - 900	70	23.1	0.200	5.0 ± 0.30	± 4.0	23	± 0.25
		695 - 805	70	24.9	0.170	5.0 ± 0.20	± 2.0	25	± 0.05
X3C09P1-05S	0.25 x 0.20 (6.35 x 5.08)	800 - 1000	70	23.1	0.200	5.0 ± 0.30	± 4.0	23	± 0.25
		869 - 894	70	24.9	0.150	5.0 ± 0.20	± 2.0	25	± 0.05
		925 - 960	70	24.9	0.150	5.0 ± 0.20	± 2.0	25	± 0.05
X3C19P1-05S	0.25 x 0.20 (6.35 x 5.08)	1700 - 2000	70	20.1	0.150	5.0 ± 0.30	± 4.0	20	± 0.25
		1805 - 1880	70	23.1	0.130	5.0 ± 0.20	± 2.0	23	± 0.05
		1930 - 1990	70	23.1	0.140	5.0 ± 0.20	± 2.0	23	± 0.05
X3C21P1-05S	0.25 x 0.20 (6.35 x 5.08)	2000 - 2300	60	20.1	0.150	5.0 ± 0.30	± 4.0	20	± 0.25
		2110 - 2170	60	24.9	0.130	5.0 ± 0.20	± 2.0	25	± 0.05
X3C25P1-05S	0.25 x 0.20 (6.35 x 5.08)	2300 - 2700	60	20.1	0.180	5.0 ± 0.30	± 4.0	20	± 0.25
		2300 - 2400	60	23.1	0.140	5.0 ± 0.20	± 4.0	23	± 0.05
		2630 - 2655	60	23.1	0.170	5.0 ± 0.20	± 4.0	23	± 0.05

20dB Directional Couplers

Part No	Size in Inches (mm)	Freq Band (MHz)	Power (W)	Return Loss (dB)	Insertion Loss (dB)	Amplitude Bal or Mean Coupling (dB)	Directivity (dB)	Freq Sensitivity (dB)
X3C08E2-20S	0.56 x 0.20 (14.22 x 5.08)	731 - 881	225	23.1	0.050	20.0 ± 0.50	22	± 0.25
X3C09E2-20S	0.56 x 0.20 (14.22 x 5.08)	800 - 1000	225	20.1	0.075	20.0 ± 1.00	20	± 0.35
		700 - 800	225	20.1	0.050	20.0 ± 0.75	20	± 0.30
		869 - 894	225	20.1	0.050	20.0 ± 0.60	23	± 0.05
		925 - 960	225	20.1	0.050	20.0 ± 0.60	23	± 0.05
X3C19E2-20S	0.56 x 0.20 (14.22 x 5.08)	1400 - 2700	225	20.1	0.100	20.3 ± 1.00	20	± 1.00
		1805 - 1880	225	24.9	0.050	20.2 ± 0.60	25	± 0.05
		1930 - 1990	225	24.9	0.050	20.0 ± 0.60	25	± 0.05
		2110 - 2170	225	24.9	0.050	20.0 ± 0.60	25	± 0.05

30dB Directional Couplers

Part No	Size in Inches (mm)	Freq Band (MHz)	Power (W)	Return Loss (dB)	Insertion Loss (dB)	Amplitude Bal or Mean Coupling (dB)	Directivity (dB)	Freq Sensitivity (dB)
X3C09P2-30S	0.25 x 0.20 (6.35 x 5.08)	800 - 1000	225	23.1	0.100	30.2 ± 1.50	20	± 0.40
		869 - 894	225	24.9	0.075	30.0 ± 1.50	20	± 0.10
		925 - 960	225	24.9	0.075	30.0 ± 1.50	20	± 0.10
		700 - 800	225	20.1	0.100	30.4 ± 1.50	20	± 0.40
X3C19P2-30S	0.25 x 0.20 (6.35 x 5.08)	1400 - 2700	225	20.1	0.100	30.4 ± 1.50	20	± 2.00
		1805 - 1880	225	24.9	0.075	30.0 ± 1.50	20	± 0.05
		1930 - 1990	225	24.9	0.075	30.0 ± 1.50	20	± 0.05
		2110 - 2170	225	24.9	0.100	30.2 ± 1.50	20	± 0.30
X3C26P1-30S	0.25 x 0.20 (6.35 x 5.08)	2300 - 2900	200	23.1	0.100	30.0 ± 1.00	20	± 0.25
		2500 - 2700	200	24.9	0.050	30.0 ± 0.80	22	± 0.10

Data current as of: March, 2012

Resistive Components

Selection Matrix

- Latest generation design and manufacturing = our lowest cost resistive family ever!
- Excellent performance in commercial wireless bands
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- Environmentally friendly – BeO-free AlN and alumina construction; lead free tin finish



SMD



Chip



Flangeless



Flanged

SMD Terminations

Part No	Size in Inches (mm)	Power (W)	Freq Band (MHz)	Return Loss (dB)
060120A15Z50-2	0.060 x 0.120 (1.52 x 3.05)	8	DC - 6000	19
C10A50Z4	0.100 x 0.200 (2.54 x 5.08)	10	DC - 3000	19
C16A50Z4	0.100 x 0.200 (2.54 x 5.08)	16	DC - 2700	26
			DC - 4000	24
C20N50Z4	0.100 x 0.200 (2.54 x 5.08)	20	DC - 2300	20
C50A50Z4	0.250 x 0.250 (6.35 x 6.35)	50	DC - 2200	26
			DC - 2700	24
C100N50Z4A	0.250 x 0.250 (6.35 x 6.35)	100	DC - 2700	24
			DC - 4000	20
C150N50Z4	0.250 x 0.250 (6.35 x 6.35)	150	DC - 2700	24
			DC - 4000	20
C200N50Z4	0.250 x 0.375 (6.35 x 9.53)	200	DC - 2200	20

Chip Terminations

Part No	Size in Inches (mm)	Power (W)	Freq Band (MHz)	Return Loss (dB)
060120A25X50-2	0.060 x 0.120 (1.52 x 3.05)	10	DC - 6000	19
A15N50X4	0.050 x 0.100 (1.27 x 2.54)	15	DC - 4500	20
A16A50X4	0.100 x 0.200 (2.54 x 5.08)	16	DC - 2200	28
			DC - 2700	25
			DC - 4000	20
A100N50X4A	0.250 x 0.225 (6.35 x 5.72)	100	DC - 3500	20
A125N50X4	0.250 x 0.250 (6.35 x 6.35)	125	DC - 2700	26
			DC - 4000	20
A150N50X4B	0.250 x 0.375 (6.35 x 9.53)	150	DC - 2000	25
			DC - 2700	20
A150N50X4C	0.225 x 0.350 (5.72 x 8.89)	150	DC - 3000	26
A150N50X4E	0.250 x 0.250 (6.35 x 6.35)	150	DC - 2000	25
			DC - 3000	20
A200N50X4	0.250 x 0.375 (6.35 x 9.53)	200	DC - 2200	20
A250N50X4	0.375 x 0.375 (9.53 x 9.53)	250	DC - 2200	20
A500N50X4	0.500 x 0.500 (12.70 x 12.70)	500	DC - 1700	20

Flangeless Terminations

Part No	Size in Inches (mm)	Power (W)	Freq Band (MHz)	Return Loss (dB)
E150N50X4	0.250 x 0.375 (6.35 x 9.53)	150	DC - 2200	25
			DC - 2700	20
E150N50X4E	0.250 x 0.375 (6.35 x 9.53)	150	DC - 2000	25
			DC - 3000	20
E200N50X4	0.250 x 0.375 (6.35 x 9.53)	200	DC - 2200	20
E250N50X4	0.375 x 0.375 (9.53 x 9.53)	250	DC - 2200	20

Data current as of: March, 2012

Flanged Terminations

Part No	Size in Inches (mm)	Power (W)	Freq Band (MHz)	Return Loss (dB)
I100N50X4	0.250 x 0.515 (6.35 x 13.08)	100	DC - 3000	20
J100N50X4	0.250 x 0.515 (6.35 x 13.08)	100	DC - 3000	20
K100N50X4	0.250 x 0.515 (6.35 x 13.08)	100	DC - 3000	20
G100N50W4	0.230 x 0.800 (5.84 x 20.32)	100	DC - 2000	25
			DC - 3000	20
G150N50W4B	0.375 x 0.870 (9.53 x 22.10)	150	DC - 2000	25
			DC - 2700	20
G150N50W4E	0.375 x 0.870 (9.53 x 22.10)	150	DC - 2000	25
			DC - 2700	20
G200N50W4	0.375 x 0.870 (9.53 x 22.10)	200	DC - 2200	20
G250N50W4	0.375 x 0.975 (9.53 x 24.77)	250	DC - 2200	20
G450N50W4	0.500 x 1.100 (12.70 x 27.94)	450	DC - 1700	20

SMD Attenuators

Part No	Size in Inches (mm)	Power (W)	Freq Band (MHz)	Attenuation xx (dB)	Return Loss (dB)
D10AAxxZ4	0.100 x 0.200 (2.54 x 5.08)	10	DC - 3000	1 - 7, 9, 10, 20 & 30	19
D50AAxxZ4	0.250 x 0.250 (6.35 x 6.35)	50	DC - 2300	20 & 30	20

Chip Attenuators

Part No	Size in Inches (mm)	Power (W)	Freq Band (MHz)	Attenuation xx (dB)	Return Loss (dB)
1615-xx	0.250 x 0.375 (6.35 x 9.53)	100	DC - 2300	20 & 30	19
B150NAxxX4	0.250 x 0.375 (6.35 x 9.53)	150	DC - 2300	20 & 30	20

Data current as of: March, 2012

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Plenary Session Speaker: **Steve Mollenkopf**

President and Chief Operating Officer, *Qualcomm*
3G/4G Chipsets and the Mobile Data Explosion

*Monday, 18 June 2012
1730-1900*

The rapid growth of wireless data and complexity of 3G and 4G chipsets drives new design and deployment challenges for radio and device manufacturers along with carriers. This talk will provide a perspective on the problem from the point of view of a large, worldwide manufacturer of semiconductors and technology for cellular and connected consumer electronics devices. The increase in device and network complexity will result in significant business opportunities for the industry.

