Vol. 56 • No. 8

August 2013

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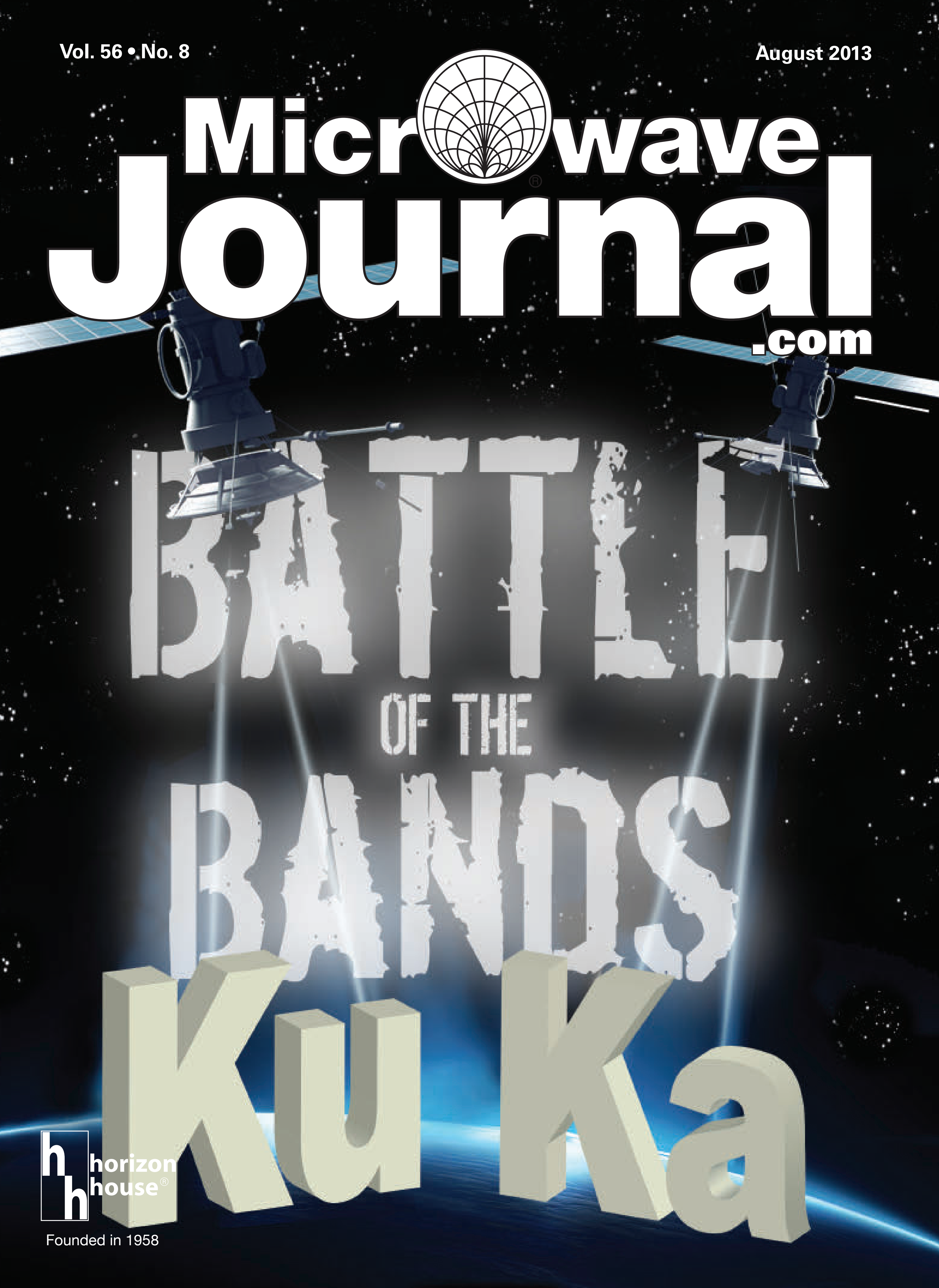

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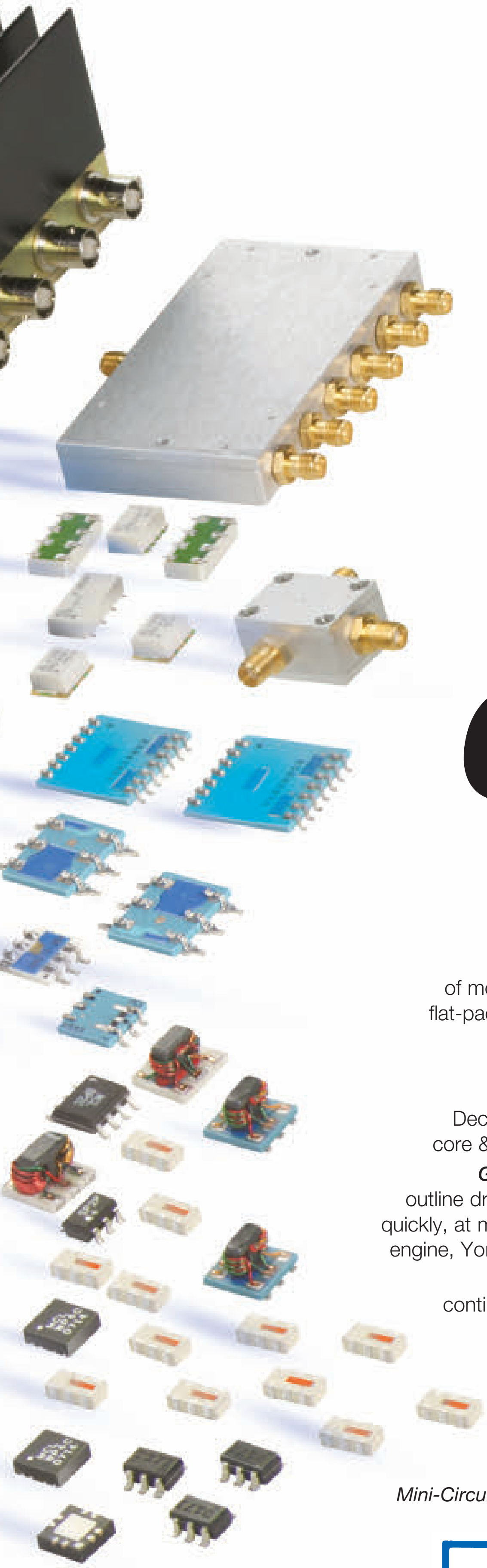


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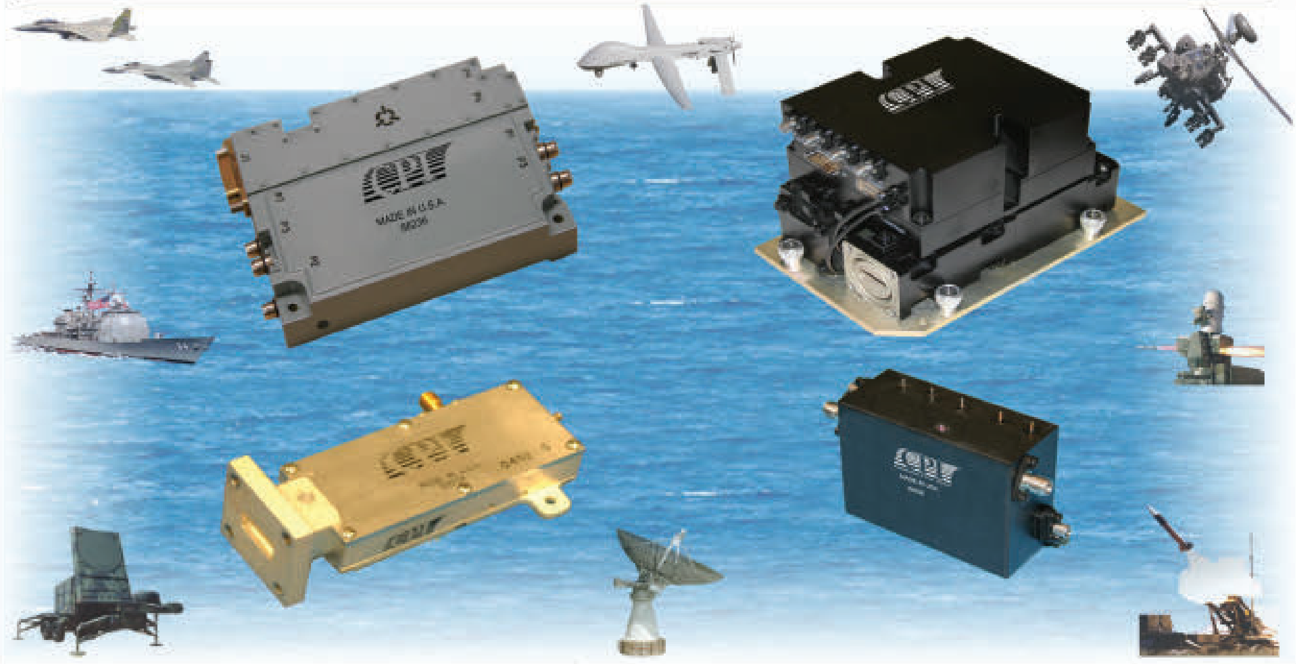

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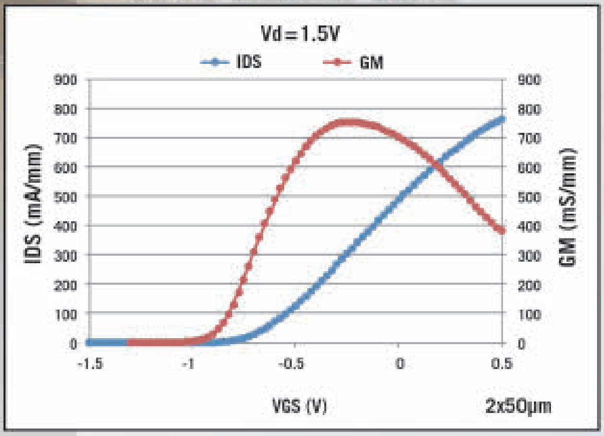

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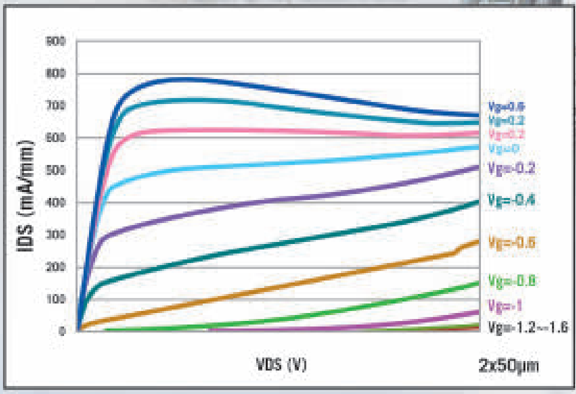

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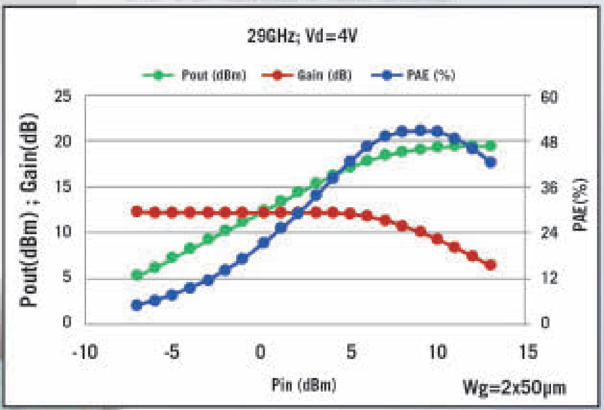
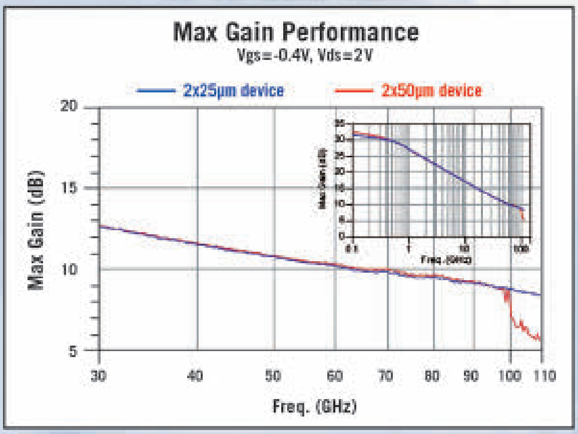


PP10 Max Gain



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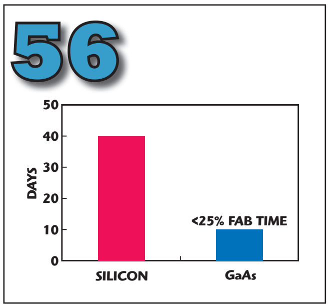

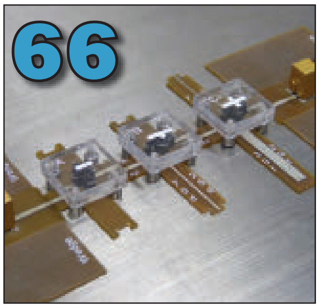

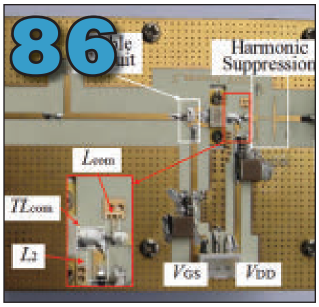

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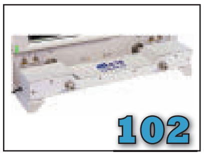

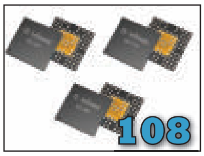

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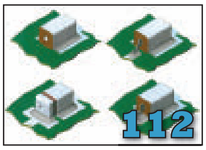

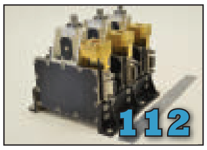

Tech Briefs

NEXT MONTH

September 2013
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- Automotive Radar: From Its Origins to Future Directions
- European Microwave Market Report
- Design of a SP8T, 50 to 1000 MHz, 20 W PIN Switch

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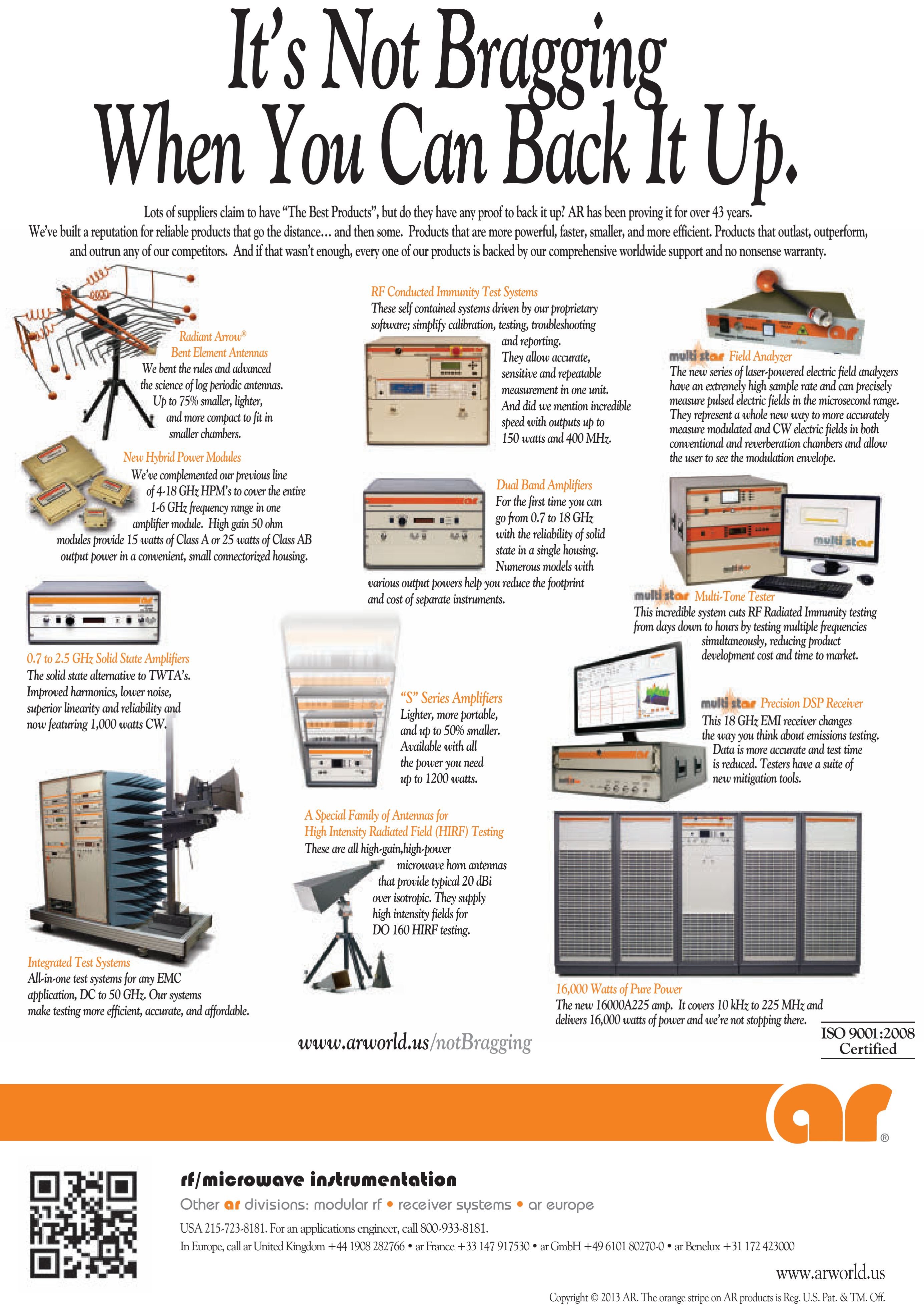
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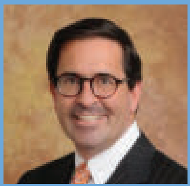
Executive Interviews



Chris Kneizys, president of **Micro-Coax Inc.**, discusses the company's experiences in the connector market on its 50th anniversary including its expertise, distribution and partnership with Rosenberger.

Anthony Sweeney, general manager of RF and microwave components group at **Mercury Systems**, discusses the company's expansion into the end-to-end systems market including various acquisitions into the RF and microwave area to complete its lineup.

June Survey

What does "73" mean to a ham operator?

The year that the song "Convoy" was released [1 vote] (1%)

Maximum ham radio bandwidth in kHz [7 votes] (9%)

Call sign-off meaning "Best Regards" [58 votes] (73%)

Model year of the Pontiac Firebird in "Smokey and the Bandit" [1 vote] (1%)

FCC maximum allowable antenna height in meters [12 votes] (15%)

White Papers

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EMI Pre-Compliance Testing
Agilent Technologies

Understanding Vector Network Analysis
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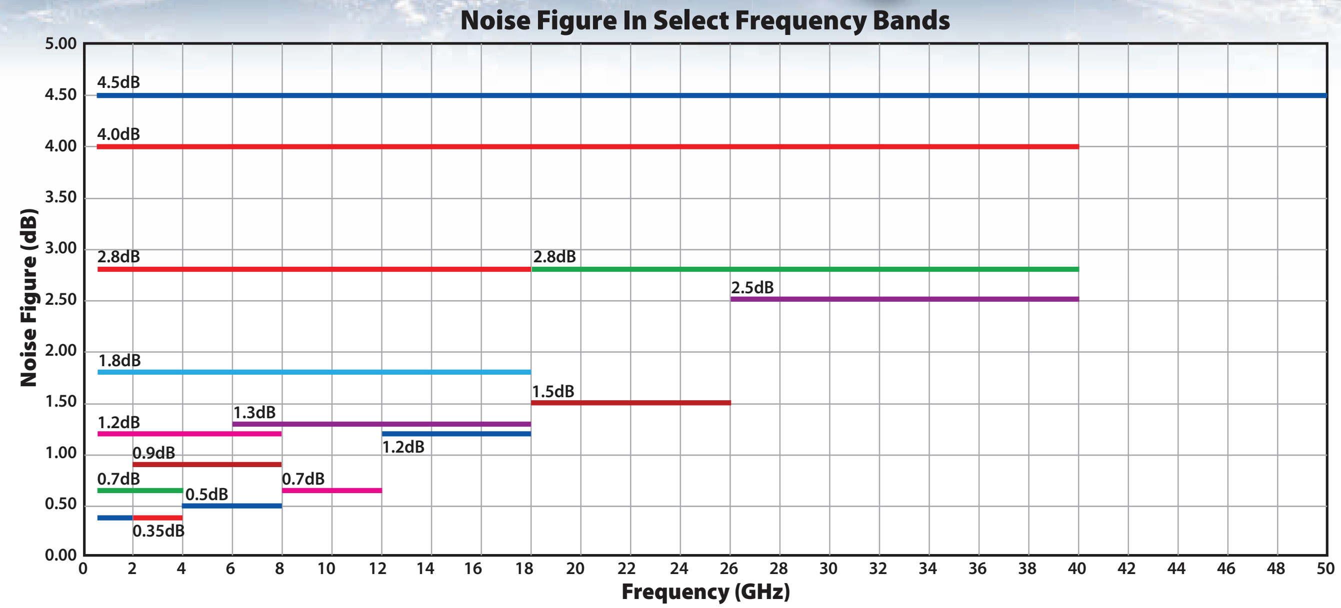

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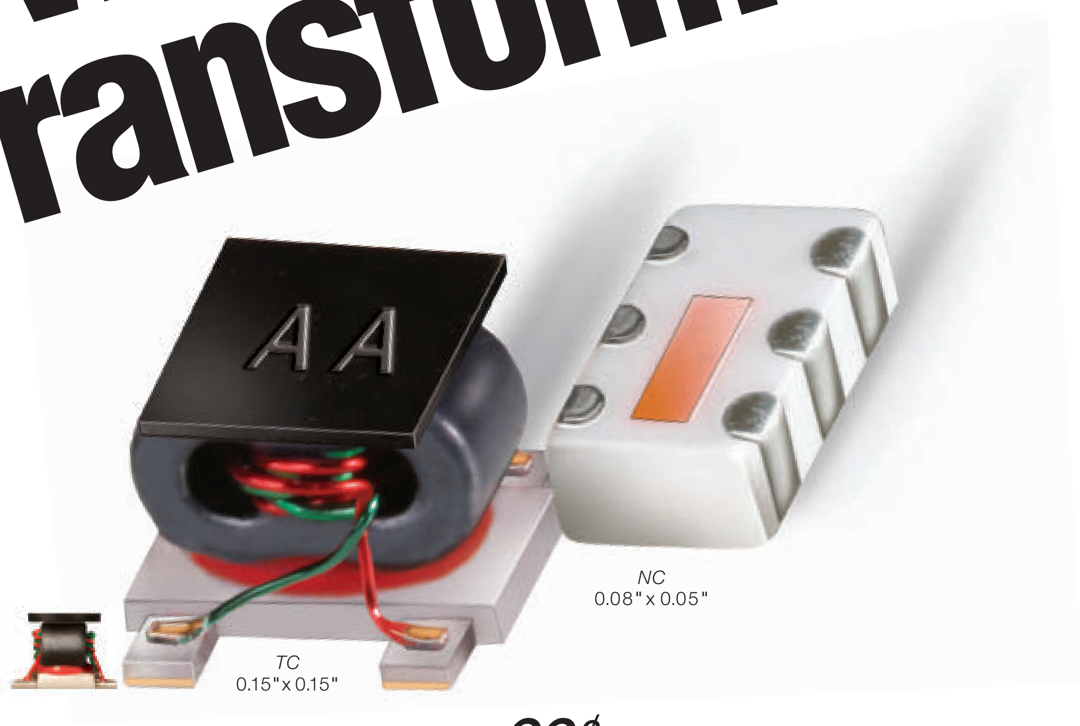

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U.S. Patents 7739260, 7761442

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1	2	3 IRMMW-THz 2013 Mainz on the Rhine, September 1st - 6th Mainz, Germany; MMS 2013 Saida, Lebanon	4	5	6	7
8	9	10 **Webinar:** MMIC Sponsored by AWR	11	12	13	14
15	16 ICUWB 2013 Ultra-Wideband Sydney, Australia	17 ION GNSS+ 2013 Nashville, TN; 11th Military Antennas Washington D.C.; **Webinar:** MMIC Amplifiers Sponsored by Mini-Circuits	18 **Webinar:** Analysis and Diagnostic Software Sponsored by MVG, SATIMO	19 **Webinar:** CST High Speed and High Power Connector Design	20	21
22	23	24 **Webinar** Sponsored by National Instruments	25	26 **Webinar:** CST Modeling and Simulation of Metamaterial-based Services	27	28
29	30 EDI CON 2014 Electronic Design Innovation Conference 电子设计创新会议 Call for Papers Deadline	1	2	3	4	5 Next month: European Microwave Week, NCC Nuremberg, Germany, 6-11 October 2013, www.eumweek.com, Meet Experts Make Friends

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EDI CON 2014
September 30, 2013

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February 14, 2014

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SEPTEMBER

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September 1–6, 2013 • Mainz, Germany
www.theconference2013.com

MMS 2013
13th Mediterranean Microwave Symposium
September 2–5, 2013 • Saida, Lebanon
www.iutsaida.ul.edu.lb/mms2013

ICUWB 2013
IEEE International Conference on Ultra-Wideband
September 15–18, 2013 • Sydney, Australia
www.icuwb2013.org

ION GNSS+ 2013
September 16–20, 2013 • Nashville, TN
www.ion.org

IDGA's Military Antennas East Summit
September 17–18, 2013 • Washington D.C.
www.militaryantennasevent.com

OCTOBER

AMTA 2013
35th Annual Symposium of the Antenna Measurement Techniques Association
October 6–11, 2013 • Columbus, OH
www.amta2013.org

EuMW 2013
European Microwave Week
October 6–11, 2013 • Nuremberg, Germany
www.eumweek.com

COMSOL Conference 2013
October 9–11, 2013 • Boston, MA
www.comsol.com/conference2013/usa

Phased Array 2013
IEEE International Symposium on Phased Array Systems & Technology
October 15–18, 2013 • Boston, MA
www.array2013.org

Microwave Update 2013
October 18–19, 2013 • Morehead, KY
www.microwaveupdate.org

IEEE COMCAS 2013
International Conference on Microwaves, Communications, Antennas and Electronic Systems
October 21–23, 2013 • Tel Aviv, Israel
www.comcas.org

IME/China 2013
8th International Conference and Exhibition on Microwave and Antenna
October 23–25, 2013 • Shanghai, China
www.imwexpo.com

4G World 2013
October 28–30, 2013 • Dallas, TX
www.4gworld.com

NOVEMBER

APMC 2013
Asia-Pacific Microwave Conference
November 5–8, 2013 • Seoul, Korea
www.apmc2013.org

2013 Loughborough Antennas & Propagation Conference
November 11–12, 2013 • Loughborough, UK
www.lapconf.co.uk

MILCOM 2013
Military Communications Conference
November 17–20, 2013 • San Diego, CA
www.milcom.org

DECEMBER

IMaRC 2013
IEEE International Microwave and RF Conference
December 14–16, 2013 • New Delhi, India
www.imarc-ieee.org

AEMC
4th Applied Electromagnetics Conference
December 18–20, 2013 • Bhubaneswar, India
http://ieee-aemc.org

JANUARY

IEEE RWW 2014
Radio Wireless Week
January 20–23, 2014 • Newport Beach, CA
www.radiowirelessweek.org

FEBRUARY

MWC 2014
Mobile World Congress
February 24–27, 2014 • Barcelona, Spain
www.mobileworldcongress.com

MARCH

SATELLITE 2014
March 10–13, 2014 • Washington D.C.
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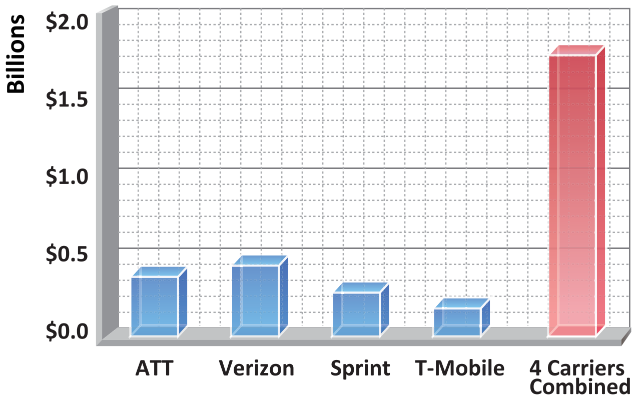

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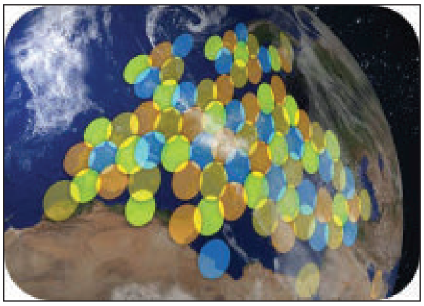
COVER FEATURE
INVITED PAPER

Separating Fact from Fiction: HTS Ka- and Ku-Band for Mission Critical SATCOM

Whether for enterprise, commercial, government or maritime services, customers who operate in remote and harsh environments use satellite services for time-sensitive, mission critical communications. Whether communicating back to headquarter offices or providing morale services to staff and crew members, it is vital that these customers that operate in remote and harsh landscapes have access to high availability, reliable communications links.

High throughput satellite (HTS) technologies with unprecedented bandwidth and power resources are being viewed as "the wave of the future" for satellite communications and networking services. Despite this tremendous potential, there is a great deal of misperception and lack of understanding about these new technologies among both customers and the industry at large. With different options, how do you pick the best one for your company's needs?

While Ka-Band satellite services have gained traction and general customer acceptance and are often viewed as the "shiny penny" of satellite communications, traditional Ku-Band SATCOM is generally viewed like business-as-usual and does not necessarily excite the imaginations of very small aperture terminal (VSAT) customers. This perception has been in part created by industry hype over Ka-Band, but this observation is overstated and does not fit all application environments. A similar phenomena was observed in the 1980s when Ku-Band systems first appeared. Many industry pundits speculated that C-Band would all but disappear from use in VSAT applications. It has turned out to be quite the contrary, as C-Band continues to grow as an important band in industrial, military and especially maritime applications where atmospheric attenuation is particularly acute. In general, all frequency bands have their place in satellite communications.



▲ *Fig. 1 High throughput satellite spot beams.*

In order to better understand the real potential and practical application of this new generation of HTS spacecraft, Harris CapRock conducted an in-depth engineering analysis of several HTS systems for customers operating in remote, mission-critical environments. Harris CapRock used industry data combined with its team's experience to compile an analysis that enables a clearer view of HTS capabilities considering beam coverage, power consumption, frequency band, link availability and actual cost per bit of transponded capacity.

A CLOSER LOOK INTO HIGH THROUGHPUT SATELLITES

A HTS system is defined as a satellite system that uses a large number of small spot beams

BEN PAWLING
Harris CapRock, Melbourne, FL
KEITH OLDS
Harris Government Communications, Melbourne, FL

distributed over a particular service area (see ***Figure 1***). These spot beams provide high signal strength and signal gain (EIRP and G/T), which allow the satellite to close links to small aperture earth stations at high data rates with positive rain-fade margin to provide good overall link availability. A typical HTS has a significant number of ultra-wideband transponders distributed among the beams, each with a bandwidth of more than 100 MHz.

HTS solutions include both Ka-Band and Ku-Band platforms. Each band is not interchangeable, and has its own strengths and weaknesses which make each better suited for some applications and less suited for others. To help understand the differences between HTS Ka-Band and HTS Ku-Band, it is best to know some information about HTS systems in general:

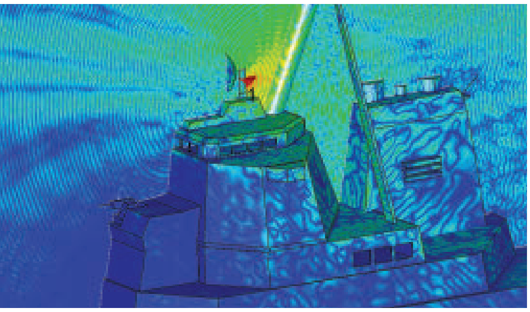
- Coverage area is divided into many small spot beams, unlike one large beam from a conventional satellite
- Each spot beam covers an area 1 to 2 percent the size of a diffused conventional beam
- Spot beams support large-scale frequency reuse for high data rates
- Smaller, more concentrated spots support higher performance than one conventional beam
- HTS systems operate in either Ku- or Ka-Band frequency.

HTS systems combine the exceptional spectrum efficiency and performance of spot-beam antennas with ultra-wideband transponders to enable unprecedented levels of bandwidth and throughput. Each spot beam reuses frequencies in multiple carriers so that a single HTS spacecraft can provide five to 10 times the capacity of traditional satellites. For the customer, this provides the potential to dramatically increase data rates, upwards of 100 Mbps to a single site and improve application performance compared to traditional satellite-based communications.

HTS spot beams generally have 3 dB beamwidths between 0.5 and 1.5 degrees. Spacecraft have been built or proposed with antennas ranging from a dozen to more than 100 spot beams. HTS payloads commonly have 5 to 10 GHz of transponder bandwidth, but channel frequencies are reused numerous times in geographically isolated spots so that the spectrum needs of the system are constrained within available satellite bands. Spot beams may be steered or fixed relative to the satellite. Since the spot beams have limited geographic coverage, HTS systems generally have special gateway beams and transponders specifically to support connections with teleports.

The narrow beamwidths associated with spot beam antennas are created by employing relatively large antenna structures that focus downlink energy and have large areas for collecting uplink energy. Consequently, these antennas greatly improve link performance, providing high data rates at much better availability than traditional regional and hemispherical beams. However, since these antennas accomplish their link improvements by focusing the radio signals into small spots on the earth's surface, these improvements come at the price of geographic coverage.

Because the coverage and performance trade off is particularly important for Ka-Band HTS systems, where the links are especially susceptible to propagation impairments due to rain and other atmospheric disturbances,



the developers of HTS systems must balance their geographic coverage needs against the link performance that small spot beams can provide (see ***Figure 2***). Antenna size scales inversely with the square of the frequency. Therefore, using very narrow spot beams to mitigate these propagation impairments is particularly attractive in Ka-Band. On the other hand, the number of transponders, the payload complexity and the spacecraft power requirements all scale directly with the number of beams on the satellite, so very small beams also limit the available service area of the HTS.

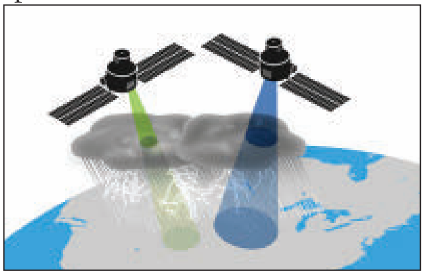
The natural contention between coverage and link performance has tended to divide Ka-Band HTS systems into two classes: those optimized primarily to achieve high availability links and those optimized primarily for large area coverage. The first class is characterized by fractional-degree antenna beamwidths, whereas the second class sacrifices link performance to use larger spot beams. Of course, a great many considerations and trade-offs go into the development of satellite communications systems, so this classification is a simplification of a much more complex situation.

KA- VS KU-BAND: PONDERING PERFORMANCE

When examining the advantages and disadvantages of Ka-Band from a technical standpoint, it is important to view the pros and cons in terms of specific target markets. In remote, harsh environments, customers generally place a higher priority on network reliability, user throughput and application performance. On one side, there are those that want a remote workspace configured as a VPN with guaranteed bandwidth and a solid, reliable service that is capable of running sophisticated applications in a heavy duty commercial environment. Alternatively, there are casual users who do not necessarily need access to a complete network, but to simply provide their crew members with access to the Internet and voice communications. Side-by-side technical and cost comparisons of Ka- and Ku-Band HTS solutions show advantages and disadvantages for both system solutions.

Cost

The use of spot beams allows both the Ku- and Ka-Band systems to achieve high spectrum efficiencies. Further, HTS systems in both bands use ultrawideband transponders and frequency reuse. These features create an economy of scale that allows satellite operators to offer bandwidth at attractive and comparable prices. However, this advantage is eroded when a Ka-Band system sacrifices link performance in favor of coverage by using larger spot beams. These factors are not discriminators between the Ku-Band spot and Ka-Band small spot systems, but Ka-Band large spot systems do not fare as well from this perspective. As a result, HTS Ku-Band



▲ *Fig. 2 Ka-Band HTS coverage vs. throughput trade off.*

spot systems actually tend to demonstrate a cost per bits per second that is more favorable than Ka-Band, when compared at the same link availability, design requirement and larger spot beam sizes.

Coverage

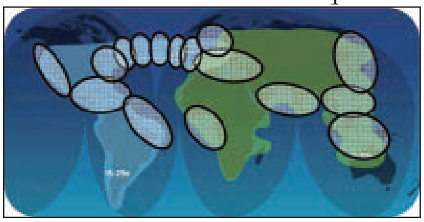
Spot beam systems are, by their nature, limited in coverage. Each spot beam generally covers at most a few thousand square kilometers. However, some HTS systems provide large fields of spot beams that collectively create continental and even global coverage, whereas others offer only a relatively small number of fixed or steerable spots in targeted areas. Ku- and Ka-Band large spot beams are similar in beamwidth and so are generally comparable in system coverage. Ka-Band small spot beams, however, generally cover only about 10 or 15 percent of the area covered by a large spot beam and these spacecraft tend to offer less total spot beam coverage.

Flexibility and Bandwidth Portability

Commitment to the development of an HTS system represents a substantial and long-term investment of resources, not just for the satellite operator but also for network providers and customers as well. The anticipated lifetime of these systems is greater than a decade, and yet their target marketplace is dynamic. Over the long term, the energy, maritime and government sectors are subject to transformation or disruption by factors such as new mineralogical discoveries, changes in shipping patterns or international crises. Thus it is advantageous to be able to relocate services and capacity to respond to major changes in the marketplace. Multiple satellite systems with near global coverage such as some of the Ku- and Ka-Band large spot systems can respond to these changes more readily than the small spot Ka-Band HTS systems (see ***Figure 3***). Ku-Band HTS systems and Ka-Band systems with other frequency backup have the additional benefit that their VSAT links can, if necessary, be reallocated to traditional systems, albeit in some cases at a loss of service performance if the back-up service operates in a significantly longer wavelength.