Closing Ceremony Speaker: **Thomas H. Lee**

Professor, *Stanford University*

The Fourth Age of Wireless and the Internet of Everything

*Thursday, 21 June 2012
1600-1730*

"Making predictions is hard, particularly about the future." The patterns of history are rarely discernible until they're obvious and perhaps irrelevant. Wireless may be an exception, at least in broad outline, for the evolution of wireless has been following a clear pattern that tempts us to extrapolate. Marconi's station-to-station spark telegraphy gave way to a second age dominated by station-to-people broadcasting, and then to today's ubiquitous people-to-people cellular communications. Each new age was marked by vast increases in value as it enlarged the circle of interlocutors. Now, these three ages have covered all combinations of "stations" and "people," so any Fourth Age will have to invite "things" into the mix to provide another stepwise jump in the number of interlocutors. This talk will describe how the inclusion of multiple billions of objects, coupled with a seemingly insatiable demand for ever-higher data rates, will stress an infrastructure built for the Third Age. Overcoming the challenges of the coming Fourth Age of Wireless to create the Internet of Everything represents a huge opportunity for RF engineers. History is not done.



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GPS Disciplined Cesium Vapor Cell Local Oscillator



The recent advent of commercially available Chip Scale Atomic Clocks (CSAC) marked a paradigm shift in the timing and frequency industry. CSACs are able to replace traditional Rubidium, Cesium, Crystal and GPS Disciplined references while providing significant performance increases as well as size and weight improvements. These improvements are so drastic that entirely new applications can now be realized that were impossible to achieve with legacy technology. CSACs enable products to be realized that run from small Lithium batteries for days to weeks, and some applications, such as underwater exploration, can achieve years of operation running on battery power. CSAC battery power-sources can be small enough to fit into the size of a cell phone while having a frequency accuracy and stability comparable to legacy Rubidium atomic frequency standards with days to weeks of operating time.

Radio, cell phone, Satellite and radar applications require oscillators with very low phase noise, and more recently, extremely high frequency accuracy, frequency stability and timing accuracy. This accuracy is measured in parts per trillion (ppt) rather than the traditional parts per million (ppm) achievable with legacy crystal oscillators as are typically used in low-power applications.

The availability of high performance GPS receivers and the first commercially-available miniature CSAC have enabled a one-million-to-one leap in performance over traditional crystal oscillators (XO) while at the same time reducing size and power consumption over legacy atomic oscillators by orders of magnitude. By combining GPS signals with the first commercially available CSAC oscillator made by Symmetricom Inc. and a purpose-designed low-phase-noise Crystal Filter Oscillator, Jackson Labs Technologies was able to introduce the first commercially available CSAC GPS Disciplined oscillator (CSAC GPSDO), shown in **Figure 1**.

CHANGING THE STATUS QUO

Traditional frequency references use Quartz crystal oscillators to generate frequencies that are typically accurate and stable to ppm when used in XOs, or tens of parts per billion (ppb) in higher-cost TCXO or OCXO oscillators. OCXOs typically dissipate several Watts of power, and require 5 to 30 minutes or more to warm up to stabilize. The best SC-cut, double-oven crystal oscillators (DOCXO) can still exhibit drift of several ppb after power on and over temperature, especially if a frequency

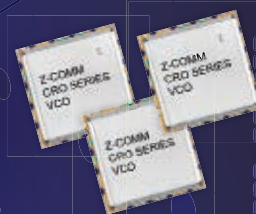


▲ Fig. 1 10 MHz CSAC GPSDO module using a Cesium vapor cell.

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CRO1940A-LF	1910	1970	0.5-4.5	-112	3.5	5
CRO2275A-LF	2250	2300	0.5-4.5	-113	1.5	5
CRO2343A-LF	2310	2376	0.5-4.5	-109	0	5
CRO2477A-LF	2440	2540	0.5-4.5	-108	3.5	5
CRO2537A-LF	2530	2545	0.5-4.5	-115	3	5
CRO2885A-LF	2880	2890	0.5-4.5	-115	7	5
CRO3069A-LF	3064	3074	0.5-4.5	-116	2.5	5
CRO3200A-LF	3200	3200	0.5-4.5	-116	11	5
CRO3662A-LF	3657	3667	0.5-4.5	-113	1.5	5
CRO3850B-LF	3850	3850	0.5-4.5	-109	2.75	5

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Product Feature

calibration is done shortly after power on at a time when the crystal is still retracing. This can result in 50 microseconds or more of timing drift per day, with the drift rate typically increasing day over day in these types of oscillators. The CSAC GPSDO can achieve sub 1 microsecond drift per day ($\sim 1.16 \times 10^{-11}$ drift over 24 hours) in a typical laboratory environment, and will maintain sub ppb accuracy over weeks and months of operation. Typical legacy Rubidium Atomic references which can be replaced by the CSAC GPSDO have a height of 1.5 inches or more, dissipate 15 to 20 W of power at cold temperatures, weigh over 1 lb and take 5 to 10 minutes to warm up at cold temperatures. They are also limited to operation below 70°C on their baseplate and require that the user supplies external frequency calibration or disciplining circuitry and software.

GPS: THE (ALMOST) PERFECT CELESTIAL REFERENCE

To counter phase and frequency drift in crystal oscillators, 1 pulse per second (PPS) aligned to Coordinated Universal Time (UTC) with nanosecond accuracies can be generated by GPS receivers independent of location anywhere around the world. They are typically used in GPSDOs to continuously calibrate the internal quartz crystal oscillator to achieve frequency and phase lock of the local oscillator to the Cesium atomic clocks used to generate the UTC reference at the U.S. Naval Observatory (UTC USNO). The GPS satellites are thus used to distribute the USNO 10 MHz frequency standard with phase accuracies typically better than one cycle at 10 MHz over short and long time periods anywhere around the world. Generating an accurate frequency is called frequency syntonization, while maintaining phase coherence to UTC is called synchronization. The best free running Cesium frequency reference cannot maintain nanosecond-level synchronization to UTC over days or weeks without calibration via GPS signals. This is due to the fact that nanosecond phase accuracy over long periods of time requires performance measured in fractional ppt, far exceeding commercially available Cesium and Rubidium reference performance. While GPSDO systems work well when GPS signals are available and are not being jammed or

spoofed, they typically require a long warm-up and stabilization time (measured in hours) and do not preserve phase and frequency accuracy without active and constant GPS reception. Operation without the benefit of GPS calibration is called holdover, or flywheel mode, and this holdover operation is where the CSAC oscillator excels when compared to crystal oscillators.

CESIUM ATOMS SAVE THE DAY

Atomic clocks have been available commercially to generate stable and accurate frequencies since at least 1958. These clocks generally use Cesium or Rubidium atoms that are excited by an external energy source and are generally interrogated by a microwave servo loop. Contrary to popular belief, non-radioactive isotopes are used in atomic clocks. This microwave servo loop controls an external reference crystal and steers the crystal onto frequency. In the CSAC, a Cesium vapor cell is excited from a VCEL Laser source. The VCEL is modulated at ~ 4.6 GHz to produce a complementary pair of sidebands separated by the extremely accurate and stable Cesium ground state hyperfine transition frequency of 9,192,631,770 Hz. A servo loop measures the light output of the Cesium vapor cell and controls the frequency of a low power 10 MHz TCXO and the VCEL microwave modulation to achieve frequency lock to the Cesium vapor cell. The CSAC oscillator then generates a highly accurate and stable 10 MHz signal. This process happens with less than 120 mW of power consumption in the CSAC. The process of locking the TCXO to the Cesium resonance is typically achieved in less than 110 seconds after power on. The Cesium vapor cell itself is only 1 cm³, and allows the overall height of the CSAC GPSDO product to be less than 0.7 inches. This size compares very favorably to industry standard DOCXO and Rubidium based units that typically have heights of 1 inch or more preventing these to be used to retrofit legacy equipment such as VME racks.