Recovering from Satellite Failure

A great deal of Ku-Band satellite service provided by traditional spacecraft is available virtually everywhere in the world. Because many Ka-Based systems are offered on closed networks, the services are often scarce. Thus, in the event of a failure on an HTS spacecraft resulting in loss of service to a spot beam or beams, it is possible to mitigate the service impact by migrating customers in the affected area to an alternate Ku-Band satellite. This same back up capability is less likely to be available at Ka-Band. Unless the customer adds a standby service for Ka-Band in Ku-Band or some other satellite band which would require ad-



▲ *Fig. 3 Intelsat Epic satellite platform uses multiple bands and beam sizes.*

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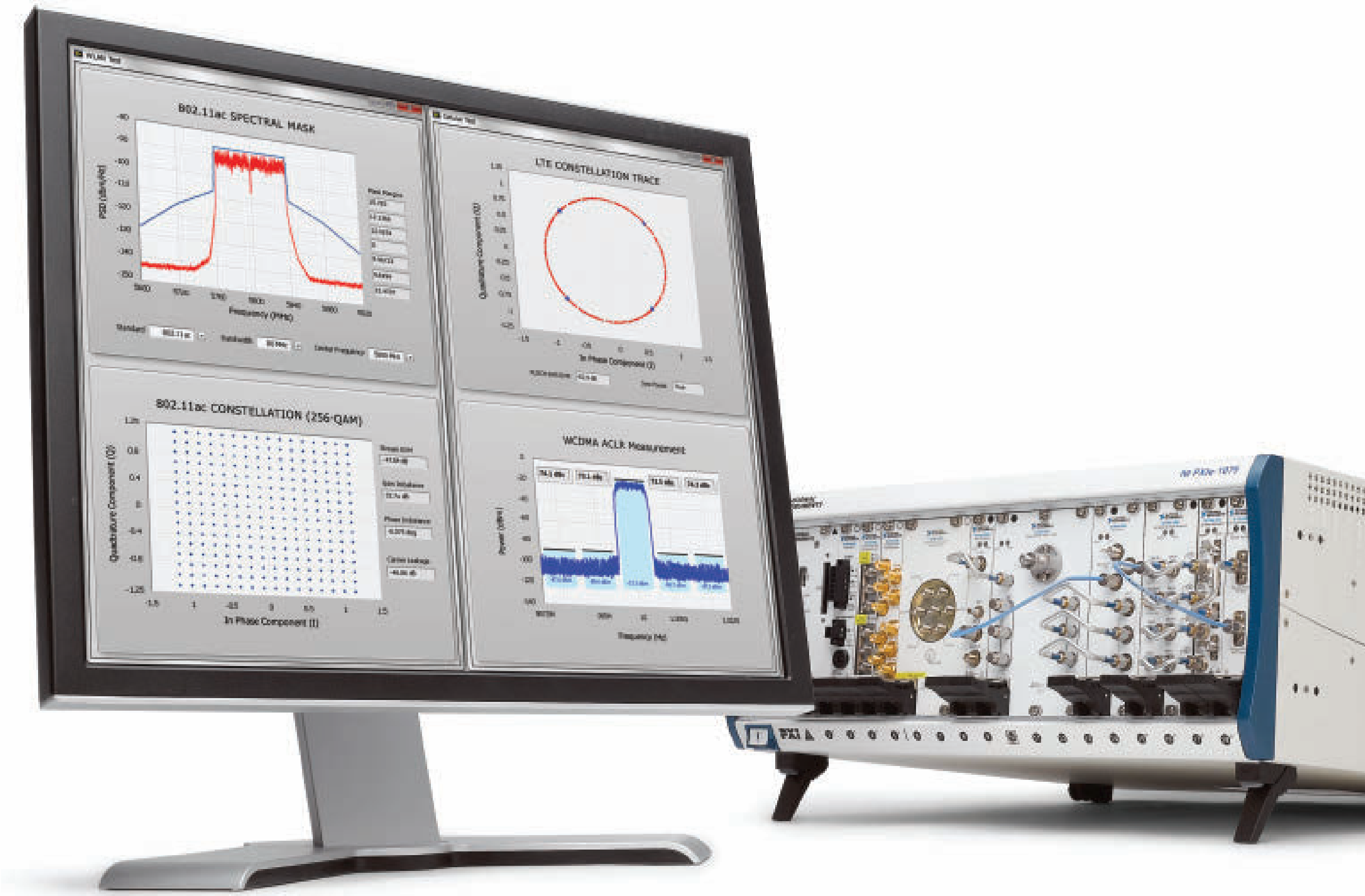

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VSAT and Equipment Costs

Ka-Band VSAT systems are less common in the marketplace and therefore can be more expensive than Ku-Band systems of similar performance. While "mass market" systems designed primarily for direct-to-home users are becoming more available at low price points, these systems are generally not suitable for industrial environments in terms of both performance and hardware reliability. The realities of RF propagation drive performance requirements for larger Ka-Band earth terminals. This means that sub-meter sized consumer grade terminals cannot deliver the speed or link availability typically required by industrial installations. Larger Ka-Based terminals of 1.2 m or greater are not yet produced in meaningful quantities and therefore remain more expensive than Ku-Band terminals. The bottom line is that the costs of HTS Ka-Band equipment may decrease as sales volumes increase, but the current costs of major components and systems are significantly higher than HTS Ku-Band equipment.

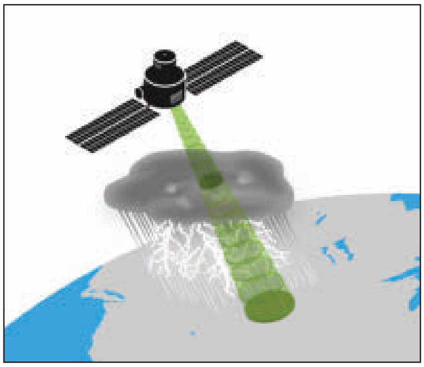


Fig. 4 Adaptive coding can reduce the effects of rainfall attenuation.

Service Reliability

The much smaller wavelength and higher frequency of Ka-Band makes its links far more susceptible to disruption from weather and other atmospheric disturbances than Ku-Band links. The use of spot beams improves Ka-Band performance, but links with Ku-Band spot beams remain much more reliable. Obtaining the same level of link availability and data rate (say more than 99.5 percent) in a Ka-Band spot beam would require exponentially more transponder power than a comparable link and antenna size in Ku-Band. It is therefore much more difficult and expensive to provide high availability and reliable services in Ka-Band than in Ku-Band – particularly in regions where heavy rainfall is common (see ***Figure 4***).

Ka-Band radio signals are more severely impacted by rain and other transient propagation conditions than lower frequency signals like Ku-Band. Consequently, Ka-Band links require higher fade margins for a given service availability than lower frequency links, and Ka-Band HTS spacecraft are designed to provide these margins. As noted, this can result in a cost penalty for the Ka-Band systems when customers demand high service reliability. However, this disadvantage can in some cases be turned to the advantage of Ka-Band services, for customers whose service needs can tolerate lower availability – such as mass market or consumer clients.

HTS SPACE SYSTEMS DESIGN CONCERNS

Originally, most HTS systems were designed for mass markets and to op-

erate in Ka-Band where small aperture antennas can provide narrow spot beams. However, satellite operators are now applying HTS technology and spot beam antennas to new Ku-Band spacecraft. As these HTS systems proliferate, operators of VSAT networks will have new technology choices when implementing solutions tailored to the application environment of their clients. HTS systems and capabilities can be leveraged in a variety of ways to extend the portfolio of service offerings available on the market.

Several technology options are available to HTS spacecraft developers, and each has advantages and disadvantages for any particular mission and marketplace. As always, the spacecraft design team must comprehensively trade these options in the context of the overall application requirements and target market. While most HTS payload trades follow well-established satellite design tenets, their more complex wideband electronics and large antennas may alter the relative emphasis placed on certain aspects of the trade space compared to more traditional spacecraft designs.

In spite of the many innovative advances in lowering launch system costs over the last few decades, the cost to orbit remains the largest single factor driving the selection of HTS payload and antenna technology. Size, weight and power requirements (SWaP) are often more significant cost drivers than the spacecraft components themselves. This is particularly true for global system operators that expect to deploy a number of HTS systems based on a common spacecraft design. Large, complex wideband HTS payloads are particularly taxing for spacecraft platforms from the SWaP perspective. Consequently, spacecraft designers tend to be more open to the use of deployable assemblies, exotic materials and other technologies that can reduce the weight and volume of the overall HTS.

Possibly the most vexing aspect of HTS architecture and technology selection facing the space system design team is having to determine how much flexibility should be incorporated into the payload to allow the system to respond to changes in the market. Payload switching, channelization and antenna steering capabilities determine whether a spacecraft is narrowly optimized to serve a particular market, or whether its coverage and capacity can be readily adapted to changing market needs.

There is ample evidence that a well-designed and constructed spacecraft can have a useful service life measured in decades, but there is far less evidence that space system operators (or anyone else) can accurately predict market trends over a similar time span. Incorporating a great deal of flexibility into such a costly and long-lived asset might seem an obvious choice, but flexibility inevitably sub-optimizes performance and/or capacity and adds cost to the system. Thus, payload flexibility may compromise the system's ability to serve its immediate target market profitably in order to be ready for something that might or might not happen. Nearly all commercial HTS payloads have been designed for specific markets and applications, although some of the HTS under development are placing more emphasis on flexibility.

Since the use of a relatively large number of spot beams is a distinguishing characteristic of HTS systems, HTS antenna system design is particularly interesting and challenging. Spacecraft designers have a number of proven but competing spot beam antenna and transponder switching technologies available when developing an HTS, and their choices are driven by the needs of the marketplace and application for which the satellite is intended.

There are three fundamental spot beam antenna technologies available for HTS applications: phased arrays, multi-feed reflectors and multiple single-beam antennas. These technologies can be applied as the exclusive antenna system for an HTS or a hybrid antenna system can be used. All of these choices have been used in commercial satellite systems and each has strengths and weaknesses for a given application. It is important that the payload design team have experience in all of these options so that they can make the optimum choice for the particular system requirement.

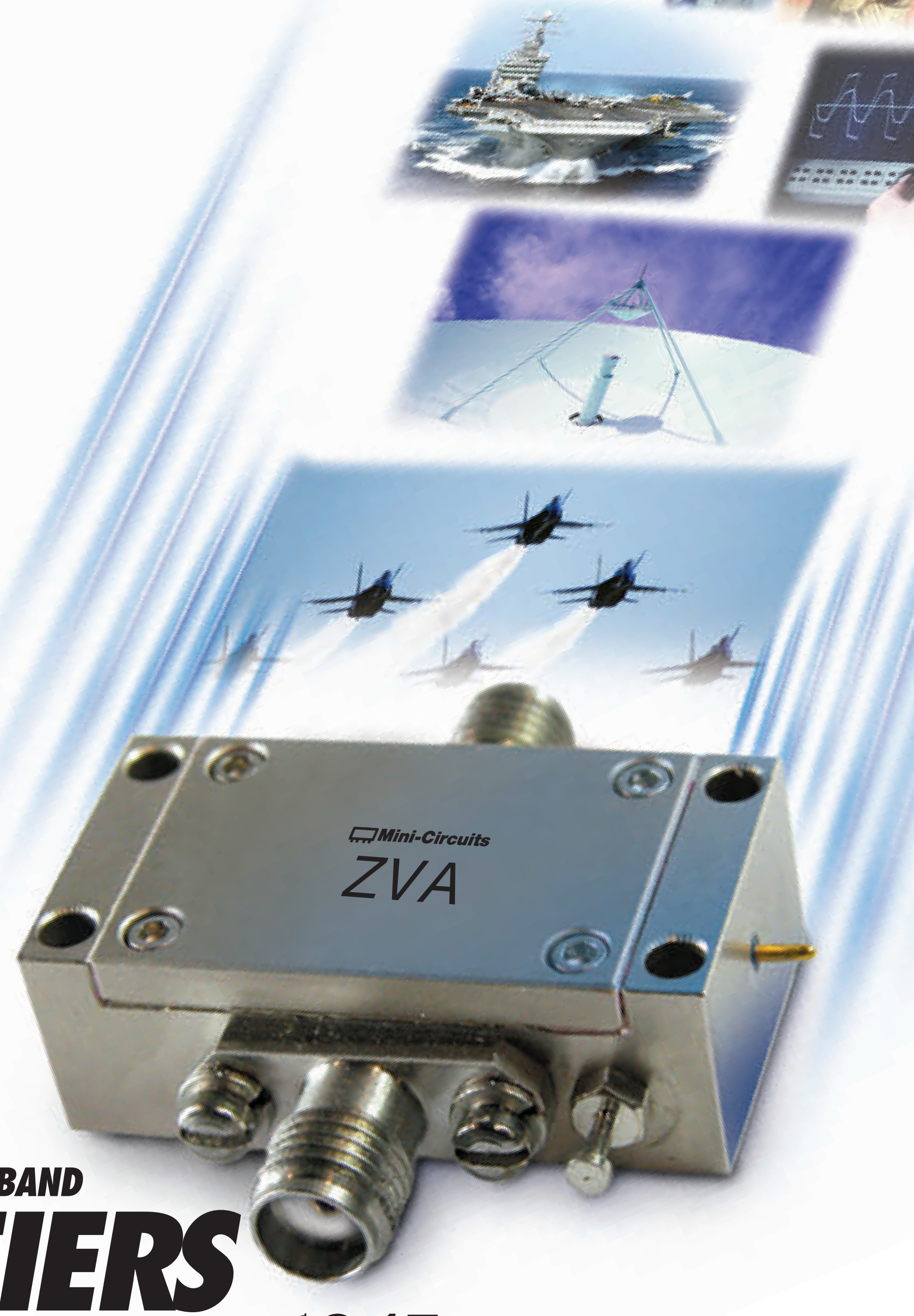
IS HTS THE WAVE OF THE FUTURE?

Customers with industrial-grade operations in remote and harsh locations demand highly reliable communications services and have ever increasing bandwidth requirements. For these kinds of clients, Ku-Band HTS systems may have a distinct advantage over Ka-Band HTS systems, as well as traditional regional and hemispheric beam systems. While Ka-Band HTS can be quite competitive for customer services that do not require particularly high reliability, such as consumer broadband access, they generally do not enable the bandwidth or link availability required by industrial customers, without an excessive, and therefore costly, use of spacecraft power and resources.

Both Ka- and Ku-Band frequencies show great promise to provide customers with a variety of next generation communications solutions, and we are beginning to see a real change and a wealth of new possibilities for satellite communication. In order to adapt and thrive in the face of these new possibilities, it is essential that CTOs and CIOs ensure their satellite systems can support the higher data rate communications forecast in the coming years.

As Ka- and Ku-Band HTS systems come online, operators such as Harris CapRock will expand their multi-band services to intelligently deploy systems that strike an optimal balance of speed, availability and cost. However, SATCOM spectrum remains limited and a valuable resource. Service providers and operators must determine how best to fit the capabilities and limitations of this new technology into their service portfolio to best meet the needs of their customers.

This article's subject matter and the HTS spacecraft analyzed by the authors are in geosynchronous earth orbit. There have been promising proposals for Ka-Band HTS systems in low earth orbit and medium earth orbit as well. Harris CapRock is following these developments with interest. However, this article does not address systems outside the geosynchronous arc. ■



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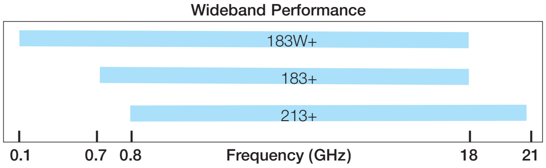

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Market for Tactical Radios Maintains Momentum Through 2022

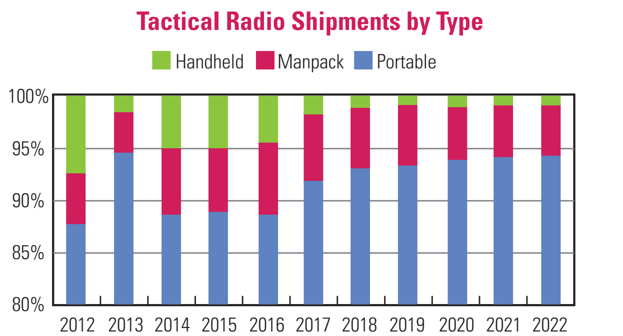
Despite pressures on global defense expenditure, there will be continued investment in communications capabilities with overall expenditure across land, air, naval and space domains approaching $29 billion. The Strategy Analytics Advanced Defense Systems (ADS) service report, "Ground Communications Systems and Components Forecast 2012-2022," forecasts that the market for land-based tactical radios will grow at a compound annual growth rate (CAGR) of 7.2 percent to reach almost $4.5 billion in 2022.

Overall spending on land-based tactical radio hardware will continue to be led by North America, representing between 37 to 39 percent of the tactical radio market, over the 2012 to 2022 timeframe. Demand from emerging markets in the Central and Latin America (CALA) and Asia-Pacific (APAC) regions will also dictate high growth rates with collective demand accounting for over 46 percent of the market for tactical radio hardware in 2022.

"We expect handheld radios to represent the bulk of the market, accounting for as much as 94 percent of shipment volumes in 2022 and just over 49 percent of market value," noted Asif Anwar director of the ADS service at Strategy Analytics. "Manpack radio shipments will also show significant growth, while portable radio shipments will remain essentially flat despite some healthy activity in the early half of the forecast."

"We expect handheld radios to represent the bulk of the market…"

"While there will still be a market for single-band radio capabilities, the multi-band sector will be the fastest growing segment across all form factors," observed Eric Higham, ADS service director North America. "This in turn will drive opportunities for technologies such as gallium nitride (GaN) with the total market for electronic components predicted to grow at a CAGR of almost 14 percent, reaching $721 million by 2022."



Source: Strategy Analytics

UAV Market Worth $8.3 B by 2018

According to a new market research report titled "Unmanned Aerial Vehicle (UAV) Market (2013-2018)," authored by Markets and Markets, the total global UAV market (2013-2018) is expected to reach $8,351.1 million by 2018 with a CAGR of 3.30 percent.

The U.S. has by far been the superior force when it comes to deployment of UAVs in the world; European deployment is rather different than in the U.S. with extensive usage of TUAVs and fewer HALE and MALE systems. SUAVs have seen a robust growth due to their widespread applications. Apart from the U.S., the countries which have shown major interest in UAVs are as follows: Brazil and Argentina in Latin America; UK, France and Germany in Europe; South Africa in Africa; Israel and UAE in the Middle East; India, Australia, Japan and South Korea in APAC. Russia too has an in-depth UAV program, but its success levels have been limited.

In addition to the military market, the market for civilian and commercial unmanned air vehicles is growing. Civilian UAV market refers to UAVs operated by non-military government. Civilian usage of UAVs is present in Australia, France, South Africa, Sweden and the U.S. With FAA regulation until 2015, the civilian UAVs market will grow at a slower rate when compared to military and security applications. USA and EU are looking at policies by which they can allow the usage of UAVs in the National Airspaces.

Global unmanned aerial vehicle market revenue is expected to grow from $7,098.6 million in 2013 to $8,351.1 million by 2018. The global UAV market is majorly driven by the growth of demand for homeland security. Maritime patrolling and counter privacy is also one of the drivers for this market.

NGC Moves New B-2 Satellite Communications Concept to the High Ground

Northrop Grumman Corp. has taken another significant step to reduce the risks and costs associated with producing an extremely high frequency (EHF) satellite communications system for the U.S. Air Force's B-2 stealth bomber.

In a demonstration conducted May 23, Northrop Grumman proved that a new active electronically scanned array (AESA) antenna it has developed for the B-2 can establish and maintain communications services with an on-orbit Air Force Advanced EHF (AEHF) communications satellite. The demo included the antenna, a Navy Multi-band Terminal and the satellite.