CSAC GPSDO – A REAL WORLD PRODUCT

The business end of the Jackson Labs Technologies CSAC GPSDO shown in Figure 1 provides various isolated low phase noise 5 MHz



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Sweep time	< 0.9 s	< 0.7 s	< 0.4 s
Weight with battery	3.6 kg (7.9 lbs)	3.6 kg (7.9 lbs)	3.6 kg (7.9 lbs)



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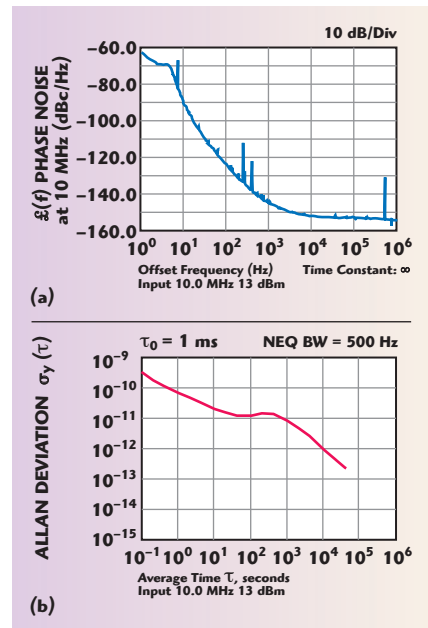
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Product Feature

CMOS and 10 MHz sine wave outputs and a UTC-synchronized 1 PPS CMOS output. An additional, low phase noise post filter reduces the phase noise of the unit by up to 13 dB and removes spurs. An RS-232 and a USB port allow the generation of NMEA-0183 and SCPI control sentences, with system status and alarms. Power consumption is typically 0.8 to 1.4 W maximum depending on the configuration, and the unit can

be powered from a +5 to +36 VDC source. A typical phase noise and Allan Deviation plot of the CSAC GPSDO is shown in **Figure 2**. The Allan Deviation plot of the CSAC GPSDO shows stabilities of better than 1/10 ppb (0.1×10^{-9}) for averaging times of one second or longer, and better than one ppt (1×10^{-12}) for averaging times of 10k seconds or longer when locked to GPS.

The CSAC GPSDO provides the



▲ Fig. 2 10 MHz CSAC GPSDO phase noise (a) and Allan Deviation (b) plots.

following typical advantages when compared to legacy Rubidium, Cesium or crystal-based products. These characteristics were heretofore not simultaneously achievable in a single product:

- Low power consumption of 0.8 to 1.4 W which does not vary significantly over temperature
- No warm-up power peaks that OXCO based products would exhibit
- Ultra-short warm-up of < 60 s typically, 110 s maximum to 0.5 ppb frequency accuracy
- Atomic long-term frequency accuracy and stability
- Wide operating temperature range of -40° to $+85^\circ\text{C}$
- Less than 0.2 ppb per g per axis sensitivity
- Very low height and weight of less than 0.7 inches and < 64 g (< 2.25 oz)
- Cesium vapor cell does not suffer from Cesium depletion allowing 100,000 hours MTBF
- Phase noise of -124 dBc/Hz at 100 Hz, -153 dBc/Hz at 100 kHz
- UTC phase and frequency synchronized and syntonized operation
- No ITAR or HazMat shipping restrictions

The CSAC GPSDO fast warm-up and low power operation allows for very fast in-field deployment of battery operated devices while maintaining phase synchronization to UTC after only a 2 to 3 minute calibration

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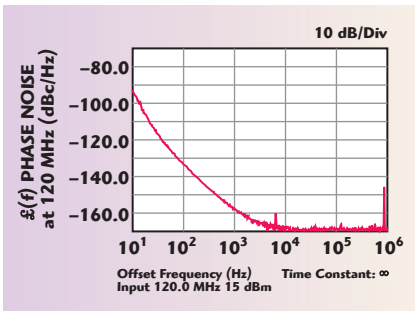
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- Precise group delay measurements on frequency converters without LO access
- Absolute phase measurements on mixers



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Product Feature



▲ Fig. 3 120 MHz CSAC GPSDO phase noise plot.



▲ Fig. 4 Small form factor CSAC GPSDO for dismounted (man-pack) applications.

to GPS. This is useful in applications such as manpack radios and jammers, underwater exploration, unmanned

aerial vehicles (UAV), as well as mobile satellite and radar stations.

120 MHz RADAR REFERENCE IMPLEMENTATION

The 10 MHz output of the CSAC GPSDO can be upconverted to higher frequencies such as L-Band radar frequencies, typically requiring additional phase noise filtering. To improve the phase noise for up-conversion applications, a 100/120 MHz companion filter oscillator was designed that connects to the CSAC GPSDO seamlessly. It maintains the CSAC GPSDO frequency accuracy and stability while improving phase noise by more than 40 dB. The filter oscillator was designed to be used in high vibration environments such as UAVs or helicopters and has internal vibration damping. The unit is 1.75" × 2.8" × 3" and includes a vibration damped and an extremely low-g sensitivity crystal with a typical sensitivity of less than 5×10^{-11} per g per axis at 100 Hz. **Figure 3** depicts the static phase noise plot of the 120 MHz filter oscillator, showing that the typi-

cal noise floor of -174 dBc/Hz is below that of the instrument that measures it. The plot was generated by beating two identical 120 MHz units against each other, which results in a plot that displays the phase noise 3 dB higher than actual. A -3 dB correction factor was not applied to **Figure 3**.

FLAVORS GALORE

Jackson Labs Technologies will shortly be offering additional versions of the CSAC GPSDO in various form-factors optimized for different applications, including an ultra-low-power version for battery-powered, long-term underwater exploration with less than 50 mW average power consumption, a ruggedized small footprint unit that is 2" × 2.5" × 0.7" in size (see **Figure 4**), and a unit with ovenized crystal cleanup post filter for ADEV performance of better than 5×10^{-12} from 1 second averaging intervals.

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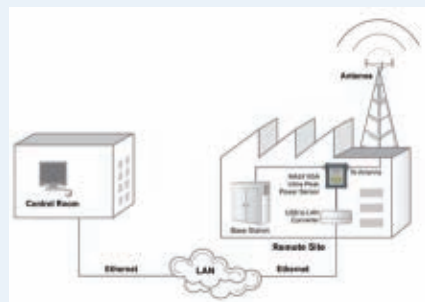
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Important Dates

Summary (~1k words + figures) **15 Dec 2012**

Notification of Acceptance **1 Feb 2013**

Final Papers (8 page max) **1 June 2013**

Special Sessions

Please provide suggestions for special sessions to the Technical Chair at info@array2013.org.

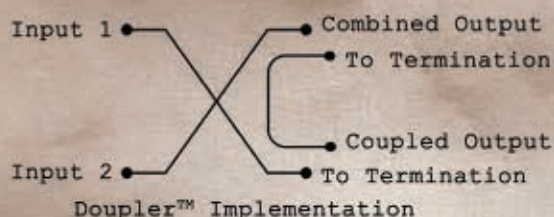
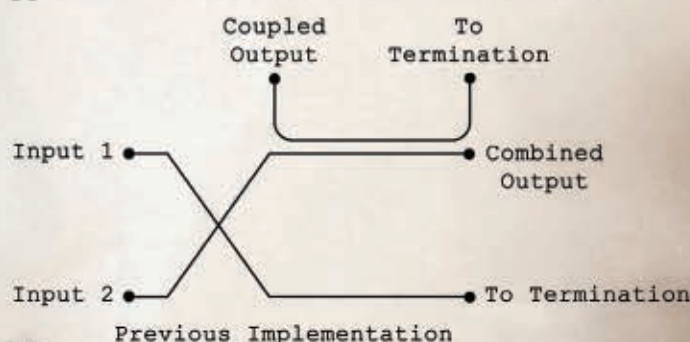
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Coupling Redefined

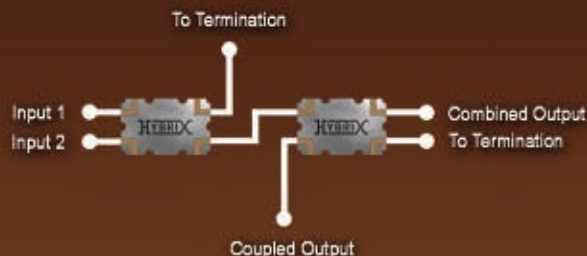
Doupler[™] (dü'-pler)

Noun:

(Engineering / Electrical Engineering) a device that combines amplifier outputs and samples power, single device with one half typical insertion loss and smaller footprint.



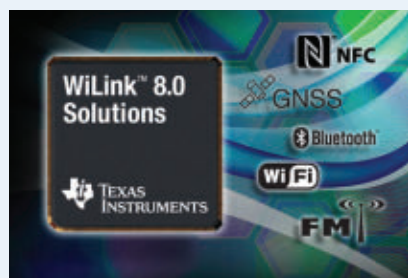
Doupler [™] Part Number	Frequency	Architecture		Launch Date
		Power Combining	Power Monitoring	
DHDL20F	2110 - 2170 MHz	3-dB Hybrid	20-dB Directional	Available Now
DHDK20F	1930 - 1990 MHz	3-dB Hybrid	20-dB Directional	Available Now
DHDL20F	1805 - 1880 MHz	3-dB Hybrid	20-dB Directional	Available Now
DDDP30F	2500 - 2700 MHz	Doherty Combiner	30-dB Directional	April 2012
DDDL30F	2110 - 2170 MHz	Doherty Combiner	30-dB Directional	April 2012
DDDP20F	2500 - 2700 MHz	Doherty Combiner	20-dB Directional	May 2012
DDDL20F	1805 - 1880 MHz	Doherty Combiner	20-dB Directional	May 2012
DDDV30F	700 - 800 MHz	Doherty Combiner	30-dB Directional	May 2012
DHDD30F	925 - 960 MHz	3-dB Hybrid	30-dB Directional	June 2012
DHDT30F	869 - 894 MHz	3-dB Hybrid	30-dB Directional	June 2012
DHDV30F	700 - 800 MHz	3-dB Hybrid	30-dB Directional	June 2012



Previous Implementation



Doupler[™] Implementation



Texas Instruments Inc. has introduced the WiLink™ 8.0 product family: a collection of single-chip solutions that integrate up to five different radios and set the stage for next-generation mobile WiFi, GNSS, NFC, Bluetooth® and FM transmit/receive applications. The WiLink 8.0 architecture supports various combinations of these technologies, allowing for customized solutions to address the unique needs and price points of all mobile markets. Each chip variant comes in a compact wafer scale package that can be mounted directly on a PCB, and includes all required RF front ends, a complete power management system and comprehensive coexistence mechanisms. At the system level, the five-radio WiLink 8.0

Five-in-One Wireless Connectivity Solutions

chip offers a 60 percent cost reduction, 45 percent decrease in size and 30 percent lower power consumption compared to traditional multi-chip offerings.