Northrop Grumman is the Air Force's prime contractor for the B-2, the flagship of the nation's long range strike arsenal, and one of the world's most survivable aircraft. An EHF satellite communications system would al-

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low the B-2 to send and receive battlefield information significantly faster than its current satellite communications system.

"Our demo marks the first time that AESA antenna technology has been used to communicate with the AEHF network," said Byron Chong, Northrop Grumman's B-2 deputy program manager. "We showed that our antenna will consistently produce and maintain the high-gain beam needed to communicate with AEHF satellites."

During the test, he added, Northrop Grumman successfully demonstrated extended data rate (XDR) communications between the AESA antenna and the AEHF satellite at EHF frequencies. XDR communications take advantage of the AEHF satellites' most advanced, most secure signaling protocols and communication waveforms.

The new antenna is designed to support both tactical and strategic missions. Its innovative "no radome" design allows it to bring new communications capabilities to the B-2 while maintaining the aircraft's major operational characteristics.

Earlier this year, Northrop Grumman validated the performance of the new antenna on instrumented test ranges. The tests verified the antenna's performance over its entire transmit and receive frequency band, and over its required range of scan angles.

Raytheon Awarded Contract for F-15C AESA Radars

Boeing Co. has awarded Raytheon Co. a follow-on contract for the sixth production lot of APG-63(V)3 active electronically scanned array radars for United States Air Force and Air National Guard F-15C aircraft.

"We have been a partner on the F-15 for more than 40 years," said Mark Kula, vice president of Tactical Airborne Systems for Raytheon's Space and Airborne Systems business. "This recent contract enables continued delivery of our APG-63(V)3 AESA radar that provides unprecedented situational awareness for the U.S. Air Force and Air National Guard."

The original contract from Boeing began in 2007 as part of the F-15C upgrade program. To date, more than 46 radar systems plus spares have been delivered. Production lot six, awarded in March of 2013, includes radar modification kits and spares for the Air Force and Air National Guard.

Raytheon recently delivered its 500th tactical AESA radar – an industry first. The company's AESA product line, flown on F-15, F/A-18 and EA-18G aircraft, has achieved more than 400,000 operational flight hours.

The APG-63(V)3 AESA radar is an all-weather, multimode radar that offers extended range, improved tracking and precision engagement for the F-15C.

SOCRATE Project Focuses on Miniature Antennas with Super-Directivity

CEA-Leti and three partners in the SOCRATE project are developing innovative concepts to significantly improve the directivity of electrically small antennas. These antennas are generally limited to omnidirectional radiation, which is suitable for many wireless applications for communicating objects, such as UHF RFID, wireless telemetry and home automation. Nonetheless, the increase in small antennas' directivity could create new wireless applications with improved spectral efficiency, reduced environmental electromagnetic impact and usage features that increase functionality.

The SOCRATE project is based on an analysis of the fundamental limits of radiation properties of compact antennas. It brings a new vision to the concepts of super-directional antennas with the contribution of new technologies.

In addition to Leti, the project includes IETR, a French umbrella organization for researchers in the electronics and telecommunications sectors, Movea, provider of data-fusion and motion-processing technologies for consumer electronics, and TAGSYS, provider of RFID-based item-level inventory management systems.

The three-year project, initiated by CEA, will build two demonstrators to illustrate how super-directivity of miniature antennas could lead to the development of new applications in object designation and tracking. Movea's interests in the project include object designation with a universal wireless remote controller. The partners will also explore how a high degree of miniaturization of the infrastructure can provide new mainstream applications, such as industrial and home automation, as well as wireless sensor networks.

JTI Will Help Europe's Electronics Industry ECSEL

The European Commission has presented an innovation investment package including plans for five Joint Technology Initiatives (JTI) in EU-funded research, representing €25 billion over the next seven years. This includes a new Electronic Components and Systems for European Leadership (ECSEL) JTI to keep Europe's electronics strategy on track via a €5 billion investment partnership designed to boost Europe's electronic components and systems design and manufacturing capabilities.

Electronic components and systems are essential for Europe's industrial landscape. They strengthen product and productivity innovation across the entire economy and play a critical role in addressing societal challenges. But as Europe's industries face fierce global competition, high research costs and the very fast-pace of technology development, cooperation, pooling of resources and building on expertise is needed to bring research faster to market and stimulate demand for European produced electronic components and systems.

The ECSEL JTI is a merger of the ARTEMIS initiative on embedded systems and the ENIAC initiative on nanoelectronics that were both set up in 2008. It also incorporates research and innovation on smart systems. ECSEL is expected to start in early 2014 and to run for 10 years. It will bring together large and small companies, world-class European research and technology organisations and academia.

...expertise is needed to bring research faster to market and stimulate demand...

In particular three private industrial associations (ARTEMISIA , AENEAS and EPoSS) will be involved, from the areas of micro-/nano-electronics, smart integrated systems and embedded/cyber-physical systems, joining partners from 25 EU member states: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom.

Japan and EU Join Forces to Tackle Data Explosion

The European Commission and Japan announced six research projects aimed at redefining internet architectures to increase the efficiency of networks in carrying data. There is a pressing need for new and more efficient networks in light of a massive online data explosion that is expected to continue over the next decade.

The world generates 1.7 million billion bytes of data per minute; data traffic volumes doubled between early 2012 and early 2013 and are expected to grow 12-fold by 2018. Such big data is growing faster than networks' capacity to carry it. The projects will receive around €18 million in funding, and touch on challenges such as cyber security, network capacity, storage, high density data traffic and energy efficiency.

"Our future Internet should know no barriers..."

The funded projects are: MiWEBA will handle capacity by making better use of existing radio frequencies in order to boost ultra-high speed and mobile connections, STRAUSS aims to enable fibre optic networks at more than 100 Gbps, NECOMA will explore new ways to enhance personal data security, GreenICN will try to ensure an efficient use of energy in information networks, ClouT will try to allow real-time control of sensors enabling smart city operations such as energy use, traffic flow or emergencies, and FELIX will set up joint EU-Japan experimental

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platforms that will help universities and research centres test new network technologies. Such new platforms will improve researchers' use of their experimental facilities.

European Commission vice-president Neelie Kroes said: "Our future Internet should know no barriers, least of all barriers created because we did not prepare for the data revolution."

Broadband Study – National Plans and Competitive Markets are Crucial

Countries with a clearly-defined national vision for broadband roll-out are significantly out-performing those taking a more laissez-faire approach to broadband development, according to a new joint report released by the International Telecommunication Union (ITU), the Broadband Commission for Digital Development and network equipment maker Cisco Systems.

According to the report, "Planning for Progress: Why National Broadband Plans Matter," raw data indicates that countries with a national broadband plan have fixed broadband penetration some 8.7 percent higher on average than countries without plans. Once the potential impact of factors like higher average income per capita, market concentration and urbanization are discounted, research suggests that countries with plans benefit from fixed broadband penetration on average 2.5 percent higher than countries without plans.

In mobile, the impact may be even greater – countries which have national broadband plans also have mobile broadband penetration some 7.4 percent higher on average than countries without plans. The report concludes that market competition also plays a strong role in boosting broadband penetration. Competitive markets are associated with broadband penetration levels some 1.4 percent higher on average for fixed broadband and up to 26.5 percent higher on average for mobile broadband.

ITU secretary-general, Dr. Hamadoun I. Toure, commented, "Governments are realizing that broadband networks are not just vital to national competitiveness, but to the delivery of education, healthcare, public utilities like energy and water, environmental management, and a whole host of government services. Broadband is the key enabler not just of human interaction, but of the machine-to-machine communications systems that will underpin tomorrow's world."

"Broadband plans clearly matter," said Dr. Robert Pepper, vice president of global technology policy for Cisco Systems. "Plans spur adoption, accelerating economic growth and increasing national competitiveness. The role of policy is to set a vision for broadband development and ensure a level playing field which then allows for the best ideas to prosper."

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IF/RF MICROWAVE COMPONENTS

GaN Microelectronics Device Market Growing

While military applications continue to drive the GaN device market, commercial applications have emerged that will help fuel rapid market growth. The recently released Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs) Forecast and Outlook, "GaN Microelectronics Market Update: 2012-2017," concludes that the overall GaN microelectronics device market closed 2012 with revenues of slightly less than $100 million. The report also forecasts that commercial RF and power management applications will begin shipping in volume during the forecast period and this activity will push the overall market to slightly more than $334 million by 2017.

"The GaN device market has been "about to take off" for a number of years…"

"The GaN device market has been "about to take off" for a number of years," noted Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs). "Based on our most recent research, it appears there are segments of the commercial market, like CATV and wireless infrastructure that are seeing higher volumes, but the broad commercial market is still not quite into the production phase. We do anticipate seeing more of these commercial segments contribute over the period and this will be the driver for strong revenue growth."

Asif Anwar, director in the Strategy Analytics Strategic Technologies Practice (STP) added, "Despite the interest and growth in commercial applications for GaN, military applications will continue to account for more than half of the GaN device revenue in 2017. The performance benefits of using GaN devices in military applications are clear and this will keep driving GaN usage."

BRIC: Four of the Top Seven Smartphone Markets in 2018

China will displace the U.S. as the largest smartphone market in 2013. Brazil and India are also forecasted to be in the top four countries for smartphone shipments by 2018. Smartphone vendor interest and the strategies of the smartphone value chain are shifting accordingly.

ABI Research forecasts that Russia will come in as the 11th largest smartphone market in 2013 and will climb to 7th in 2018. "With room to grow, the emerging BRIC nations are displacing established markets such as the U.S. and Japan as market leaders in terms of smartphone shipments," stated senior analyst, Michael Morgan.

ABI Research forecasts that the top five countries in 2018 will account for 51 percent of worldwide smartphone shipments while the BRIC countries will account for 33 percent of smartphone shipments. By 2018, Western Europe and North Americas' share of smartphone shipments will be 33 percent (equal to BRIC) down from 39 percent in 2013. It is clear that the growth of the smartphone market over the next five years will depend on operators and handset OEMs delivering optimized and price appropriate solutions to the BRIC consumers.

In terms of total handset shipments, the BRIC countries are already in the top five, but have lagged in their global smartphone share. ABI Research notes that over the past two years, Android paired with low cost hardware has opened the door to increasingly lower ASPs for smartphones. "When you look at operating system share in emerging markets, you tend to find that Android has been busy fulfilling its mission to bring the Internet to consumers who can't afford a traditional PC or Laptop," added senior practice director, Jeff Orr.

"With room to grow, the emerging BRIC nations are displacing established markets…"

Worldwide Carrier Wi-Fi Deployments Reached a Total 4.9 Million Hotspots in 2012

"Despite the successful adoption of 3G and 4G mobile data services, the number of Wi-Fi Hotspots has continued to proliferate and are anticipated to surpass 6.3 million by the end of 2013," comments industry analyst, Khin Sandi Lynn. The number includes Wi-Fi hotspots deployed by fixed-line and mobile carriers as well as third-party operators (e.g., Boingo, iPass, etc).

Wi-Fi has very much become a complement to 3G and 4G services and is now a mainstay of connectivity for the majority of smartphone, tablet, and laptop users because it is often free in many public Wi-Fi locations. This is particularly the case when a mobile user is roaming – Wi-Fi networks can help the user save a significant amount on mobile data roaming charges.

As mobility is increasingly important for users, fixed broadband operators are also building Wi-Fi hotspots in order to provide fast and reliable Internet connections when the customers are away from home. Five cable companies from the United States (Cox, Comcast, Time Warner, Optimum and Bright House) have agreed to allow their customers to access more than 100,000 Wi-Fi hotspots installed nationwide.

ABI Research's "Wi-Fi Access Points" profiles Wi-Fi hotspots installed by both mobile and fixed-line carriers and third-party operators. Detailed market trends and market forecast information for key regions around the globe are provided.

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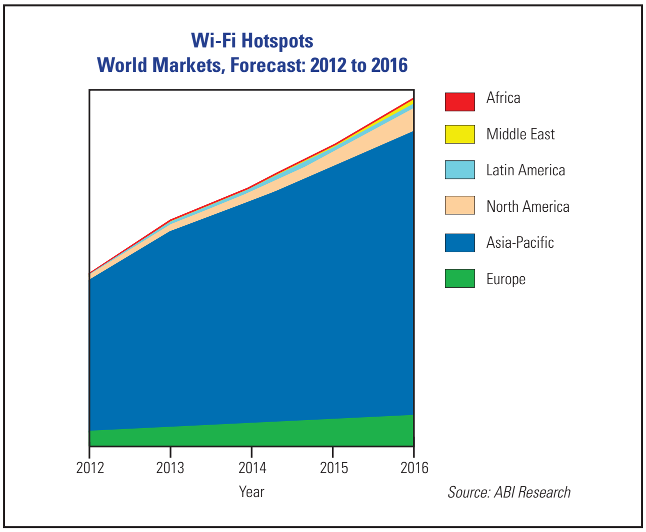
Smartphones Will Account for Nearly Half of Both 802.11ac and 802.11ad Chipset Shipments in 2018

The growth of 802.11ac and 802.11ad will occur in very different ways. 802.11ac will explode into devices, including smartphones, from the start while 802.11ad will see a more modest and staggered growth. 802.11ac is being pushed into smartphones by key carriers' device requirements that are in sync with 802.11ac hotspot plans for more robust Wi-Fi offloading. "The push towards 11ac adoption overpowers the minor additional cost of dual-band 802.11n/802.11ac chipsets that will be used in smartphones," states research director Philip Solis. "Perhaps surprising even to industry insiders, we will likely see 2×2 802.11ac implementations in smartphones in a few years."

The proportion of various 802.11ac-enabled products will remain relatively consistent from 2013 to 2018, with smartphones making up 40 percent of those in 2013 and 46 percent in 2018, where over 3.5 billion Wi-Fi chipsets with 802.11ac will ship. The Wi-Fi Alliance is just about to start certification of products using the protocol, yet its shipments have started and are already on track to distribute hundreds of millions this year. 802.11ac finally pushes Wi-Fi more toward the 5 GHz spectrum which is cleaner and permits for the much larger channel sizes that allow for greater speeds and capacity.

802.11ad will phase from larger to smaller products, starting from peripherals and larger non-handset mobile devices and shift to smaller and thinner devices over time. 802.11ad will make its way into smartphones in 2015, changing the proportion of 802.11ad-enabled products compared to prior to 2015. Smartphones will account for nearly half of all 802.11ad-enabled products in 2018, though with less than half the volume in smartphones compared to 802.11ac. Even so, over 1.5 billion chipsets with 802.11ad will ship in 2018. 802.11ad pushes Wi-Fi into higher-speed, lower-power personal area networking that will be used simultaneously with other Wi-Fi protocols.



Around the Circuit

Laura Glazer, Staff Editor

MERGERS & ACQUISITIONS

CPI International Inc. and its wholly owned subsidiary **Communications & Power Industries LLC** (CPI) have acquired **M C L Inc.**, a manufacturer of power amplifier products and systems for the satellite communications market and a wholly owned subsidiary of **MITEQ Inc.** Under the terms of the agreement, CPI acquired the assets of M C L using cash on hand. The acquisition will be integrated into CPI's Satcom Division. CPI will honor M C L's current sales commitments, and will continue to operate M C L's manufacturing facility in Bolingbrook, IL. for the period necessary to fulfill these backlog commitments.

Nokia Corp. and **Siemens AG** have entered into a definitive agreement pursuant to which Nokia acquires Siemens' entire 50 percent stake in their joint venture, Nokia Siemens Networks. The acquisition has been approved by the board of directors of Nokia as well as the managing and supervisory boards of Siemens, and is subject to the customary regulatory approval process. The purchase price for Siemens' stake is €1.7 billion and the transaction is expected to close during the third calendar quarter of 2013. Upon closing of the planned acquisition, Nokia Siemens Networks will become a wholly owned subsidiary of Nokia.

COLLABORATIONS

Versatile Power Inc. announces a new partnership with **PowerGate LLC** to bring enhanced power capabilities to customers in the form of engineered power systems. PowerGate, specializing in standard power supplies with more than 7500 standard AC/DC power supplies and DC/DC converters from 1 to 3000 watts, announces the addition of design services with the Versatile Power team which specialize in the design of custom engineered power subsystems for OEM applications. With this partnership, an entire spectrum of custom power solutions is now available ranging from modified standard products to completely custom designs.

Agilent Technologies Inc. and **Tyndall National Institute** at University College Cork, Ireland opened a new laboratory for research and teaching in next-generation wireless communications. This state-of-the-art laboratory at Tyndall will enable advanced training and research on radio frequency integrated circuits for high-speed wireless data communications for video applications and contactless sensors for biomedical and security applications. The laboratory is named after the 1909 Nobel prize-winning Italian scientist, Guglielmo Marconi (also known as the father of wireless communications), who moved to Ireland to carry out his research.

NEW STARTS

Cassidian has launched the Sagitta project, which will conduct basic research into future Unmanned Aerial Systems (UAS). With Sagitta, the company is opting for an approach known as 'open innovation,' under which research will be conducted in cooperation with German universities and institutes. Sagitta is concerned with a total of seven research areas of UAS development: preliminary aircraft design, aerodynamics, flight control systems, communications and data processing, vision-based flight control and air-to-air refuelling, materials and structure, autonomous flight and mission control, simulation and systems integration. The Sagitta project includes the construction of a flight demonstrator to verify the validity and feasibility of the theoretical research.

With its vast experience in key markets, in which integrated silicon passive components have a strong added value, **IPDiA** has launched a new R&D program, named MediLight 2017, to meet the demands of future innovative medical and lighting markets and the company's long-term roadmap. In cooperation with 'historical' R&D partners, CEA-Leti and CRISMAT (CNRS, ENSICAEN, UNICAEN), MediLight 2017 will drive IPDiA's innovation on: high voltage and very high density 3D nanostructured integrated silicon capacitors; 3D Interposer development combining new assembly performances for ultra-miniaturization.

Aeris Communications announced that it is providing network services to the automotive industry on the GSM network in North America, in addition to its long established position with CDMA technology. The industry was seriously injured when the analog network was shut down and today it faces a similar risk. With multiple network technologies available, Aeris is uniquely positioned to not only provide the automotive OEMs with solutions designed specifically for their applications, but a solution that reduces the risk of obsolescence – a proposition that is critical to the connected vehicle industry and the M2M space in general.

Huawei has opened its new UK headquarters at 300 South Oak Way, Green Park, Reading. The move reaffirms the company's long-term commitment to the UK and is the first significant milestone in the company's pledge to invest £1.3 billion into the economy over a five year period. The new 140,000 sq ft office complex will house Huawei's main UK operation and will help meet the future needs of the company's growing workforce.

Huber + Suhner has opened its new state-of-the-art facility in Changzhou, East China. The opening of this facility enables the company to manufacture products from all three core technologies – radio frequency, fiber optics and low frequency – in China. This is an important milestone for Huber + Suhner as to date copper cables were manufactured in Switzerland only. At CHF 60 million this is the single biggest investment in the company's history. The

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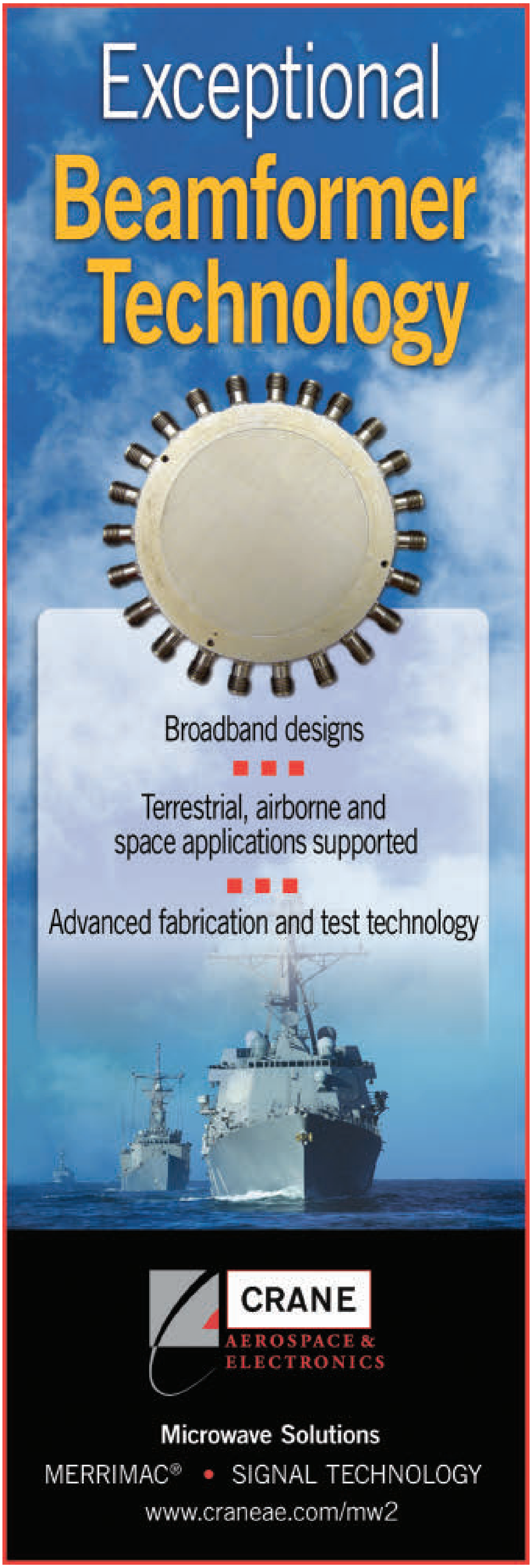

new 30,000 m^2 factory will allow Asian customers to receive a broader range of locally produced Huber + Suhner solutions at the accustomed high level of quality.

SenarioTek announced the opening of its new 12,000 sq ft facility in Santa Rosa, CA. The larger space integrates research, development and manufacturing for the continued expansion of the switch matrix, frequency converter and calibration product lines. The new facility allows for a productive workflow with dedicated production, test and quality areas. There is additional room for system development, which allows for ease of movement through production, test and shipping. The interactive work areas increase positive communication and ensure high quality products.

ACHIEVEMENTS

Anritsu Corp. announced that the company has received the world's first PTCRB approval for its ME7873L RF Conformance Test System meeting the LTE Rel-10 Carrier Aggregation Standard. The new 4G mobile LTE-Advanced standard supports the carrier aggregation function offering faster communication speeds than the LTE technology now being deployed worldwide. This carrier aggregation function uses multiple frequencies in one band to increase both the peak and average data speeds, reaching the 3GPP standards of 300 Mbps for downloads while targeting future speeds of 1 Gbps.

Northrop Grumman Corp. and the **U.S. Navy** have completed the first arrested landing of the X-47B Unmanned Combat Air System (UCAS) carrier demonstration aircraft on the deck of the USS George H.W. Bush (CVN 77) off the coast of Virginia. The X-47B aircraft took off from Naval Air Station (NAS) Patuxent River, MD, July 10. A mission operator aboard the carrier took control of the aircraft and monitored the flight operations, which included several planned precision approaches in preparation for the first arrested landing. The arrested landing effectively brought the aircraft from approximately 145 knots to stop in less than 350 feet.

ITT Exelis received National Security Agency (NSA) certifications for its SideHat and the Soldier Radio-Rifleman (SR-R) radios. Certification allows the radios to operate up to the "SECRET" level and be fully integrated into the U.S. Army's tactical communications network.

The Global Positioning System, which millions of people use every day for precise navigation and timing, recently became more accurate and reliable as the fourth **Boeing** GPS IIF satellite began operating in the U.S. Air Force network. Launched May 15, that satellite was handed over to the Air Force after 19 days of post-launch validation to stabilize the vehicle and activate the navigation payload, and set healthy on June 21. The new satellite replaces an earlier Boeing-built model launched in 1996.

CONTRACTS

The **Navy** awarded **Raytheon Co.** a $279.4 million cost-plus-incentive-fee contract that will transform how the service executes its Airborne Electronic Attack (AEA) mission. As a result of the contract, Raytheon will conduct the

Around the Circuit

Next Generation Jammer (NGJ) Technology Development (TD) phase. The 22-month TD phase is the next step in transitioning mature components into testable subsystems as well as developing a preliminary design for the new jamming pods for the EA-18G Growler AEA aircraft. Raytheon Co. will be required to design and build critical technologies that will be the foundational blocks of NGJ.

Harris Corp. received a $92 million contract from a Middle Eastern nation for an integrated command, control and communications system. The system will provide this customer with advanced capabilities for use in defense and security missions. The system leverages the latest in Harris' wideband tactical radios and integrated systems capabilities to provide fully networked Internet Protocol-based voice, data and video services across the mission area.

Mercury Systems Inc. announced it received $3.6 million in follow-on orders from a leading defense prime contractor for integrated microwave assemblies (IMA) for an airborne electronic warfare (EW) application. The orders are expected to be shipped by the end of Mercury's fiscal 2014 third quarter.

ITT Exelis has received a $3.2 million contract from **Ball Aerospace & Technologies Corp.** to design an advanced receiver chain for the U.S. Air Force Weather Satellite Follow-on (WSF) program. The new design will improve measurements of ocean surface winds used for severe weather forecasting. Under the contract, Exelis will enhance the design of a digital receiver – based on an Exelis subsystem used on the Global Precipitation Measurement Microwave Imager (GMI) instrument – for incorporation into a future WSF GMI. The WSF program and GMI will provide the U.S. Air Force with next-generation weather forecasting capabilities.

Thales Alenia Space, serving as prime contractor, has signed a study contract with **French Defense Procurement Agency** (DGA) to enhance communications between ground and military mission aircraft through a telecommunication satellite without interruption during extreme flying conditions (attitude, tight turns, landing). The aim of Kit Aero Large Bande (KALB), which translates as Wide Band Airborne Kit, is to develop a high throughput airborne SATCOM terminal compatible with a wide range of aircraft including A400, MRTT and ATL2.

PEOPLE

Pasternack Enterprises Inc. announced **Terry G. Jarnigan** has been named chief executive officer and member of Pasternack's board of directors, where he will be responsible for the company's overall strategy and management. Jarnigan joined Pasternack in 2010 as vice president of business development and most recently held the title of president. Prior to joining Pasternack, Jarnigan served as president and CEO of Tri-Star Electronics Intertnational Inc. **Brian MacDonald**, Pasternack's chief financial officer since 2005, has been named president. The company's former chief executive officer, **Chuck Becker**, has been elected chairman of the board of Pasternack Enterprises Inc.

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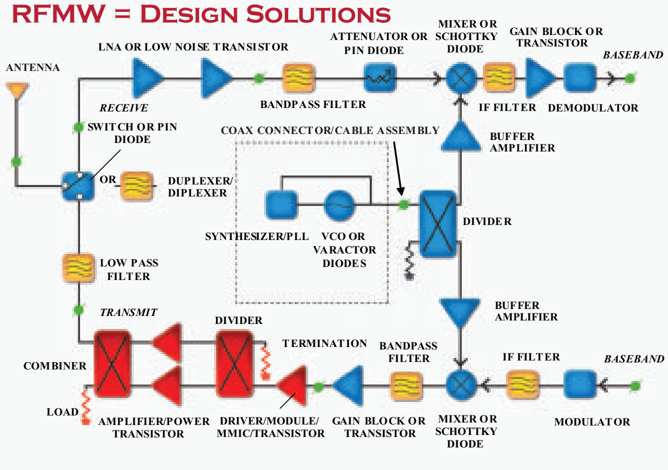

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Around the Circuit

Radio Frequency Systems (RFS) announced the addition of **Eldon Prax** as national director of installation services and business development. Prax has over 30 years of experience in the electronics and telecom industry and has been an integral part of the build-out campaigns of major carriers and is highly skilled in directing the evolution of technical solutions from conception through implementation while adeptly managing the needs of customers, teams and projects. In his new role at RFS, Prax will be responsible for further developing the RFS brand and strategically bringing RFS' value proposition to new sectors.

▲ *Paul Lowbridge*

Microwave Marketing has appointed **Paul Lowbridge** as technology director. Having joined the company and played a great part in its recent advances he has agreed to join the board and help steer the business development activities over the next few years. Lowbridge, who holds a BSC in Electronic Engineering, is well known and respected for his technical support across broad markets and will add great depth to the sales team. From the early stages of UK microwave development at Hirst Research, he has had spells with high calibre microwave businesses including AEI Semiconductors, Marconi Electronic Devices (MEDL) and GEC Plessey.

REP APPOINTMENTS

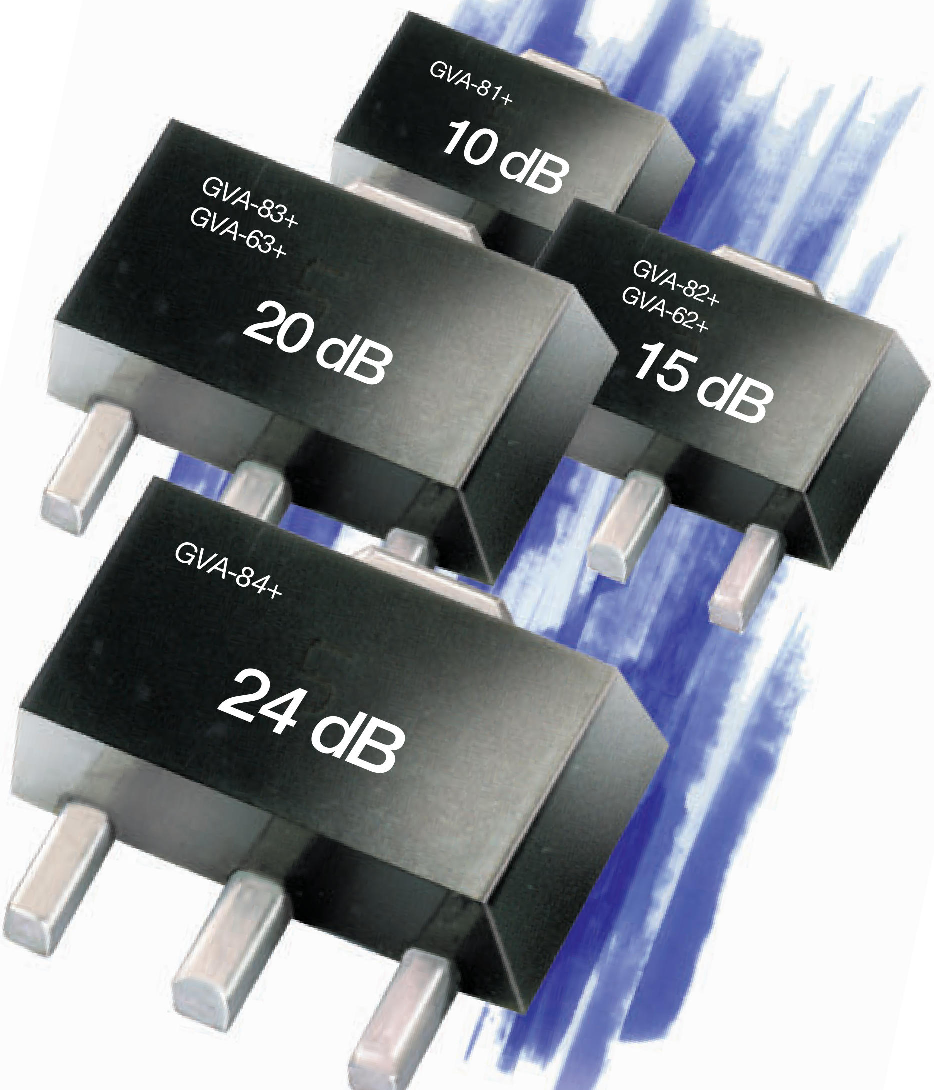
Alpha Micro Wireless has signed an agreement with European antenna innovators **2J Antenna** to supply its customers with a broad range of high quality TS16949/ISO9001 certified external and embedded antenna solutions.

Delcross and **CST** announced that Delcross Technologies' Electromagnetic Interference Toolkit (EMIT) and Savant are now available worldwide through all CST sales channels. The software will also be fully supported by CST's team of electromagnetic specialists.

Emerson Network Power announces the extension of its partnership with **Newark element14**. Newark element14 is already a distributor of the Johnson and Trompeter product lines and will now serve as a global distributor of the Semflex and AIM-Cambridge product lines as well.

East Coast Microwave Distributors Inc. announced that it has been appointed an Authorized Global Franchised Distributor for **The Phoenix Company of Chicago**'s product line of RF/microwave contacts and connectors.

RFMW Ltd. and **Scintera Networks Inc.** announced a worldwide distribution agreement effective immediately. According to the agreement, RFMW will distribute Scintera's portfolio of RF power amplifier linearizers (RFPAL) to support a broad range of customers serving markets including cellular infrastructure, microwave point-to-point, digital terrestrial broadcast and many other general applications requiring RF linearization.



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IF/RF MICROWAVE COMPONENTS

Turning Complexity into Breakthrough Simplicity

Editor's note: As a part of our ongoing coverage of the evolution of the mobile RF front end, Skyworks has contributed the following piece about how a best-of-breed approach will meet the future needs of this market. Previously, our June cover story, contributed by Qualcomm, described its new all single module CMOS approach to meet the future needs of the mobile RF front end.

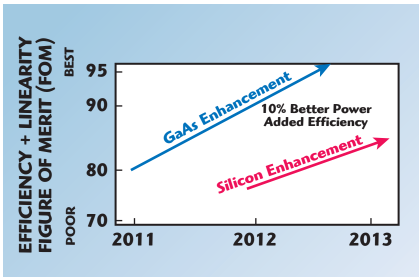
Peter Gammel, Ph.D
Skyworks Solutions, Woburn, MA

Consumer demand for thinner mobile platforms with extended talk times and lightning fast, anytime anywhere data access is driving the need for an unprecedented level of analog and RF complexity for smartphones, tablets and ultrabooks. This is particularly true as the wireless market transitions to 4G and 5G technologies, where the front end architectural challenges have never been greater and are being compounded by the emergence of demanding coexistence, shielding and harmonics issues, not to mention the traditional power efficiency, size and cost constraints.

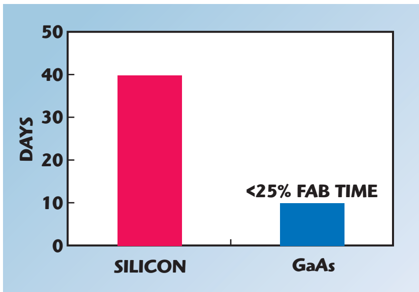
As a result, OEMs are increasingly focused on uniquely defining their RF architectures as a means to differentiate their platforms, battling for consumer mindshare and operating system leadership. Consequently, front end circuit board real estate has become precious beachfront property as system providers seek high performance and highly flexible solutions for the next generation flagship platforms. At the same time, as the R&D, IP and manufacturing scale requirements grow to support LTE, W-CDMA and GPRS/EDGE as well as WiFi, GPS, Bluetooth®, Mobile TV, RFID and other non-cellular services, the list of viable suppliers capable of addressing all of these applications is significantly narrowing. The stakes have never been higher and the distinction between winners and losers will undoubtedly become much more apparent over the coming years.

TWO DISTINCT FRONT END APPROACHES: BEST-OF-BREED VERSUS ALL SILICON

Over the past decade, leading system-level innovators including Infineon, Ericsson, Freescale, Renesas, Silicon Labs, STMicroelectronics and Texas Instruments, among others, have aggressively pursued the leveraging of silicon processes to address RF front end requirements. Despite the attractiveness of de-



▲ *Fig. 1 GaAs vs. CMOS enhancements.*



▲ *Fig. 2 Fabrication cycle time.*

signing in a ubiquitous, bulk silicon process technology, this approach has been met with limited success. Not a single such device is in high volume production and, in virtually all cases, investment has ceased. This is because GaAs performance in the front end has prevailed and continues to push the performance envelope for the foreseeable future (see ***Figure 1***), even with new technologies that improve CMOS performance, such as envelope tracking. By using those same technologies, GaAs maintains its 10 percent plus performance advantage. Further, the performance gap between the two processes across several other metrics including cycle time (see ***Figure 2***), and cost per fabrication mask run is dramatic and certainly not lost on system integrators who strive for time to market advantages, extended battery life and smaller form factors.

The underlying reason for silicon's limited success as a power amplifier platform is quite simple. When given the choice, OEMs opt for better power added efficiency (PAE) and lower cost as well as faster time to market provided by other process technologies and architectures. CMOS or SOI amplifiers still have a place in the market. It is just not where efficiency and ruggedness are paramount.

Nevertheless, new claims within a system-oriented model have recently emerged and once again, untested arguments for silicon integration and product standardization sound compelling. However, simple physics and the inexorable need for a barrier between the amplifier and the transceiver dictate that the front end will neither be subsumed by the RF section nor will it follow Moore's law given limited scalability in silicon.

Most importantly, while there is a certain degree of elegance associated with offering a complete, standardized solution to address all of the forthcoming cellular band requirements, a product must still meet OEM expectations across several key metrics including performance, size, cost and time to market. The failure to satisfy all requirements and expectations will not suffice – a design is only as strong as its weakest link.

At a higher level, market demand for the best performing solutions has shown that an integrated silicon approach imposes significant performance trade-offs with limited design flexibility – an unacceptable approach in a performance-driven and fast-moving market. Instead, OEMs prefer to choose their own band configurations and are also quite comfortable mixing and matching components to achieve performance at a competitive cost, while differentiating their products.

NEXT GENERATION SOLUTIONS

With approximately 50 bands either being deployed or soon to be established, OEMs and system engineers alike are searching for architectures to adequately manage the proliferation of bands and the increasing complexity of RF front ends. While the vast majority of OEMs prefer to address the challenge by leveraging best-in-class discrete solutions and system-in-a-package solutions to optimize performance (see ***Figures 3*** and ***4***), others prefer a completely integrated front end system.