The WiLink 8.0 family includes highly integrated, five-radio WL189x solutions, tailored for smartphones, tablets, eBooks, ultrathin computing devices and other feature-rich mobile products. The WL187x, WL185x and WL183x solutions provide additional options for higher to mid-tier devices, while the WL180x solutions address lower-cost mobile markets. The product family includes integrated RF front ends for both 2.4 and 5 GHz.

WiLink 8.0 solutions are available for all WiFi throughput ranges, either using 2×2 MIMO or SISO 40 MHz. Capable of reaching more than 100 Mbps WiFi TCP throughput on the

2.4 and 5 GHz bands, the chips promise the fastest mobile streaming and high-definition mobile video capabilities, including WiFi Direct™ and wireless display – all with low latency, low power consumption, and open source software support. WiLink 8.0 chips with integrated WiFi MIMO yield 25 percent smaller size and 50 percent power savings as compared to other MIMO solutions.

As the first combo chip family to embed a complete NFC controller solution, WiLink 8.0 devices make NFC integration possible on any mobile device. The WiLink 8.0 combo chip with integrated NFC yields a more than 50 percent size reduction as compared to non-combo solutions.

Texas Instruments,
Dallas, TX (972) 644-5580,
www.ti.com/wilink8.

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www.sgmcmicrowave.com



Application Note



The new Agilent application note on 802.11ad, "Wireless LAN at 60 GHz – IEEE 802.11ad Explained" introduces and discusses in detail the proposed 802.11ad, providing up to 7 Gbps throughput using approximately 2 GHz of spectrum at 60 GHz over a short range. It addresses the requirements and challenges of the higher data throughput needed to support today's "unwired office." It is available now at www.agilent.com/find/WLAN. Registration is required to download.

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



Application Profile

Providing backhaul for third- and fourth-generation wireless systems has become one of the greatest issues facing wireless carriers as data rates dramatically increase. Microwave point-to-point links are proving to be a cost-effective solution. As always, interference is an issue, and cavity filters can play a vital role in eliminating it in both new and existing installations. This paper provides useful information for anyone involved in the installation and maintenance of these systems. It is available at www.anatechelectronics.com and www.amcrf.com.

Anatech Electronics,
Garfield, NJ (973) 772-4242, www.amcrf.com.



EMC & RF Testing Catalog



AR's new product catalog is now available from your local AR sales associate. 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, at www.arworld.us.

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



Multiphysics Simulation Kit

Meeting and exceeding ever-increasing scientific and engineering requirements calls for faster and more accurate simulations of processes and designs. A wider number of factors need to be considered, often described by different sets of equations or physics that are intricately coupled to each other – Multiphysics. This CD introduces you to the concept of Multiphysics Modeling and the important place it has in today's modeling community. COMSOL Multiphysics® is the ultimate tool for simulating such phenomena, which is demonstrated in the animated tutorials on this CD.

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



Selection Guide



The selection guide summarizes over 1000 products, including 20 new products. New for this publication is a clocks & timing ICs section featuring over 30 products. The guide is organized by RF & microwave, analog & mixed signal and LO frequency generation IC sections along with modules and instrumentation. The new and expanded product line section includes a new LNA, triple balanced mixer, wideband direct quad modulator, broadband time delay, linear voltage regulator, microwave PLLs & VCOs and PLL chipset. The guide also contains an expanded market & application solutions section. Request your copy at www.hittite.com by selecting "Submit Inquiry" in the left hand navigation.

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



Connector Catalog

Southwest Microwave Inc. announces the availability of its Version 5.0 Connector Catalog. The 112 page catalog features its full line of connectors, including Super SMA, N, TNC, SSMA, 2.92 mm, 2.40 mm and End Launch as well as adapters, cable connectors, launch accessories and installation/tools. The catalog also includes specifications and test data. Download at www.southwestmicrowave.com or for a printed copy, email connectors@southwestmicrowave.com.

Southwest Microwave Inc.,
Tempe, AZ (480) 783-0201, www.southwestmicrowave.com.

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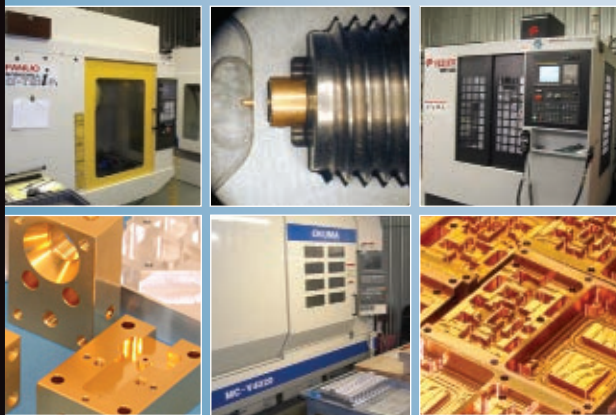
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www.microtoolinc.com

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Catalog Update



Test & Measurement Catalog 2012

VENDORVIEW

Rohde & Schwarz set standards in research, development, production and service. As a key partner of industry, network operators and public institutions, they offer a broad spectrum of market-leading solutions for state-of-the-art technologies, including LTE-Advanced, the mobile radio standard of the next generation, as well as for extremely high-frequency applications up to 500 GHz. Rohde & Schwarz meets the growing de-

mand by offering products for signal generation, signal analysis, network analysis and power measurement.

Rohde & Schwarz,

Munich, Germany +49 89 41 29 0, www2.rohde-schwarz.com.



In-Building Solutions Catalog

Smartphones and tablets have triggered a boom on the mobile communications market. The need for area-wide network coverage and large bandwidths is still increasing. Classic telephony and internet applications are being replaced by mobile devices. Use is at the same time increasingly shifting indoors and buildings must be equipped with their own antenna systems. For in-building coverage, SPINNER has been offering solutions under the trademark

MNCS® for the sharing of different networks, frequencies and bands. Complex multi-operator systems are SPINNER's strength as well as components for signal distribution. SPINNER therefore presents its in-building solutions catalog.

SPINNER GmbH,

**Munich, Germany +49 89 12601-0, USA: (770) 263-6326,
www.spinner.group.com.**



Rail and Transit Products Brochure

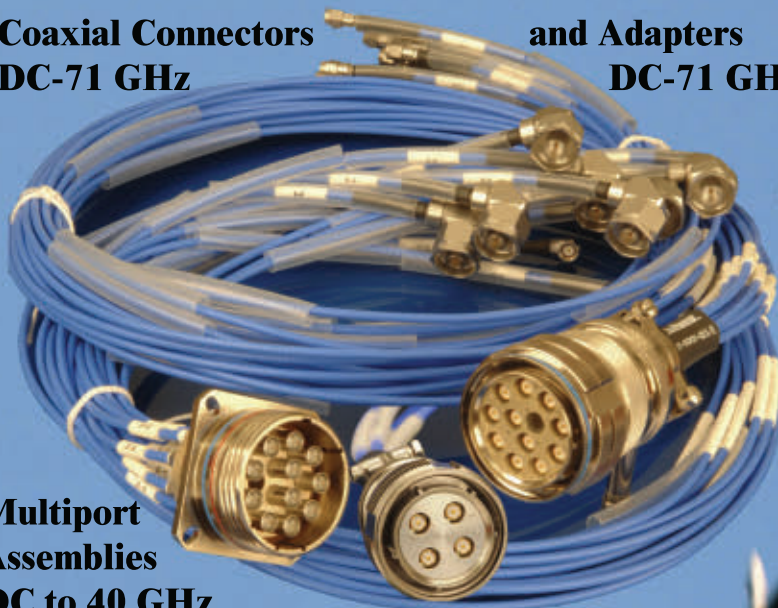
Times Microwave Systems announces the availability of its Rail and Transit Wireless Products brochure. The four page brochure includes wireless products from Times in support of the major upgrades underway in rail radio communication systems, subway and metro applications, Communication Based Train Control (CBTC), as well as the early stages of the Positive Train Control (PTC) rollout for class one railroads. Included in the brochure are the popular LMR® low loss, flexible coaxial cables, connectors and cable assemblies as well as the innovative Times-Protect® lightning and surge protection devices used in the rail industry.

Times Microwave Systems,

Wallingford, CT (800) 867-2629, www.timesmicrowave.com.