Regardless of the preferred architecture, leading manufacturers like Skyworks have amassed valuable expertise spanning multiple process technologies including CMOS, SiGe, SOI, BiCMOS and GaAs, among others, and has developed an arsenal of

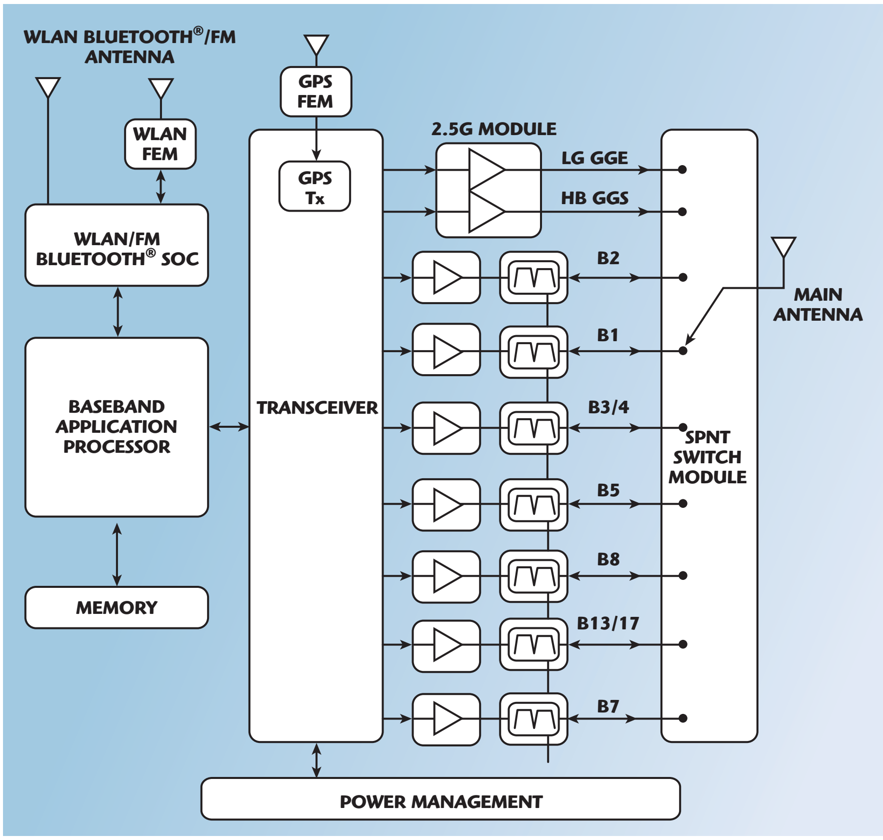


Fig. 3 Example of a discrete implementation approach.

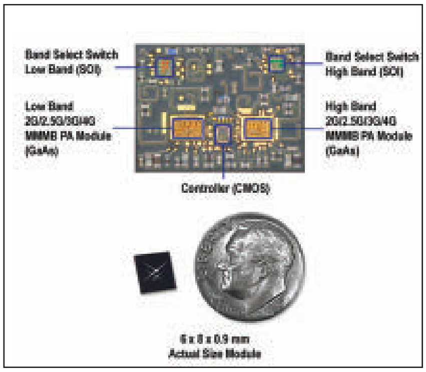


Fig. 4 System in a package solution comprised of low band high band 2G/2.5G/3G/4G multimode, multiband power amplifier modules (GaAs), low and high band select switches (SOI) and a controller (CMOS).

advanced and proprietary packaging techniques to deliver the highest performing systems solutions. This capability allows Skyworks to create systems that are specifically tailored to OEM platforms and applications.

SkyOne™, for example, is a platform that integrates all the RF and analog content between the transceiver and antenna. SkyOne leverages Skyworks' full technology portfolio and advanced multichip module capabilities including proprietary shielding and packaging and is the world's first semiconductor device to condense multiband power amplifiers and high throw switches along with all associated filtering, duplexing and control functionality into a single, ultra-compact package, all in less than half the area of the industry's most advanced approach. At the same time, this solution provides the best linearity and power added efficiency for smart RF integration. As a result, SkyOne offers smartphone, tablet and ultrabook OEMs improved efficiency, a reduced number of RF paths, ease of implementation and a scalable platform as bands increasingly proliferate worldwide. Its footprint supports a family of solutions with different bands and antenna configurations, thereby enabling its customers to launch a truly global phone from a single design platform that addresses worldwide carrier requirements and greatly reduces their engineering effort and time to market.

Since the launch of SkyOne in the fall of 2012, the customer and partner response has been particularly strong due to its design flexibility and customizability – key attributes in the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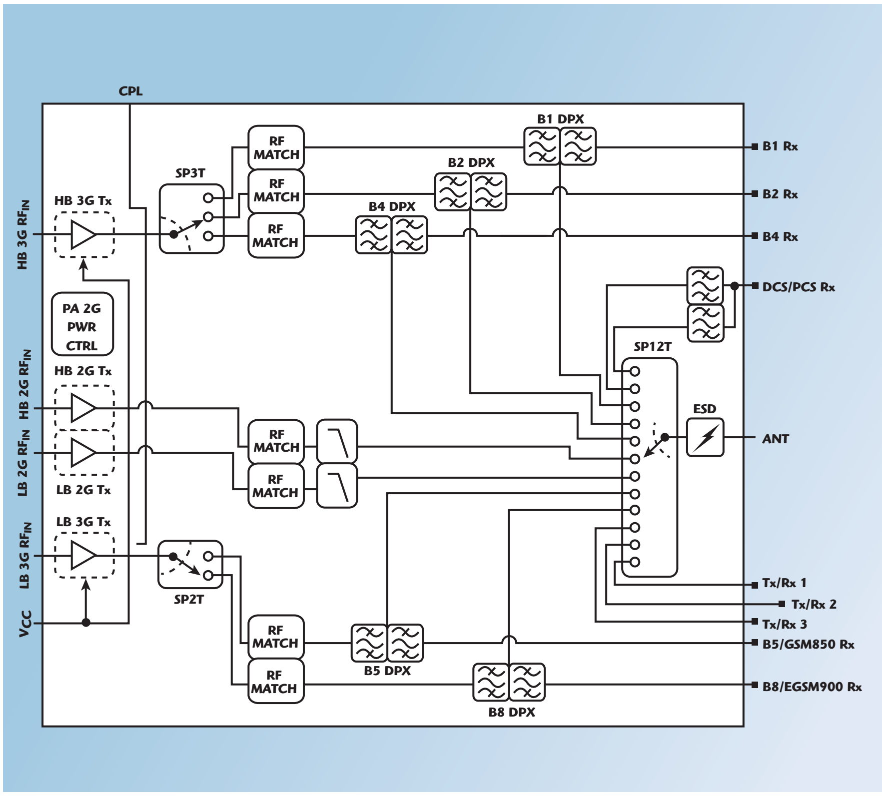


▲ *Fig. 5 SkyOne™ block diagram integrating all RF and analog content between the transceiver and the antenna.*

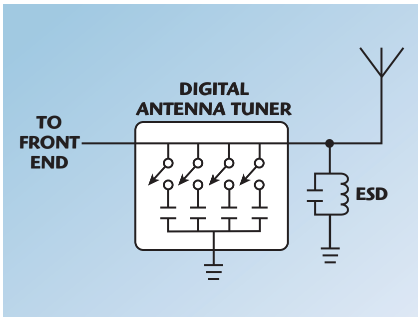
context of a rapidly evolving market. By leveraging the best process technology for a given product partitioning – whether it is switching performed in SOI, long haul amplification in GaAs, device control in CMOS, or WiFi amplification in SiGe – SkyOne is the epitome of a process agnostic approach (see ***Figure 5***).

ANTENNA TUNING

Another critical and rapidly evolving technology for next generation devices is antenna tuning. Switches can be applied for both on-antenna aperture tuning as well as the antenna-feed impedance tuning. Because these have very different characteristics, with some applications calling for high Q and low R_{on}, and others calling for minimum C_{off}, they must be optimized for the specific antenna structures being used. With these needs in mind, Skyworks delivers a variety of new antenna tuning products that bring value to OEMs. Skyworks' product portfolio includes active antenna tuning solutions based on FET switching technology that allow improved impedance matching for a single antenna across a wider bandwidth. This reduces power stress on the transmitter side and increases sensitivity on the receiver side (see ***Figure 6***).

CARRIER AGGREGATION

Skyworks has also introduced breakthrough RF switching technology that is enabling early adopters to implement carrier aggregation solutions. Carrier aggregation allows mobile service providers to combine spectral bands, increasing data rate throughput by utilizing two or more bands simultaneously instead of the single band method used currently. This gives consumers an enriched



▲ *Fig. 6 Digital antenna tuner example using a shunt switched capacitor bank.*

data experience regardless of location. Skyworks' devices support standardized inputs to popular industry chipsets (MIPI RFFE compatible) and address both transmit and receive switching paths. Skyworks' carrier aggregation switching solutions are compliant to tier-one carrier-driven specifications, offer dedicated receive diversity functionality to accompany the primary antenna switch path, are based on SOI and PHEMT wafer process technologies, and are available in many different configurations.

ENVELOPE TRACKING

Other ongoing challenges in the increasingly complex RF front end include improving power savings and talk time. Recent PAE improvements, including envelope tracking, help enhance performance since power amplifiers and associated components still consume a significant percentage of system power.

Envelope tracking enables the voltage supplied to the final RF stage power transistor to be changed dynamically and synchronized with the RF signal passing through the device. The supply voltage is reduced from its maximum value and is allowed to track the signal envelope, resulting in lower dissipated energy (see ***Figure 7***). An envelope tracking amplifier operates at its optimum efficiency for all envelope levels, greatly improving efficiency when operating with envelope varying signals. Envelope tracking is expected to deliver 200 to 500 mW, or more, in battery power savings, along with 20 to 30 percent less dissipated power, lower heat dissipation, and improved 3G/4G coverage per base station since less back-off will be required.

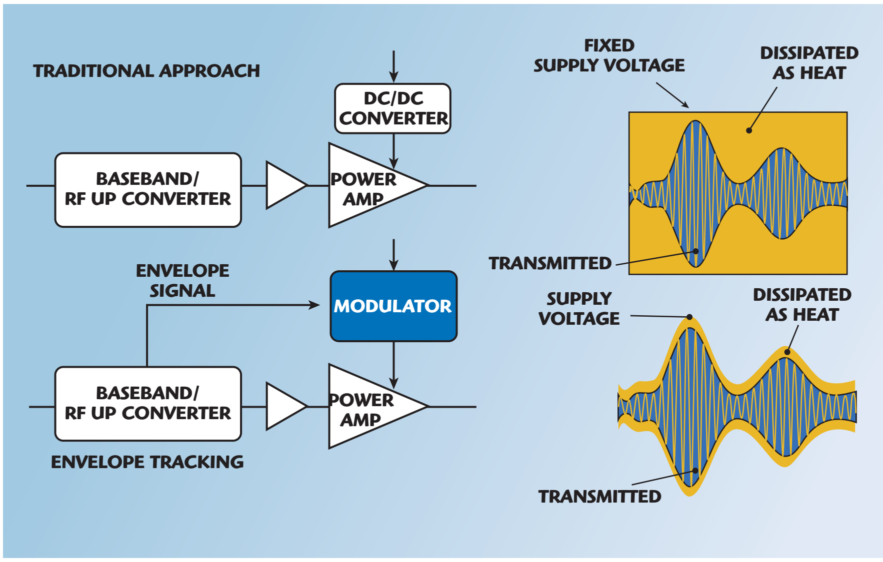


Fig. 7 Envelope tracking vs. the traditional approach.

CONCLUSION

Consumer demand for mobile platforms that are able to roam globally and interface seamlessly to any and all network topologies remains unabated and is demanding an unprecedented level of RF complexity. As a result, OEMs are seeking partners who can deliver front end solutions that preserve battery life, increase data rates, solve signal interference problems and occupy minimal board space. This need plays directly to Skyworks' strengths and technology-agnostic approach. While others continue to bet on a singular architecture or process technology, and develop solutions that are convenient to their particular business models, Skyworks is investing in all core building blocks and specialized process technologies to deliver everything from best-in-class discrete products to complete system solutions. This approach gives customers maximum design flexibility for the highest performing solutions. Most importantly, it enables OEMs to focus on what's important to their business models and in bringing highly innovative, next-generation platforms to market faster. ■

Microwave Training Kit: Eductika

This article describes an innovative education kit known as Eductika. It is dedicated to students and teachers in electronics. The main concept is the assembly of basic puzzle elements to create microwave passive components such as filters, couplers and antennas. The design of an ultrawideband filter using this kit is provided as an example. All steps from theory through measurement are illustrated. Good agreement is shown between the simulation and the measurement.

The development of new applications in telecommunications has contributed to the rapid increase of wireless technology, especially within the microwave electronics field. The field of microwave electronics requires good theoretical and practical knowledge of waveguide propagation, lumped/distributed element concepts and wavelength related phenomena, as well as knowledge of electromagnetic (EM) simulation techniques such as 2D planar and 3D full-wave.[1-3] This is why Elliptika has developed an education kit known as Eductika.[4] The scope of this first education kit is microstrip passive devices but other applications, such as antennas, are also under development. Eductika allows one to build partial or entire passive microwave functions from basic puzzle elements.

Eductika is composed of basic sub-sets of microwave passive components aimed at teaching students microwave fundamentals. It offers a simple way to acquire, through practice, skills in various subjects such as the physics of microstrip lines, impedance matching devices and synthesis of elementary functions (e.g., couplers, power dividers, bandpass/lowpass filters, short/open circuit stub filters) as well as some passive functions of higher complexity based on these elementary functions.[5] Furthermore, Eductika helps students to become familiar with the use of measurement instruments such as the vector network analyzer (VNA).[6] This education kit also allows students to use computer aided design (CAD) tools. In fact, there is collaboration between Elliptika and ANSYS®[7] to improve the simulation part of the kit. This partnership has led ANSYS to create a new library in its simulation tool, ANSYS DesignerRF™, in which it incorporates the puzzle pieces of microwave components proposed by Eductika. This enables students to verify theory through simulation before implementing and testing their microwave designs.

In this article, we discuss the principle of the microwave puzzle with a description of the various puzzle pieces found in the Eductika kit and the resources available in the ANSYS high frequency toolkit library. As an example,

Alexandre Manchec, Yann Clavet, Eric Rius and Abbas Elmostrah
Elliptika, Gouesnou, France
Alain Michel and Erwan Lecomte
ANSYS, Montigny le Bretonneux, France
Jean François Favennec and Cedric Quendo
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Amplitude Variation, Narrow Band	±0.5dB across any 50MHz (100MHz to 500MHz) ±0.5dB across any 100MHz (500MHz to 18GHz)		
Phase Variation, Narrow Band	±2° over any 50MHz (100MHz to 500MHz) ±2° over any 100MHz (500MHz to 18GHz)		
Phase Resolution	0.8° max.		
Return Loss (Input / Output)	10dB min.		
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RF Input Power (CW) Damage Threshold	+30dBm CW max.		
Control Type - Frequency Control Setting (Optional) - Phase Shift Setting - Attenuator Setting	 8-Bit TTL for 100MHz Bands & More Accuracy 9-Bit TTL 8-Bit TTL		
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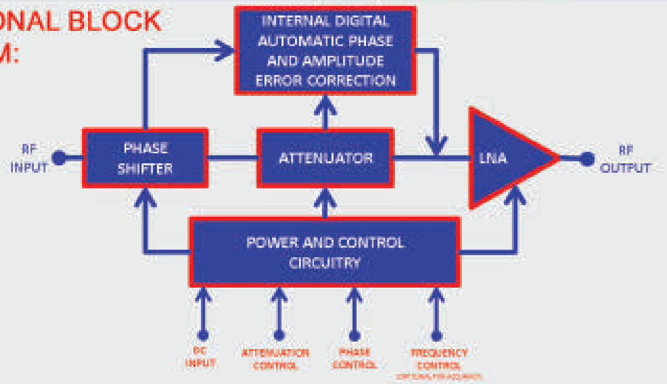

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to demonstrate how the kit may be used, we describe the steps for the design and construction of an ultra wide bandpass (UWB) filter based on short circuited stubs.

EDUCTIKA COMPONENTS PUZZLE

This very complete puzzle game consists of microstrip line sections with different impedances and lengths which can be seen printed on the pieces. These lines can simply be linked together by different connecting items (e.g., T-junction, cross junction or a direct connection between two lines). ***Figure 1a*** and ***Figure 1b*** show puzzle pieces with examples of open and short circuited lines and connections. ***Figure 2*** shows a set of components from the Eductika library (a) not connected or (b) interconnected in order to build a microwave circuit. The connecting items positioned between the microstrip puzzle pieces ensure an electrical contact between the metal tracks of adjacent puzzle pieces on a magnetic plate.

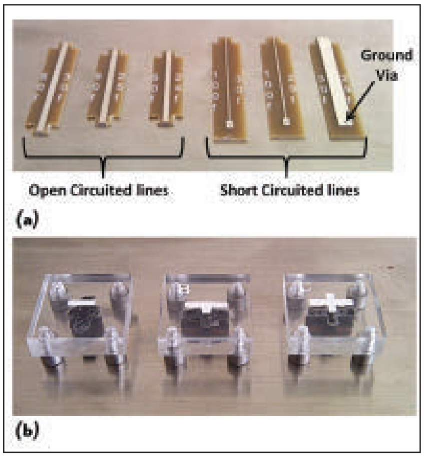


Fig. 1 Microstrip Lines (a), Connecting Items (b): Direct Connection [A], T-Junction [B], Cross junction [C].

To help students understand electromagnetic field, circuit and system simulation software, ANSYS has developed, in partnership with Elliptika, an Eductika toolkit library for ANSYS DesignerRF. This library, ***Figure 3a***, includes the basic elements of the Eductika kit: microstrip lines open or short circuited, connectors and feeds.

The microstrip lines are parameterized in width and length, enabling the user to reproduce all elements of the physical Eductika kit. Each element of the library, ***Figure 3b***, consists of a symbol and footprint associated with an analytical model – ***Figure 3c***. The student starts a design by selecting the Eductika technology file, which automatically loads the library, substrate and stackup definition. The student builds the microwave function by connecting the components in the schematic. This automatically creates the layout the same way as the circuit is assembled on the magnetic plate with Eductika Kit (see ***Figure 4***). Using the ANSYS DesignerRF Solver On Demand (SOD) technology, the student is able to run, in just a few clicks, a simulation with different solvers: Circuit (Nexxim), 2.5 EM (Planar EM) and 3D EM (HFSS). The Eductika toolkit library for ANSYS DesignerRF is provided with eight tutorials that guide the student to build and simulate different microwave functions in ANSYS DesignerRF.

THEORY OF A 4TH ORDER UWB FILTER

The "Bandpass stub filters" box provides a way of studying the design of broadband bandpass filters with stubs in microstrip technology.[4] The filter is designed on Neltec substrate with relative permittivity of 3.8, loss tangent of 0.007, and thickness of 0.711 mm. The trace metal is copper with a metallization thickness of 17 µm. This practical class activity has three parts: design, synthesis and simulation. The filter is required to have a center frequency of 1.5 GHz with a bandwidth (BW) of 750 MHz. ***Figure 5*** shows a schematic of the proposed 4th-order UWB filter achieved using ideal lines. It consists of four $\lambda_0/4$ short-circuited (SC) stubs placed in parallel and interconnected by three quarter-wavelength admittance inverters.[4] The wavelength

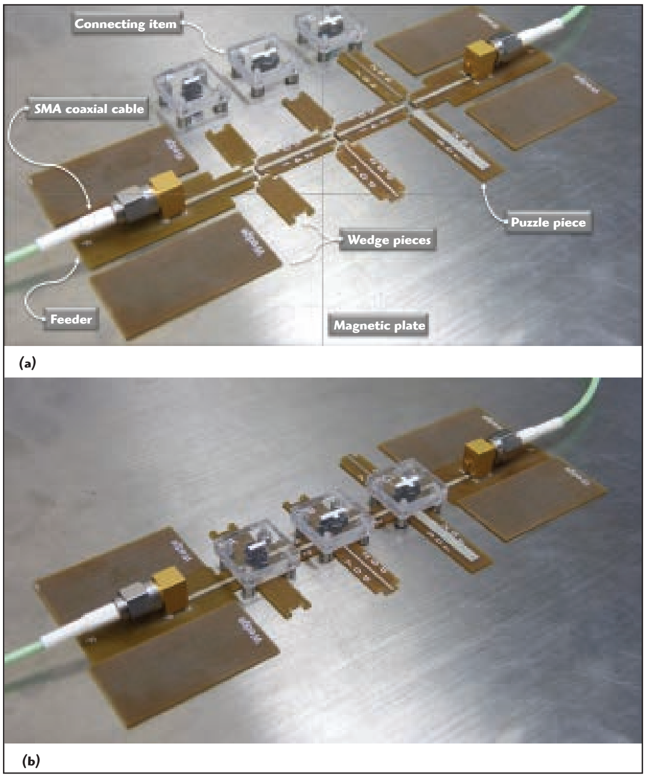


Fig. 2 A set of components from Eductika library (a), Components interconnected to build a microwave circuit (b).