**Coaxial Connectors
DC-71 GHz**

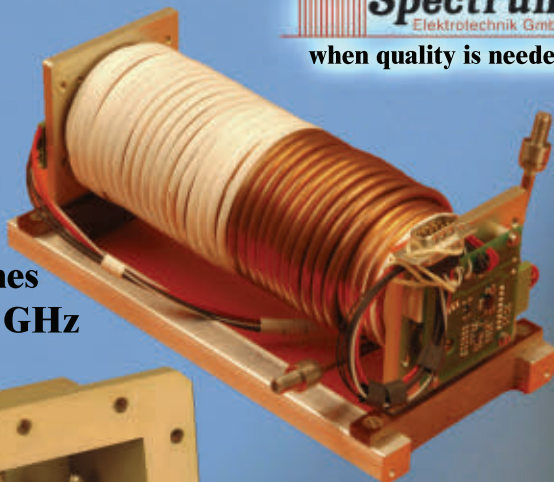
**and Adapters
DC-71 GHz**



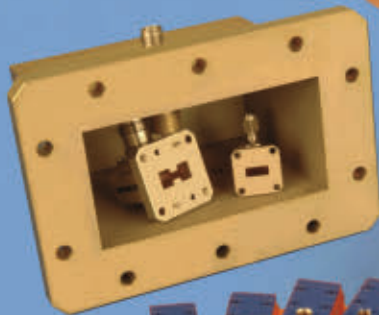
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GaN Amplifier



Aethercomm model number SSPA 1.7-2.2-70 is a high power, GaN amplifier that operates from 1700 to 2200 MHz min-

imum and is packaged in a compact, rugged enclosure. This amplifier is designed for operation in harsh environments where communication systems are deployed. Typical output power is 90 to 100 W across the band at P_{Sat} . This RF amplifier employs digital circuitry for command and control. Power gain at 70 W P_{out} is 48 to 50 dB across the band typically. Input and output VSWR is 2.0:1 maximum. This unit is equipped with DC switching circuitry that enables and disables the RF devices in 5 μ secs maximum. The power consumption in the off state is 10 W typical.

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

Solid-State Amplifiers



With AR's 0.7 to 18 GHz dual band amplifiers, you have freedom like never before. You pick the power from 5 to 80 W. You

pick the bandwidth from 0.7 to 8 GHz, 0.7 to 10.6 GHz or 0.7 to 18 GHz. We put it together for you in one package that costs less weighs less and takes less space than two separate amplifiers.

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

Olympian Oscillators



Bliley Technologies introduces the second product in the Olympian family of oscillators. The Zeus Series OCVCXO offers customer speci-

fied output frequencies between 30 and 130 MHz with phase noise performance down to -178 dBc/Hz at 100 KHz offset. This series has exceptional performance with optional frequency stability versus temperature from ± 500 ppb down to ± 50 ppb. Excellent long term aging is typically ± 1.50 ppm after 20 years. The rugged package comes with an SMA female output and EMI feed thru on all DC inputs. A RoHS compatible version is available as the NVG108C while the standard unit's part number is NV108C.

Bliley Technologies,
Erie, PA (814) 838-3571,
www.bliley.com.

Oscillator Family

Crystek's model CCHD-957 HCMOS CLOCK oscillator family has been designed specifically for High Definition Audio (HD Audio). It features a typical low close-in phase noise of -100 dBc/Hz at 10 Hz offset, and a noise floor of -169 dBc/Hz.



With this extreme low phase noise performance, you will "Hear the Difference." It also features a

"Standby Function," that is, when placed in disable mode, the internal oscillator is completely shut down in addition to its output buffer being placed in Tri-State. This family is housed in a 9×14 mm SMT package and operates with a +3.3 V power supply.

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

Linear Amplifier



The BBS3G6QHM (SKU 2135) is a dual-band, ultra broadband high power linear amplifier. This solid-state 50 W amplifier covers the 300 to 3800 MHz instantaneous frequency band



(targeting the high use, wireless infrastructure bands) and is ideally suited for RF/MW component testing, RF labora-

tory testing and EMC/RFI immunity and susceptibility testing. The self contained, air cooled unit is housed in a standard single R3U chassis. The amplifier is fully equipped with a microprocessor controlled LCD touch screen display for control, internal monitoring and status reporting. Control and status is accessible remotely via GPIB/IEEE-488, RS-422 and TCP/IP Ethernet. Low distortion and optimum RF device performance makes this amplifier suitable for all signal modulations and can operate both in an open loop gain adjustment or ALC mode.

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

TCXO

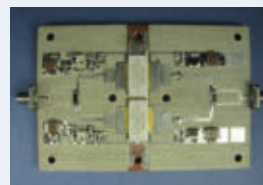


Statek. The T72 offers stability to ± 0.2 ppm (-40° to $+85^\circ\text{C}$), g-Sensitivity of $\leq 2.5 \times 10^{-9}/\text{g}$, a phase noise floor of -155 dBc/Hz (typ. 10 MHz), and low current consumption to 1.9 mA (typ. with clipped sine output). The T72 TCXO, available from 10 to 50 MHz, offers clipped sine wave output and 3.3 V supply voltage. Electronic frequency control (EFC) is provided for precise tuning or phase locking applications. The T72 Series TCXO has been designed to deliver

reliable frequency control performance for a variety of wireless applications, and is well suited for mobile, battery powered applications including GPS and WiMAX. The T72 TCXO stability is not affected by vibration and temperature fluctuations, making it ideal for exploration and tracking equipment applications. Shock level is available to 50,000 g.

Greenray Industries Inc.,
Mechanicsburg, PA (717) 766-0223,
www.greenrayindustries.com.

Radar Pallet



Integra Technologies announced an S-Band radar pallet. Part number ILP3135M240 is a 50 Ω matched high power pulsed radar

pallet amplifier for S-Band radar systems operating over the instantaneous bandwidth of 3.10 to 3.50 GHz. The pallet amplifier supplies a minimum of 240 W of peak pulse power under the conditions of 300 μ s pulse width and 10 percent duty cycle and with 30 W input drive level. All units are 100 percent screened for large signal RF parameters.

Integra Technologies Inc.,
El Segundo, CA (310) 606-0855,
www.integrattech.com.

GaN Wideband Amplifier

The main target of the GaN, 100 W, wideband, 2 to 6 GHz amplifier module is the Electronic Counter Measures (ECM), and jamming markets. The 100 W capability allows ECM and jamming system designers greater flexibility –

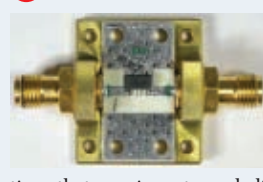


the higher power offers extended operational range and the availability of such power from a single module facilitates compact system design.

Working off a 28 V supply, with inbuilt DC protection circuitry, over temperature and full reverse RF power protection and ruggedized aluminum housing makes the amplifier modules suitable for the harshest environments.

Microwave Amplifiers,
Nailsea, UK +44 (0) 1275 853 196,
www.microwaveamps.co.uk.

MMIC Amplifier



Mini-Circuits' PHA-1+ ultra high dynamic range MMIC amplifier is designed specifically for applica-

tions that require extremely linear performance, particularly wideband, advanced digital communications systems such as TD-SCDMA that require excellent ACLR suppression and low EVM. The E-PHEMT based PHA-1+ provides typically +42 dB OIP3, which translates to ex-

TINY Wideband Transformers



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Rugged, repeatable performance.

At Mini-Circuits, we're passionate about transformers. We even make our own transmission line wire under tight manufacturing control, and utilize all-welded connections to maximize performance, reliability, and repeatability. And for signals up to 6 GHz, our rugged LTCC ceramic models feature wrap-around terminations for your visual solder inspection, and they are even offered in packages as small as 0805!

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A Mini-Circuits exclusive, this new feature is now available on every open-core transformer we sell. Top Hat speeds customer pick-and-place throughput in four distinct ways: (1) faster set-up times, (2) fewer missed components,

(3) better placement accuracy and consistency, and (4) high-visibility markings for quicker visual identification and inspection.

More models, to meet more needs

Mini-Circuits has over 200 different SMT models in stock. So for RF or microwave baluns and transformers, with or without center taps or DC isolation, you can probably find what you need at minicircuits.com. Enter your requirements, and Yoni2, our patented search engine, can identify a match in seconds. And new custom designs are just a phone call away, with surprisingly quick turnaround times gained from over 40 years of manufacturing and design experience!

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New Waves

tremely linear performance in multi-carrier and complex signal environments such as TD-SCDMA supporting ACLR₁ Measurements of better than -60 dBc at +10 dBm output and EVM of 0.57% (rms) and 2.95% (pk) at the same power.

Mini-Circuits,
Brooklyn, NY (781) 934-4500,
www.minicircuits.com.

VCOs



Norden Millimeter is introducing a new line of VCOs that are full waveguide band from WR-42 to WR-10. These VCOs operate in frequency ranges from 18 to 26.5 GHz, 26.5 to 40 GHz, 33 to 50 GHz, 40 to 60 GHz, 50 to 75 GHz, 60 to 90 GHz, and

75 to 110 GHz. These VCOs have input regulators to minimize pushing effects and with the amount of multiplying, amplifying and filtering these units have, there is no load pulling phenomena.

Norden Millimeter Inc.,
Placerville, CA (530) 642-9123,
www.nordengroup.com.

RF Amplifier



The Ophir RF model 5227 is an 80 to 1000 MHz, 500 W minimum output power RF amplifier. This amplifier utilizes Class A linear power devices that provide an excellent third order intercept point, high gain and a wide dynamic range. This is the perfect choice for test and measure-

ment systems needing high power in the smallest commercially available package possible. This RFPA is backed by a three year warranty and Ophir RF's commitment to total customer satisfaction.

Ophir RF,
Los Angeles, CA (310) 306-5556,
www.ophirrf.com.

Gunn Oscillators

VENDORVIEW



The HGM and HGV series Gunn oscillators cover the 7 to 150 GHz frequency range. A wide variety of designs provide solutions for most applications. Units are available with mechanical and/or electrical tuning, providing many possible tuning configurations. Superior frequency and power stability are achieved using cavity designs and optimal diode selection.

Heaters can be provided to achieve greater frequency stability. GaAs and InP Gunn diodes are used depending on the frequency and performance requirements. Cavity designs are mated with the proper Gunn diode to maximize performance. Gunn oscillators are used as sources for mixer LOs, to drive multipliers, transmitters and radars. Options available include voltage regulators, heaters, isolators, heat sinks and micrometer tuners.

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

Low-Noise Amplifiers

VENDORVIEW



Skyworks Solutions has introduced three low-noise and high-linearity LNAs for 1.6 to 3 GHz receiver applications. The SKY67002-396LF (1.6 to 2.1 GHz high linearity LNA), SKY67003-396LF (2 to 3 GHz high linearity LNA), and SKY67102-396LF (2 to 3 GHz ultra low noise LNA) are single-stage, GaAs

PHEMT LNAs that offer ultra low noise figure, high linearity, and excellent return loss in a small QFN package. On-die active bias design ensures consistent performance and enables unconditional stability. These LNAs are designed for wireless infrastructure OEMs who require a high-performance, cost effective solution.

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

Power Amplifier



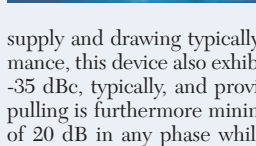
TriQuint Semiconductor unveiled the industry's smallest dual-band PA duplexer (PAD) for global 3G and 4G smartphones. The new TRITIUM Duo™ family combines two band-specific power amplifiers and duplexers in a single compact module, effectively replacing up to twelve discrete

components. The TRITIUM Duo family shares a common 6 × 4.5 mm footprint, giving designers the flexibility to support multi-band, multi-mode operations across multiple platforms.

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

High Performance VCO

The SMV5550B-LF, a high performance VCO, generates frequencies between 5000 and 6000 MHz, covering the 1000 MHz bandwidth with in 0 to 10 V of control. The device covers an area less than 0.10 sq. inches while exhibiting phase noise performance of -80 dBc/Hz, typically, at 10 kHz from the carrier. The SMV5550B-LF delivers 3 ± 3 dBm into a 50 W load with a nominal 5 V



supply and drawing typically 24 mA. In addition to its low noise performance, this device also exhibits excellent second harmonic suppression of -35 dBc, typically, and provides better than 1.1:1 tuning linearity. Load pulling is furthermore minimized to less than 10 MHz with a return loss of 20 dB in any phase while it pushes less than 20 MHz/V with a 5% change in the nominal supply. The SMV5550B-LF operates at a temperature range of -40° to 85°C and is packaged in Z-Communications miniature SUB-L surface-mount package measuring 0.3" × 0.3" × 0.08".

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

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Up/Down Converters
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Multipliers
Improved Harmonics
Lower Input RF Drive
AGC Control

www.wrighttec.com

Model	Frequency (MHz)	Tuning Voltage (VDC)	DC Bias (VDC)	Typical Phase Noise @ 10 kHz (dBc/Hz)
DCMO & DCFD Series				
DCMO25-S	20 - 50	0.5 - 24	+5 @ 30 mA	-114
DCMO514-S	50 - 140	0.5 - 24	+5 @ 28 mA	-105
DCMO818-S	65 - 165	0.5 - 24	+5 @ 28 mA	-108
DCMO1027	100 - 270	0.5 - 24	+5 @ +12 @ 20 mA	-112
DCMO1129	110 - 330	0.5 - 24	+5 @ +12 @ 22 mA	-112
DCMO1545	150 - 450	0.5 - 24	+5 @ +12 @ 22 mA	-108
DCMO1807	180 - 570	0.5 - 24	+5 @ +12 @ 26 mA	-108
DCMO2290-S	220 - 600	0.5 - 24	+5 @ 28 mA	-108
DCMO2476	240 - 760	0.5 - 24	+5 @ +12 @ 26 mA	-108
DCMO3288-S	320 - 880	0.5 - 24	+5 @ 21 mA	-109
DCMO3288-12	320 - 880	0.5 - 24	+12 @ 25 mA	-80
DCPD35105-S	300 - 1050	0.5 - 25	+5 @ 51 mA	-112
DCMO40110-S	400 - 1100	0.5 - 24	+5 @ 37 mA	-103
DCMO40110-8	400 - 1100	0.5 - 24	+8 @ 39 mA	-104
DCMO40110-12	400 - 1100	0.5 - 24	+12 @ 38 mA	-105
DCMO50120-S	500 - 1200	0.5 - 24	+5 @ 37 mA	-102
DCMO50120-12	500 - 1200	0.5 - 24	+12 @ 28 mA	-103
DCMO50170-S	500 - 1700	0.5 - 25	+5 @ 35 mA	-100
DCMO50170-12	500 - 1700	0.5 - 25	+12 @ 29 mA	-100
DCMO60210-S	600 - 2100	0.5 - 24	+5 @ 28 mA	-96
DCMO60210-10	600 - 2100	0.5 - 24	+10 @ 25 mA	-100
DCMO60220-S	600 - 2200	0.5 - 24	+5 @ 28 mA	-98
DCMO60220-12	600 - 2200	0.5 - 24	+12 @ 29 mA	-99
DCMO602200-12	600 - 2200	0.5 - 18	+12 @ 35 mA	-101
DCMO100230-S	1000 - 2300	0.5 - 24	+5 @ 35 mA	-98
DCMO100230-12	1000 - 2300	0.5 - 24	+12 @ 33 mA	-101
DCMO110250-S	1100 - 2500	0.5 - 25	+5 @ 25 mA	-100
DCMO110250-8	1100 - 2500	0.5 - 25	+8 @ 30 mA	-102
DCMO130275-S	1300 - 2750	0.5 - 24	+5 @ 20 mA	-95
DCMO136270-8	1360 - 2700	0.5 - 20	+8 @ 36 mA	-93
DCMO150318-10	1500 - 3100	0.5 - 22	+10 @ 32 mA	-96
DCMO150318-S	1500 - 3200	0.5 - 20	+5 @ 24 mA	-93
DCMO150320-S	1500 - 3200	0.5 - 18	+5 @ 33 mA	-92
DCMO170340-S	1700 - 3400	0.5 - 20	+3.5 @ 18 mA	-85
DCMO170348-S	1700 - 3450	0.5 - 18	+5 @ 43 mA	-88
DCMO172330-S	1720 - 3320	0.5 - 24	+5 @ 22 mA	-94
DCMO190410-S	1900 - 4100	0.5 - 18	+5 @ 45 mA	-90
DCMO200430-S	2000 - 4300	0.5 - 17	+5 @ 50 mA	-89
DCMO250512-S	2500 - 5125	0.5 - 14	+5 @ 51 mA	-76
DCYR & DCYS Series				
DCYR0260-S	200 - 600	0.5 - 28	+5 @ 60 mA	-119
DCYR0307-S	300 - 970	0.5 - 28	+5 @ 38 mA	-112
DCYR09125-10	500 - 1250	0.5 - 24	+10 @ 43 mA	-110
DCYS100200-12	1000 - 2000	0.5 - 28	+12 @ 33 mA	-105
DCYS180585-S	1800 - 3600	0.5 - 20	+5 @ 47 mA	-90
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DCYS200400P-S	2000 - 4000	0.5 - 22	+5 @ 45 mA	-95
DCYS250500-S	2500 - 5000	0.5 - 14	+5 @ 45 mA	-75
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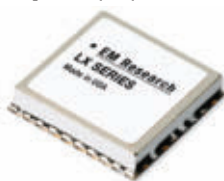
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New Products

Components

Frequency Synthesizer



The LX-7800 frequency synthesizer operates at a fixed-frequency of 7800 MHz and features low power consumption and exceptionally-low phase noise (<92 dBc/Hz at 10 KHz). This unit is available in cost-effective, high-volume Tape-N-Reel de-

signs. LX-7800 provides +8 dBm output power. The unit is designed for SatCom, commercial wireless and military COTS applications. Custom units are available in fixed and programmable frequencies from 5 MHz to 8 GHz in a standard surface-mount package of 0.75" × 0.75" × 0.15".

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

Power Dividers

KRYTAR Inc. announces eight new two-way power dividers offering high performance over the broadband frequency range of 6 to 40 GHz in single, compact packages. The new power dividers frequency coverage includes: Models 6060400 and 6060400K from 6 to 40 GHz; Models 6100400 and 6100400K from



10 to 40 GHz; Models 6180400 and 6180400K from 18 to 40 GHz; Models 6265400 and 6265400K from 26.5 to 40 GHz.

All eight models feature greater than 14.5 dB isolation and ±0.38 dB amplitude tracking. The two-way dividers exhibit insertion loss of less than 1.9 dB across the frequency range. Maximum input VSWR is 1.9 and phase tracking is ±6.5 degrees. Each power divider is a compact package measuring 1.30 (L) × 1.00 (W) × 0.40 (H), and weighing only 1.1 ounces.

KRYTAR,
Sunnyvale, CA
(408) 734-5999,
www.krytar.com.

Ceramic Filter



NIC introduces 728 to 746 MHz LTE Band 12 (Downlink) ceramic filter, a

high performance ceramic filter for cellular and base station applications in the LTE band. This filter operates in LTE band 12 (downlink) offering low insertion loss and high rejection in adjacent bands. Features include: high selectivity and low insertion loss, compact package, competitive pricing and quick delivery, quick turn prototypes (delivery in 3 to 4 weeks ARO), and custom configurations designed up to X-Band.

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

Single-Pole Switch



PMI model P2T-1G18G-10-R-528-SFF-HIP10W is a single pole, two throw, reflective switch capable of operating with an input power of 10 W CW over the 1 to 18 GHz frequency



range. This model features high input power handling capability while offering very fast switching speeds of 40 nsec. This switch

is compact in size and weight and only consumes 2.5 mA of positive and 2.5 mA of negative DC current making it suitable for a wide range of applications.