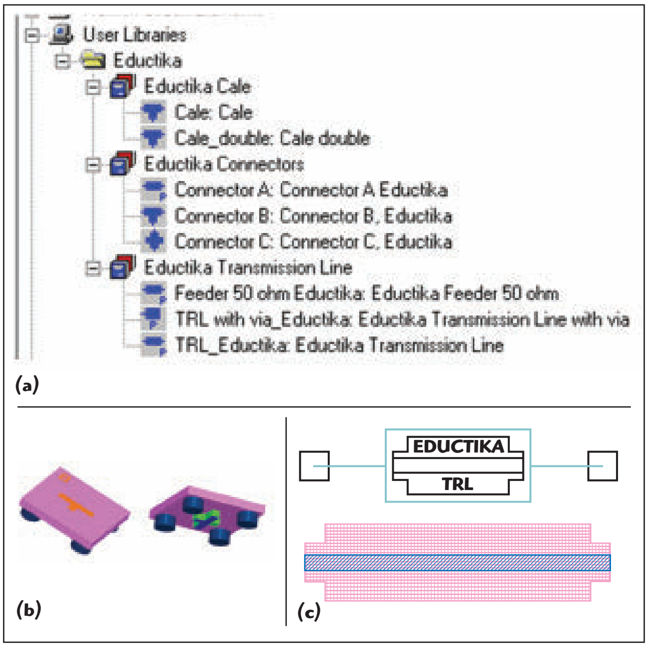
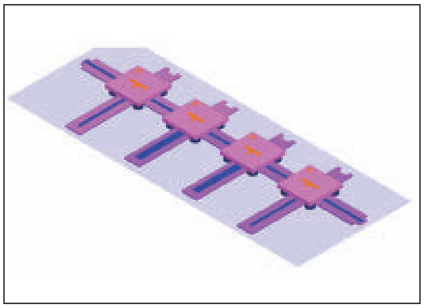
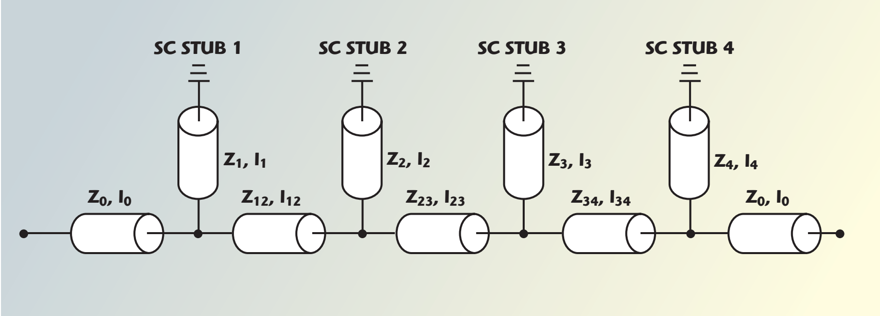


Fig. 3 Eductika library in ANSYS DesignerRF™ (a), 3D view of connector B, (b) Symbol and footprint of microstrip line (c).



▲ *Fig. 4 3D view of the UWB filter in ANSYS Designer.*



▲ *Fig. 5 Fourth order UWB filter.*

in the propagation medium is λ_0 at the center frequency (f_0) of the filter. In Figure 5, Z_0 designates the input and output impedances of the filter. Z_1, Z_2, Z_3 and Z_4 are the characteristic impedances of the four short-circuited stubs and Z_{12}, Z_{23} and Z_{34} are the characteristic impedances of the three interconnecting lines.

To design the filter, the Tchebyscheff approximation is used with a bandwidth ripple A_m = 0.01 dB. After specifying the relative bandwidth (w) by

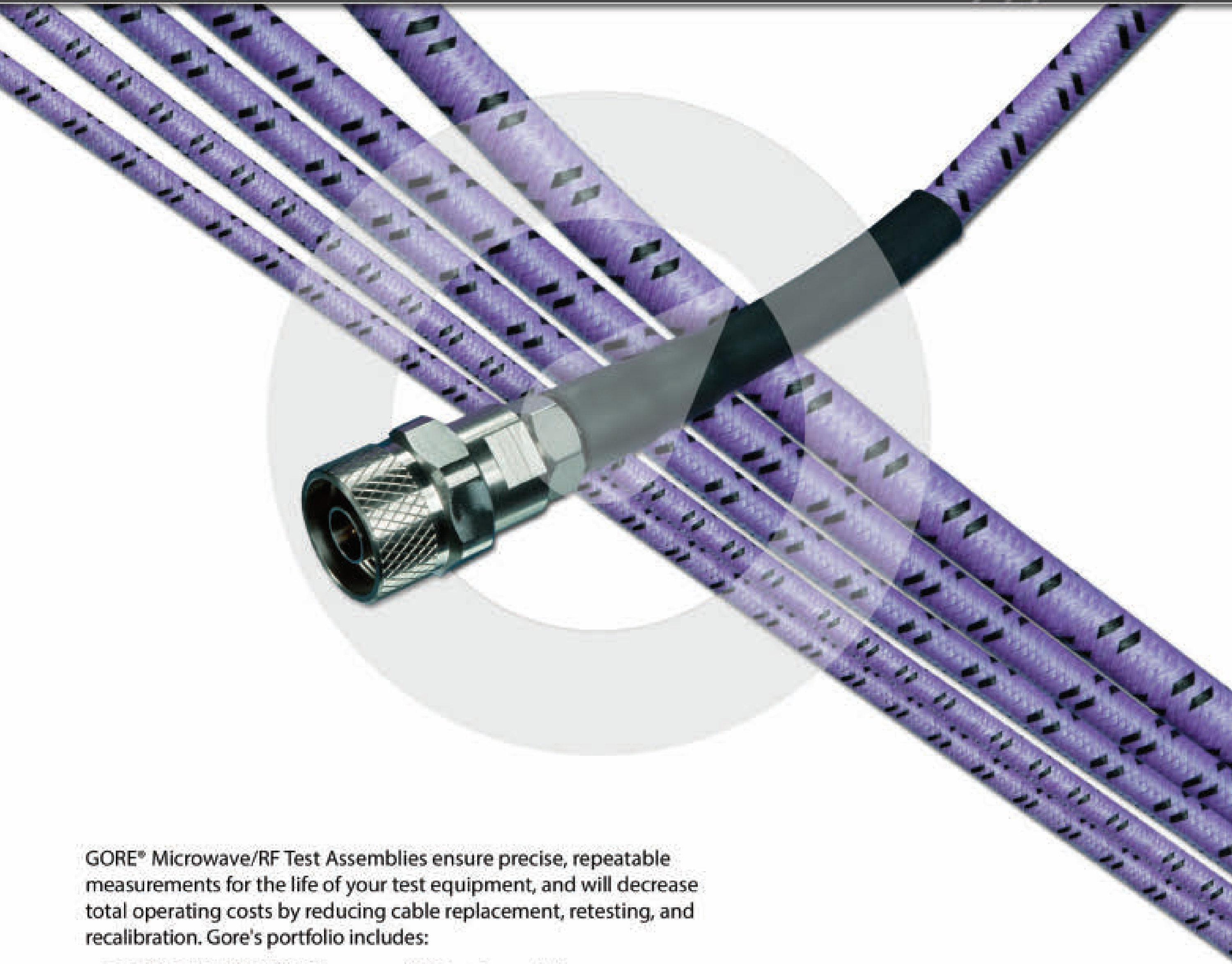
$$w = \frac{BW}{f_0} \tag{1}$$

the characteristic impedances of the SC stubs and the interconnection lines are calculated using equations 1 to 10 in Reference 1 (p. 57). With $Z_0 = 50\ \Omega$, and for $d = 0.9$ (where d is an adjustment parameter of the filter), the values of Z_1, Z_2, Z_3, Z_4, Z_{12}, Z_{23} and Z_{34} are:

$Z_1 = Z_4 = 50.0\ \Omega$
$Z_2 = Z_3 = 30.1\ \Omega$
$Z_{12} = Z_{34} = 48.4\ \Omega$
$Z_{23} = 49.1\ \Omega$

SIMULATION AND MEASUREMENT

Once the theoretical study is completed, the high frequency toolkit of ANSYS DesignerRF is used to verify the electrical response of the UWB filter. As mentioned, the collaboration of Elliptika and ANSYS has led ANSYS to create a library that contains puzzle pieces of the Eductika kit. The filter is simulated by using microstrip puzzle pieces and realized on a Neltec substrate (ε_r = 3.8, h = 0.711 mm). The company uses the microstrip line calculator of ANSYS DesignerRF to determine the different lengths of puzzle pieces. ***Table 1*** summarizes the characteristic impedances and lengths of the UWB filter



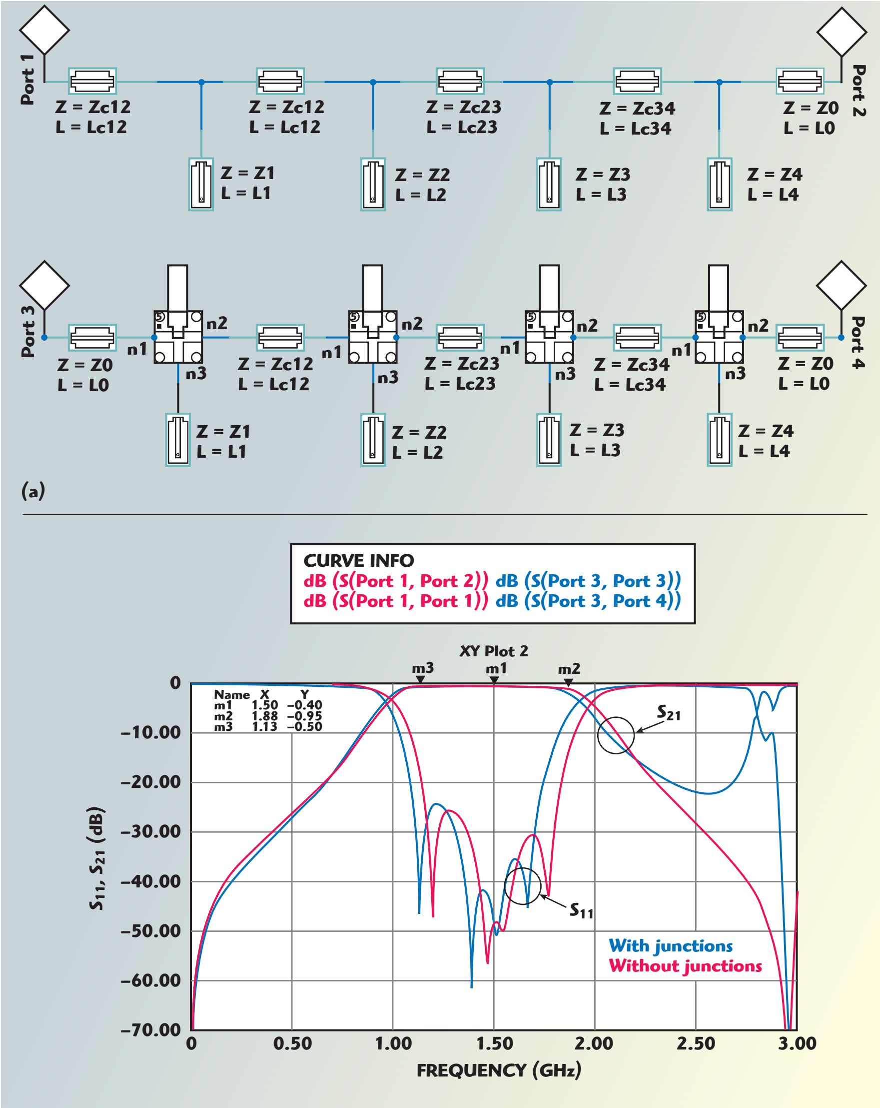
and the corresponding puzzle pieces that can be found in the Eductika kit.

Figure 6a shows the schematic circuit of the UWB filter realized by ANSYS DesignerRF software with and without taking into account the junctions between the lines. The associated electrical responses are presented in ***Figure 6b***. The comparison between responses shows a difference at high frequencies. The electrical response of the circuit without junctions is what is desired; however, when junctions are added, undesired capacitive effects influence the electrical response at high frequencies. To adjust the response, one option is to modify the length of the interconnecting transmission lines. The new values are shown in ***Table 2***. ***Figure 7*** shows the electrical response of the modified UWB filter which now corresponds to the desired response.

Once theoretical design and the simulation are complete, the UWB filter is built on a magnetic plate, ***Figure 8a***, and measured using an Anritsu VNA. ***Figure 8b*** compares measurement and EM simulations, showing good agreement, particularly in terms of passband insertion loss and stopband rejection. Insertion loss at the center frequency, for example, is 1.31 and 1.25 dB, respectively, for HFSS simulation versus measurement. Moreover, the desired bandwidth of 750 MHz was achieved.

CONCLUSION

Eductika provides students with a comprehensive understanding of high frequency circuits, from theory through measurement. Using a puzzle game, students can readily construct circuits using different passive microwave components. It enables students, through a structured and interactive learning environment, to become familiar with complex electromagnetic concepts and tools used for design, simulation, and measurement. ■



▲ *Fig. 6 Schematic circuit of the UWB filter with junctions (bottom) and without junctions (top) (a), and associated electrical responses (b).*

TABLE I

SUMMARY OF MICROWAVE PUZZLE PIECES OF THE UWB FILTER

Component	Characteristic Impedances and Lengths	Puzzle Pieces
SC Stub 1 (Z_1-l_1)	50 Ω - 29.1 mm	50 Ω - 29 mm
SC Stub 1 (Z_1-l_2)	30.1 Ω - 28.1 mm	30 Ω - 28 mm
SC Stub 1 (Z_1-l_3)	30.1 Ω - 28.1 mm	30 Ω - 28 mm
SC Stub 1 (Z_1-l_4)	50 Ω - 29.18 mm	50 Ω - 29 mm
Interconnection Line (Z_{12}-l_{12})	48.4 Ω - 29.18 mm	50 Ω - 29 mm
Interconnection Line (Z_{23}-l_{23})	49.1 Ω - 29.14 mm	50 Ω - 29 mm
Interconnection Line (Z_{34}-l_{34})	48.4 Ω - 29.18 mm	50 Ω - 29 mm

TABLE II

SUMMARY OF MICROWAVE PUZZLE PIECES OF THE MODIFIED UWB FILTER

Component	Puzzle Pieces
SC Stub 1 (Z_1-l_1)	50 Ω - 29 mm
SC Stub 1 (Z_1-l_2)	30 Ω - 28 mm
SC Stub 1 (Z_1-l_3)	30 Ω - 28 mm
SC Stub 1 (Z_1-l_4)	50 Ω - 29 mm
Interconnection Line (Z_{12}-l_{12})	50 Ω - 25 mm
Interconnection Line (Z_{23}-l_{23})	50 Ω - 25 mm
Interconnection Line (Z_{34}-l_{34})	50 Ω - 25 mm

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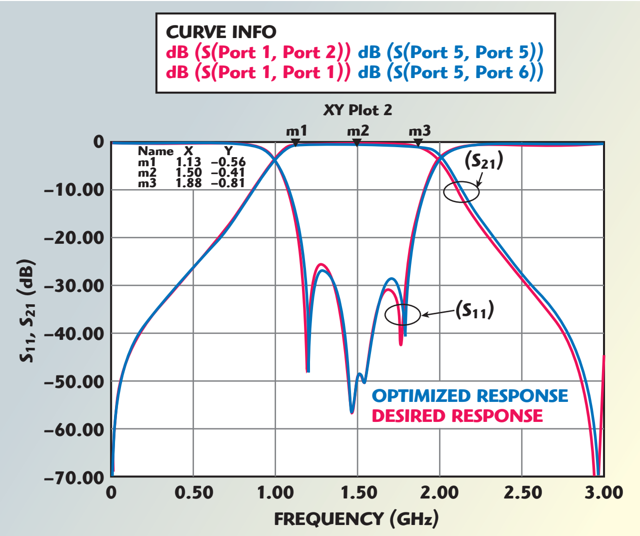
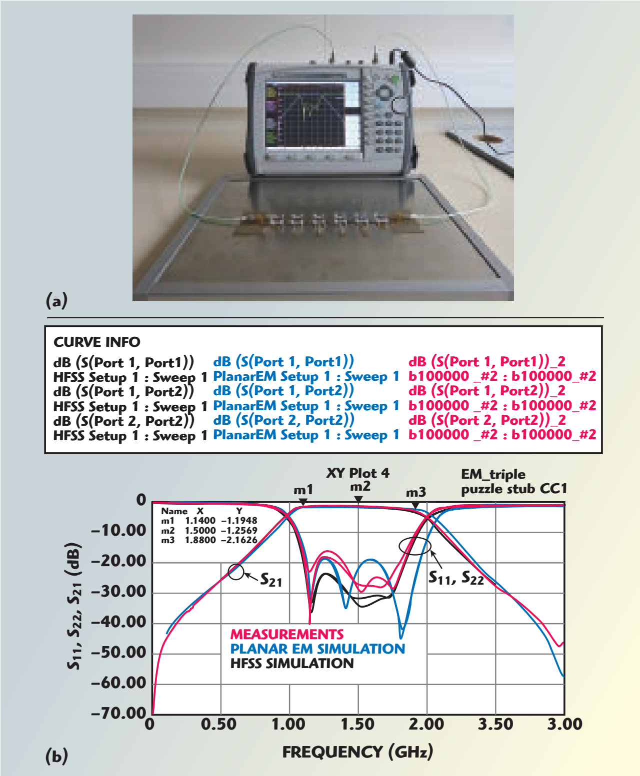


▲ *Fig. 7 Desired filter response (red line) compared with the response of the optimized design (blue line).*



▲ *Fig. 8 Network analyzer display showing the response of the assembled UWB filter (a), circuit simulation of the modified UWB filter design (black line) compared with the measured response of the assembled filter (red line) (b).*

Trend Spotting at IMS 2013

The International Microwave Symposium (IMS), also referred to as Microwave Week or MTT (after the IEEE microwave society that organizes the symposium), held its annual gathering in early June with a return to the Seattle venue last visited by our industry en-masse in 2002. For those attending, the business on the exhibition floor mostly ranged from reasonable to robust, the technical program offered the latest results from industry R&D and academia and the Seattle weather could not have been more perfect.

The MTT-S reported a total attendance number of approximately 7500. This compares on par with the 7700 at IMS 2012 in Montréal. The booth staff was up slightly (3704 versus 3568) while the number of attendees (technical session and exhibition visitors) was slightly lower (3842 versus 4118). On the exhibition side, there were a total of 580 companies, 78 of which were reported by organizers as first time exhibitors.