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

RF Resistor



Richardson RFPD Inc. announced immediate availability and full design support capabilities for a new ultra-high-reliability, 400 W, flanged RF resistor with brazed construction from An-

aren. The G400B50W5 offers 50 Ω resistance and can handle 500 K on/off cycles, which is

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To meet the demands set by commercial and defense related wireless communication systems, radar and avionics, designers of high-frequency electronics are required to develop products with greater levels of performance and functionality, often with a smaller physical footprint and shorter design cycle. The increasing complexity of advanced RF/microwave devices with

interactions between RFICs, packages and PCBs poses a real threat to design success. Our panel of experts will discuss the nature of these challenges and the latest solutions available to designers to reduce design failure. An open panel discussion session will follow the presentations including audience questions from both live and online participants.

Speakers:

Chris Morton, Device Modeling Business Manager, Agilent Technologies
Steve Reyes, Product Marketing Manager Network Analyzers, Anritsu
Gary Simpson, CTO, Maury Microwave
Josh Moore, Solution Architect, AWR Corporation

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New Products

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Richardson RFPD,
LaFox, IL (630) 208-2700,
www.richardsonrfpd.com.

Precision Adapters

Southwest Microwave Inc. (SMI) announces a full range of precision adapters, both within-series and between-series, encompassing SMA, SMA to N, 2.92 mm, 3.5 mm to 2.40 mm, 2.92 mm to 2.40 mm, SSMA to 2.40 mm, and 2.40 mm. Plus unique 0.9 mm to 1.85 mm. They offer near metrology grade performance, referred to as precision and are ideally suited for



length. SMI adapters provide an economical lower cost solution for critical production and test requirements.

Southwest Microwave Inc.,
Tempe, AZ (480) 783-0201,
www.southwestmicrowave.com.

Broadband Double Balanced Mixer

The SGS-5 is a broadband double balanced mixer, constructed to meet stringent environ-

mental requirements in military, industrial and commercial applications. This product has excellent electrical performance across the

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levels of +10, +13 or +17 dBm. The DC coupled IF makes this mixer ideal for up and down conversion, image rejection, modulators and phase detectors.

Synergy Microwave Corp.,
Paterson, NJ
(973) 881-8800,
www.synergymicrowave.com.

Bi-Directional Coupler



The model C8060-102 is a high power 20 dB bi-directional coupler that covers the entire 200 to 6000

MHz band at 200 W CW. Model C8060-102 is rated for 200 W CW, and is ideal for lab environments where one coupler can meet multiple testing requirements. The coupler is 4.8" x 0.88" x 0.5" and it is designed for military and commercial applications. It has an operating temperature of -55° to +85°C and is available with SMA Female Connectors.

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

Semiconductors

Direct I/Q Modulator



Hittite Microwave Corp. has launched a new high linearity wideband direct I/Q modulator, HMC1097LP4. The HMC1097LP4E is a high linearity, low noise direct quadrature modulator RFIC that is rated from 100 MHz to 6 GHz. This wideband direct modulator exhibits an



outstanding output IP3 of +30 dBm, noise floor of -160 dBm/Hz, output P1dB of +11 dBm, and sideband suppression

of -46 dBc. The RF output port is single-ended and matched to 50 Ohms with no external components while the LO input operates from drive levels between -6 and +6 dBm, and can be driven in either differential or single-ended mode. The HMC1097LP4E has a flexible architecture where its output IP3 can be further optimized over different frequencies up to 6 GHz. The HMC1097LP4E exhibits a very fast enable/disable feature that can be used to reduce system power dissipation in TDD-based cellular communication systems.

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



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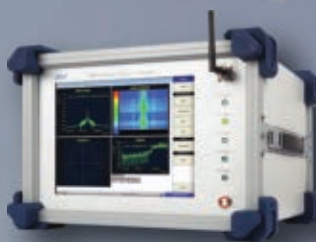
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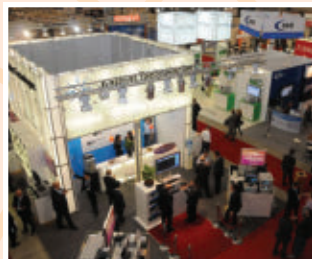
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Brian Barr and Dan Burkhard,
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White Paper, SemiGen

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Frequency Matters.

New Products

PHEMT Process

The PPH15X-10 MMIC GaAs power PHEMT process has been successfully space evaluated and is now part of the European Preferred Part List established by the European Space Agency/European Space Components Information Exchange System (ESA/ESCIES). This process is optimized for wideband high power amplification up to 45 GHz with a typical F_t of 65 GHz and a power density >750 mW/mm at 6 V. It includes two metal interconnect layers, precision TaN resistors, high value TiWiSi resistors, two MIM capacitor densities (250 and 625 pF/mm²), air-bridges and back-end via-holes. A BCB protection option is also available on PPH15X-10 for repeatable package performance. Applications include medium power amplifiers, K- and Ka-Band power amplifiers, VSAT and point to point radio.

United Monolithic Semiconductors,
Villebon-sur-Yvette, France
+33 (0)1 69 86 32 00,
www.ums-gaas.com.

Systems

Front End Module



RFMD's new RF6504 is a Front End Module (FEM) for 433 to 470 MHz AMI/AMR systems. The Tx port provides a PA with nominal output power of 30 dBm and gain of 15 dB. The Rx passthrough port is on a separate path. Both are combined with a single antenna port and SP2T switch, all presented in a 5.5×5.0 mm, 28-pin package.

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

Full-Band Receiver



Spacek Labs model ME-15x2 is a full-band receiver that downconverts all of E-Band (60 to 90 GHz) to an IF of 1 to 31 GHz. The conversion loss is 7 dB typical, 13.5 dB max. The LO is derived from a customer supplied 29.5 GHz signal at +15 to +17 dBm that drives a passive doubler generating +5 dBm at 59 GHz. The mixer requires +15 VDC at 10 mA bias. The RF port is WR-12 waveguide and the LO and IF ports are coaxial 2.9 mm "K" (f) connectors.

This receiver can be used to extend the frequency range of a spectrum analyzer with close in measurements using a customer supplied stable LO source.

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

Test Equipment

Vector-PIM Tester



This instrument, which is based on a Non-Lin-IM and PIM-tester from Rosenberger, supports accurate PIM measurements, localisation of IM-obstacles, and exact modelling of IM-defects. It enables users to perform calibrated complex PIM measurements. The software manages the calibration and error correction, and supports various PIM-tests as well as

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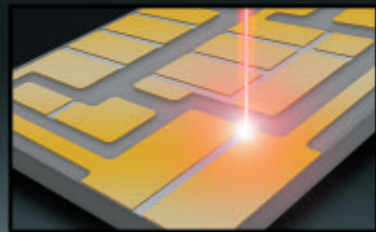


Model LVC440-495VS tunes 440MHz to 495MHz and is used in handheld wireless RF applications. A bias voltage of 1.5V delivers + 2.0dBm power with only 5ma current consumption. Phase noise is -94dBc @ 10kHz offset. Package size is 0.175 inch square with height of .075 inch. Supplied on T&R and priced @ \$4.95 ea for 10k quantity.

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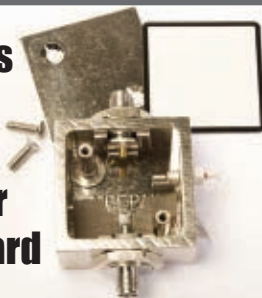


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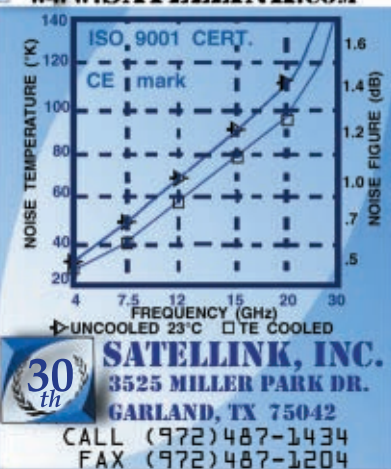


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The Book End



Handbook of RF and Microwave Power Amplifiers

Edited by John L. B. Walker

Amplifier design is changing rapidly as GaN and LDMOS have taken root in some high power applications. Efficiency levels are being pushed to unprecedented levels above 50 percent in many applications by applying new design techniques and models. Covering state-of-the-art developments and emphasizing practical communications applications, this is a complete reference book on power amplifiers. John Walker of Integra Technologies has brought together a team of expert authors that cover most every topic related to the subject, includ-

ing: devices (Si LDMOS and VDMOS, GaAs FETs, GaN HEMTs), circuit and amplifier design (discrete, hybrid and monolithic), CAD, thermal design, reliability and system applications/requirements for RF and microwave transistor amplifiers. Industry experts such as Inder Bahl, Steve Cripps and Stephen Maas were contributors to this book.

It is well organized with separate chapters for three types of RF power transistors (silicon, GaAs and GaN/SiC) and separate chapters for amplifiers of different types (HF/VHF/UHF, microwave and IC). It covers the basics and progresses into more complicated subjects including design, modeling, analysis, realization, integration, thermal design, reliability and measurements. The applica-

tions and measurements sections are very thorough, making up the last few hundred pages and covering many sub-topics. It is a good reference for both commercial and military designers and could be used for academic or industrial use. Whether you are an RF transistor designer, amplifier designer or a system designer, this is a good all inclusive reference book for RF and microwave transistor power amplifiers.

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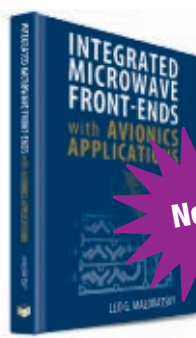
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Live webcast: 4/5/12, 1:00 PM ET

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Fast and Accurate Frequency Converter Characterization

This webcast discusses new methods for characterizing frequency converters with external or embedded local oscillators, using Agilent's PNA-X high-performance network analyzer and the latest measurement algorithms. Featured measurement includes a new method for measuring group delay without the use of reference or calibration mixers.

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Technical Education Series

Presented by: Dr. Joey Bray, Royal Military College of Canada

Radar Fundamentals

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Live webcast: 4/24/12, 11:00 AM ET

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This webcast will introduce the new multi-measurement capability of the 89600 VSA software to address wireless R&D needs. We will discuss real life challenging test scenarios and demonstrate how to run multiple VSA's side-by-side within a single, optimized user interface, either controlling several instruments at once, or sharing a single instrument among several measurements.

Live webcast: 4/25/12, 1:00 PM ET

Agilent in LTE Series

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Optimize UE Design for Greater Battery Run-Time

This webcast will discuss the challenges of verifying battery consumption during different UE operating modes and the tools available to measure the effects in power consumption resulting from the complex interactions between hardware, firmware, operating system and applications. It will evaluate the benefits of test automation.

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THOUSAND MONKEYS

A big building in which a thousand monkeys are living is lit by a thousand lamps. Every lamp is connected to a unique on/off switch, that are numbered from 1 to 1000. At some moment, all lamps are switched off. But because it is becoming darker, the monkeys would like to switch on the lights. They will do this in the following way.

Monkey 1 presses all switches that are a multiple of 1.

Monkey 2 presses all switches that are a multiple of 2.

Monkey 3 presses all switches that are a multiple of 3.

Monkey 4 presses all switches that are a multiple of 4.

Etc.

How many lamps are switched on after monkey 1000 pressed his switches?

And which lamps are switched on?



BEACH WALK

Along the beach are a number of poles standing at equal distance from each other. The poles are numbered 1, 2, 3, 4, Alice is walking from the first pole to the last one and back, Bob is doing that in the opposite direction. They start at the same time and walk with constant, but different velocities. Their first encounter is at pole number 10, their second (when they're both on the way back) at pole number 20. How many poles are standing along the beach?



ALSO HAVING BIRTHDAY TODAY?

What is the smallest size that a group of people can be in order to have that the probability that two people out of the group have a birthday on the same day be larger than 1/2?



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PLD	30-130 MHz	P.L. Crystal	-95	-115	-140	-155	-155	-	100 MHz	13
PLD-1C	130-1000 MHz	P.L. Mult. Crystal	-80	-100	-120	-130	-135	-	560 MHz	13
BCO	100-16.5 GHz	P.L. Single Loop	-65	-75	-80	-90	-115	-	16.35 GHz	13
VFS	1-14 GHz	Multiple Freq. Dual Loop	-60	-75	-110	-115	-115	-	12.5 GHz	13
DLCRO	.8-26 GHz	P.L. CRO Dual Loop	-60	-85	-110	-115	-115	-138	10 GHz	13
PLDRO	2-40 GHz	P.L. DRO Single/Dual	-60	-80	-110	-115	-120	-145	10 GHz	13
CP	.8-3.2 GHz	P.L. CRO Single Loop	-80	-110	-120	-130	-130	-140	2 GHz	13
CPM	4-15 GHz	P.L. Mult. Single Loop	-60	-90	-105	-110	-115	-130	12 GHz	13
ETCO	.1-24 GHz	Voltage Tuned CRO	-	-	-70	-100	-120	-130	2-4 GHz*	13

* Octave band.

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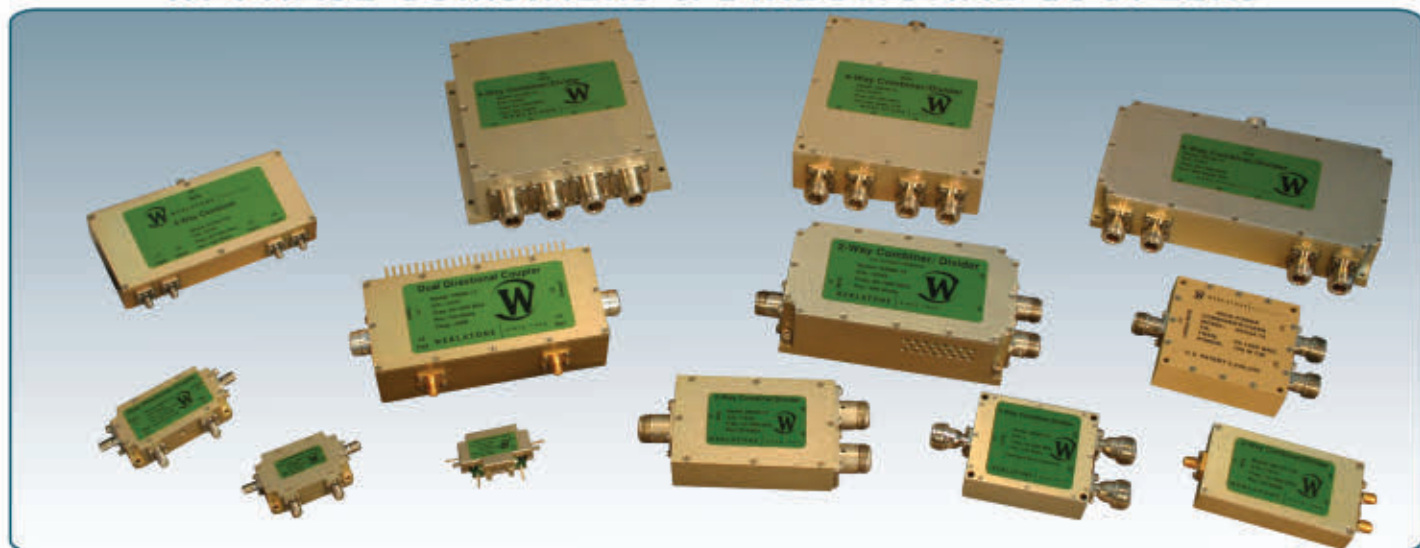
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Model	Type	Frequency (MHz)	Power (WCW)	Size (Inches)	Insertion Loss (dB)	VSWR	Isolation (dB)
D6233	2-Way	10-1000	25	3.25 x 2 x 1.1	0.75	1.35:1	20
D8632	2-Way	20-1000	50	2.2 x 2.02 x 1.5	0.7	1.40:1	20
D8300	2-Way	20-1000	100	2.45 x 2 x 0.91	0.5	1.35:1	20
D8544W*	2-Way	20-1000	100	2.85 x 2.5 x 1	0.5	1.35:1	18
D8682	2-Way	20-1000	500	5.2 x 2.65 x 1.8	0.6	1.35:1	15
D8851W*	2-Way	20-1000	500	5.6 x 3.05 x 1.8	0.6	1.35:1	15
D7365	4-Way	20-1000	100	5 x 2 x 1	0.75	1.35:1	20
D7439	4-Way	20-1000	250	5 x 5 x 1.5	0.75	1.35:1	18
D8746	4-Way	20-1000	500	7.2 x 3.5 x 1.4	0.7	1.35:1	15
D9048	4-Way	20-1000	500	5 x 4.7 x 1.4	0.6	1.35:1	17

* "W" references a Watertight Design

Dual Directional Couplers

Model	Coupling (dB)	Frequency (MHz)	Power (WCW)	Size (Inches)	Insertion Loss (dB)	VSWR	Directivity (dB)
C8858	40	10-1000	250	2.09 x 1.16 x 0.57	0.4	1.30:1	20
C8631*	40	20-1000	150	1.5 x 0.95 x 0.5	0.35	1.25:1	20
C8696	40	20-1000	150	1.76 x 1.16 x 0.57	0.35	1.25:1	20
C8686	40	20-1000	500	5.2 x 2.7 x 1.7	0.35	1.25:1	20

* Non-Connectorized / Tabs

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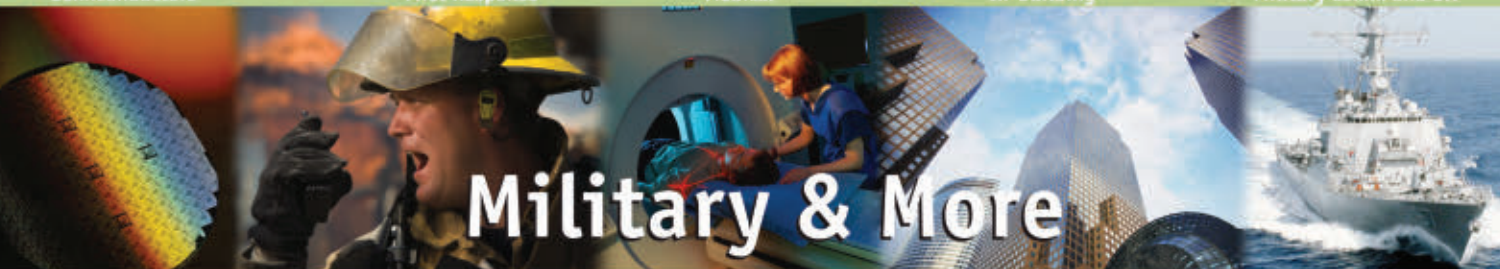
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