With three concurrent symposia (IMS, the RFIC symposium and ARFTG symposium), numerous social events and a major vendor exhibition, the week was its usual flurry of activities. This year's IMS technical program (sessions and workshops) covered a lot of ground, providing a glimpse at the technology trends driving the industry. Delegates were offered presentations on the most recent advances in a diverse range of topics related to high-frequency electronics including novel materials and structures (i.e., carbon nanostructures, graphene-loaded and substrate integrated waveguide), semiconductors (GaN, HEMT, HBT, RF SOI, etc.), low power consumption devices, real-time RF data acquisition, digital techniques for linearization and multi-band operations, reconfigurable front ends, dynamic tuning, etc.

From a 60,000 foot view, papers were organized into five tracks to help engineers get a better sense of which technologies are currently being developed (Active and Passive Components); how these technologies are being developed (Field and Circuit Technologies); where these technologies will be used (Systems and Applications) and what will come next (Emerging Technologies). The society also introduced several special panels and workshops this year (Death of GaN Panel and Wireless Day Symposium) and hosted several notable social events. This year's Women in Microwaves reception, which continues to grow

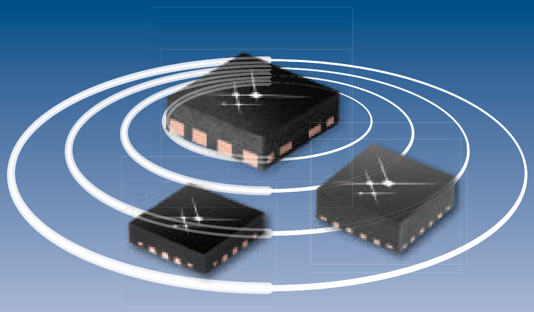
David Vye and Patrick Hindle
Microwave Journal

in popularity and attendance, was co-located with the Ham Radio social at the Seattle Space Needle.

As the technical content at IMS has grown, the society leadership and this year's local steering committee did an excellent job of organizing the structure of the program and social events. The effort to cater to students, young engineers and microwave's female population is a trend that has been occurring over the past several years and is vital to a forward looking industry that needs to expand and engage a new generation of technologists.

And as the industry has evolved, IMS has come to represent the largest North American gathering of microwave professionals, many of whom interact at similar events throughout the year and across the globe including European Microwave Week, Asia Pacific Microwave Conference (APMC) and EDI CON (China). The diversification of gatherings and locations represents one industry trend that is spreading the development of microwave technology and business opportunities across borders and into new markets. As a result, IMS is increasingly attended by international delegates and exhibitors. The internationalization of the industry, discussed in the cover story of *Microwave Journal*'s MTT-S show issue (May) was clearly apparent in Seattle and represents another component in developing new engineering talent.

Many IMS delegates and exhibitors have been attending year after year, turning the event into an annual reunion with no shortage of familiar faces and a few facelifts. RFMD took the occasion to share the company's new look and branding with its industry friends. TriQuint added a new tagline – Reach Further, Reach Faster™ and M/A-COM Technology Solutions is now simply MACOM. Among the new exhibitors were a number of smaller local companies that took advantage of the venue's return to the Pacific Northwest. Many of these new exhibitors included component and subassembly manufacturers introducing new technologies and looking to make a



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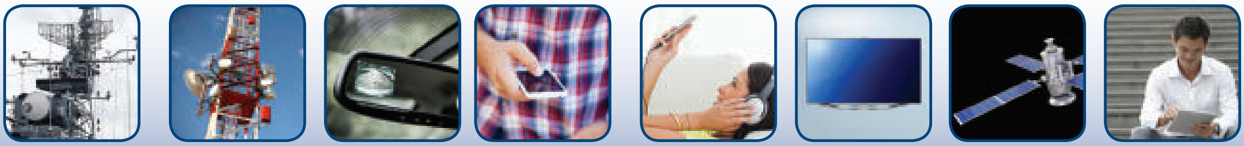

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name for themselves or companies that are tangential to the microwave industry (thin film and micro-assembly manufacturing, testing services, EMC/EMI solutions and materials).

Several sizable companies, which are perhaps better known for their products outside the microwave space and who just began exhibiting over the past couple of years, increased their presence at this year's show. Companies such as National Instruments, Texas Instruments, Cadence and IBM have significantly increased their booth size and marketing impact at IMS, signaling their growing participation and influence in the RF/microwave market.

Another observable trend in the exhibition hall was the growing importance of device packaging as a competitive advantage for many companies while it is often an overlooked part of device performance by others. High power devices, transistors and diodes are being offered in low cost plastic packaging with power levels up to 100 W (pulsed). MACOM and Nitronex now offer GaN transistors in plastic surface mount packages and likewise, Freescale and NXP offer LDMOS transistors in plastic surface mount versions. This reduces costs significantly in applications where performance similar to more expensive ceramic packages can be maintained. MACOM and Aeroflex/Metelics have done a similar thing with diodes at relatively high frequencies and are still able to maintain performance.

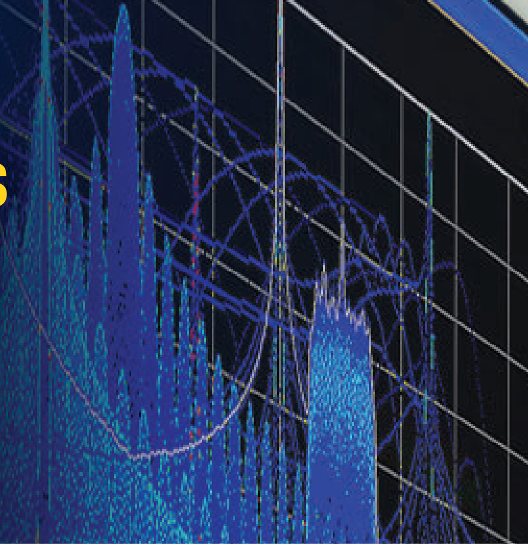
Another new trend is in the area of 3D packaging as several companies now offer solutions utilizing stacked structures. A few examples include Crane Aerospace which offers 3D fusion bonding of laminate layers with devices sandwiched in between the layers, Nuvotronics which offers 3D AirCoax miniaturized microwave networks and 3D Glass Solutions which provides 3D features in a glass-ceramic substrate. One of the RF industry's biggest announcements of the year was Qualcomm's entry into the RF mobile front end market with the release of its new FEM featuring 3D packaging (featured in our June cover story).

The “Death of GaAs?” event run by Strategy Analytics on Thursday offered many varying views on the subject. It started with some market overviews of how GaAs has grown over the years and the looming threat of the Qualcomm CMOS front end which is expected to be out later this year. Several companies showed that CMOS PAs have caught up with GaAs in the high volume handset market, but WIN Semiconductor pointed out that the reality is that GaAs currently still dominates the market even with these newer CMOS PAs being widely available.

Most panelists agreed that CMOS PAs will continue to gain some market share but it will be a slow process as GaAs is still cost competitive and performs very well compared to other technologies. SOI and SOS switches are also replacing GaAs in many slots and will continue to do well in lower cost applications. SOI switches are widely replacing GaAs switches in handsets while GaAs continues to do well in higher performance applications. However, SOS switches are giving GaAs competition in the high performance area in some applications.

The DARPA presentation covered a program that is creating the best of all worlds by combining InP HBT, GaN and MEMS technologies on the same platform. GaN was also reviewed as it is replacing GaAs in some of the high power applications with its higher power density. GaN might actually take more market share from GaAs in the near future than Si, but they are both eating away at GaAs market share. Bottom line, GaAs is still a competitive technology in many areas but is losing some market share from both Si and GaN technologies.

Several companies and marketing analysts took the opportunity to present their perspective on market trends impacting the industry. Regional trends for defense spending were discussed in a special session on “Defense Market Opportunities for RF Technologies” presented by Strategy Analytics. SA analysts are forecasting a decline in European and North American budgets in contrast to the projected growth in



Add real-time analysis to accelerate wireless development

Modern wireless signals and complex signal environments are challenging for RF engineers who are trying to bring advanced products to market quickly and at low cost. These engineers must contend with crowded signal bands and complex techniques for sharing spectral resources through the use of agile signals and sophisticated modulation schemes.

Problems can be subtle or elusive, and can affect one's own signal or those from other spectrum users. Therefore, it's essential to find and solve issues as early as possible to avoid excessive costs and missed market windows. In most cases, a combination of today's major signal analysis tools is the most certain path to wireless success.

Swept analysis for performance and familiarity

RF spectrum analyzers are the fundamental tool for wireless engineers for good reasons. They're straightforward to use, cost-effective, and available at a range of price/performance points to match the needs of both R&D and manufacturing. They play an important role in component and subsystem testing and standards compliance, especially for out-of-band measurements such as spectrum emissions mask (SEM) verification.

Spectrum analyzers allow easy optimization of performance and speed in demanding measurements by allowing fundamental measurement parameters such as center frequency, span, and resolution bandwidth to be independently set over a wide range. This sets them apart from real-time spectrum analyzers (RTSAs) and vector signal analyzers (VSAs) and contributes to ease of use and confidence in interpreting results.

RTSAs for finding elusive signals and understanding agile signal behavior

Dynamic or agile signals and a crowded spectral environment often outrun the capabilities of traditional swept spectrum analyzers. Discovering such signals may also be difficult for VSAs, especially if they are unexpected or their duty cycle is very low. RTSAs and their advanced displays can fill this vital measurement gap using the same type of digital IF architecture as modern wireless receivers. Consider Figure 1, which shows two measurements of the same part of the 2.4 GHz ISM frequency band.

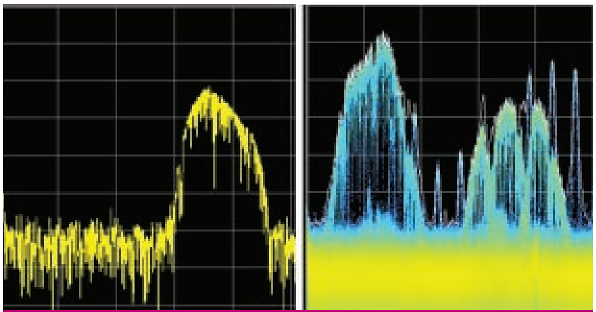


Figure 1. *These are spectrum measurements of the lower half of the 2.4 GHz ISM band. The swept spectrum result (left) is not real-time and misses low-duty-cycle Bluetooth and WLAN signals, which appear clearly in the RTSA density view (right).*

On the left, the spectrum analyzer's own measurement dynamics (a sweeping resolution bandwidth filter) interact with the dynamics of multiple signals in the ISM band to produce an incomplete measurement. One of the wide WLAN signals is not seen, and the very short Bluetooth hops are not shown at all.

The RTSA density display on the right is the result of gap-free analysis that shows every signal present, plus a display that represents how often a signal occurred in terms of color. Although the Bluetooth signals are very infrequent (and thus blue in color), they are still shown clearly.

Frequency mask triggering for real-time and vector signal analysis

The real-time processing power of RTSAs can also be used to generate triggers for measurement or signal capture. By using limit masks enhanced with logical tests (such as when a signal leaves a mask and re-enters) the RTSA can constantly monitor a selected band for specific signals or signal behavior. In the example (Figure 2), a measurement is triggered only by a specific Bluetooth hop, ignoring WLAN signals and other Bluetooth hops.

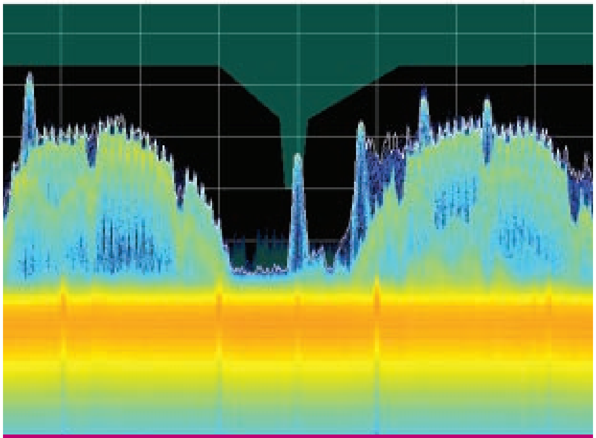


Figure 2. *This frequency mask trigger is configured to capture a particular Bluetooth hop and to ignore the WLAN signals and other Bluetooth hops.*

Instead of waiting for a Bluetooth burst at a specific frequency, the mask and logic of an FMT could be configured to focus on troublesome signal behavior such as frequency or amplitude instability or improper channel assignments. All these FMT approaches are part of a signal-discovery process that typically leads to vector signal analysis as a troubleshooting tool.

VSAs for in-depth analysis, capture and troubleshooting

VSAs are the most powerful tool for wireless analysis and troubleshooting, and their combination of demodulation, signal capture, and flexible post-processing is ideal for tracking down problems with complex and agile signals. Adding the FMT capability of an RTSA to a VSA provides a uniquely effective way to capture and analyze any desired signal or spectral event.

VSAs can record signals both before and after the trigger event, yielding critical insights about cause and effect in wireless systems. Agilent 89600 VSA software also has the ability to change signal center frequency and span after signal capture. This filtering and re-sampling removes other signals from the analysis process and allows the engineer to perform vector analysis or demodulation on any signal within the captured span.

Combining RTSA and VSA tools with swept analysis on a single platform

Wireless engineers face challenges and trade-offs in multiple domains at once, and no single RF tool can meet every need. Agilent's upgradeable PXA and MXA X-Series signal analyzers provide a combination of swept, real-time and vector signal analysis that is the fastest, most certain path to answers for wireless engineers.

Putting RTSA to work with the N9020A MXA

The Agilent MXA X-Series signal analyzer is designed to accelerate the development of new wireless devices for quicker delivery to manufacturing and the marketplace. It has the versatility to easily adapt to evolving test requirements by addressing multiple formats, generations and devices.

Real-time spectrum analyzer capability can be added as an upgrade to new and existing MXAs. Coupled with 160 MHz of analysis bandwidth, the MXA enables accurate characterization of next-generation signals in wireless communications and connectivity.

The Agilent X-Series signal analyzers are an evolutionary approach to signal analysis that spans instrumentation, measurements and software. This provides the flexibility to satisfy business and technical requirements across multiple products and programs – now and in the future.

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spending expected from the Asia-Pacific, Middle East-Africa and Caribbean and Latin American regions. While sequestration and austerity measures in the U.S. and Europe are expected to impact the rollout of next-generation platforms such as the F-35, the speaker emphasized that technology will be an important differentiator between suppliers and that there will be a continued emphasis on improving capabilities in the areas of radar, electronic and communications.

Investing in technology to maintain a competitive advantage was the underlying theme at a press event held by Agilent Technologies. General manager Greg Peters presented an insightful long view of U.S. defense procurement, highlighting trends in spending levels and revenue allocation over time and events (Cold War, Iraq, Afghanistan, etc.). Emphasizing the DoD's shift toward complex integrated, multi-platform systems and the evolving technology needed to support these systems in the field, Peters painted a future of test systems for the defense sector that will be focused on faster measurements, better performance and able to address the cost of ownership.

While sequestration could be a driving force in the development of new technologies that will help companies differentiate themselves and assume a competitive edge, it is also forcing the DoD to keep older systems operational. This trend is driving a second market for the microwave replacement components that are needed to keep aging systems alive. While technology trends continue to push higher performance and reduce size and costs, custom engineering is also required to design new products to fit into pre-existing sockets. Custom engineering is the lifeblood for a large number of companies in the microwave industry and events such as IMS provide the face-to-face interaction that leads to chance encounters and discovery of new opportunities.

A timeless trend. ■

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An Inverse Class E Power Amplifier with Finite DC-Feed Inductance

This article reports the design and experimental characterization of an inverse Class E power amplifier (PA) with a finite DC-feed inductance. The output matching network is designed to transform the standard circuit impedance to the optimum device matching impedance with inherent harmonic suppression characteristics. The inverse Class E PA achieves a peak drain efficiency of 70.6 percent and power added efficiency (PAE) of 67.2 percent, with a gain of 13.2 dB, while providing 40.7 dBm output power at 2.87 GHz. It can produce output power greater than 38.2 dBm with a drain efficiency better than 60 percent across a 250 MHz bandwidth.

The Class E power amplifier, introduced by N. Sokal and A. Sokal in 1975,[1] has become very popular at RF and microwave frequencies due to its simplicity and high efficiency. As the dual to the classical Class E PA, the inverse Class E PA has several advantages. First, it operates with a lower peak voltage, which relaxes the high breakdown voltage requirement of the active device. Second, the internal parasitic inductance of packaged devices can be absorbed by the series inductor in the inverse Class E topology.[2,3] There are some studies addressing this in the existing literature but almost all of the work assumes that the DC feed inductance has an infinite impedance.[2-8] In practice, however, it is impossible to realize an RF choke with infinite impedance at the fundamental frequency and its harmonic components. Moreover, using a finite DC-feed inductance has the advantage of minimizing size, cost and complexity of the overall circuit. The effect of a finite DC-feed inductance on the performance of an inverse Class E amplifier is analyzed and the design equations are given in references Mury et al[9] and Hietakangas et al.[10] An additional capacitor is introduced in Mury et al[9] to resonate with the finite DC-feed inductance at the second harmonic frequency.

This article presents an inverse Class E PA with finite DC-feed inductance which is resonant with a part of the parallel circuit capacitance at the fundamental frequency. The finite

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DC-feed inductance is realized as a short-circuited shunt stub. Theoretical expressions are derived for the circuit elements and the analysis is verified through simulation. For experimental validation, an inverse Class E PA employing a gallium nitride (GaN) high electron mobility transistor (HEMT) device is fabricated and measured.

INVERSE CLASS E CIRCUIT DESIGN

Fundamental Theory

Figure 1(a) shows the ideal equivalent circuit of an inverse Class E PA with finite DC-feed inductance. It consists of an active device as an ideal switch, a series inductor (L_1), a parallel inductor (L_2), a shunt resonant circuit (L_pC_p) tuned to the operating frequency, a compensation capacitor (C) and a load resistance (R). This circuit is usually analyzed based on preliminary assumptions.[4] The output voltage and current are sinusoidal and are defined as

$$v_R(\omega t) = V_R \sin(\omega t + \varphi) \tag{1}$$

$$i_R(\omega t) = V_R G \sin(\omega t + \varphi) \tag{2}$$

where $\omega = 2\pi f_0$, f_0 is the fundamental frequency, V_R is the load voltage amplitude, φ is the initial phase, and $G = 1/R$ is the load conductance.

From ***Figure 1 (b)***, it is seen that

$$V_{DD} - v_R(\omega t) = V_{DD} - v_{L_2}(\omega t) \tag{3}$$

$$v_{L_2}(\omega t) = \omega L_2 \frac{di_{L_2}(\omega t)}{d(\omega t)} = v_R(\omega t) \tag{4}$$

When the switch is ON for $0 < \omega t < \pi$, the voltage on the switch is

$$v_{sw}(\omega t) = 0 \tag{5}$$

At the same time, the current flowing through L_1 can be written as

$$i_{sw}(\omega t) = \tag{6}$$

$$\frac{1}{\omega L_1}\int_0^{\omega t}(V_{DD} - v_R(\omega t))d\omega t =$$

$$\frac{1}{\omega L_1}\left(V_{DD}\omega t + V_R\cos(\omega t + \varphi) - V_R\cos\varphi\right)$$

When the switch is OFF for $\pi < \omega t < 2\pi$ the current

$$i_{sw}(\omega t) = 0 \tag{7}$$

and voltage across the switch is given by

$$v_{sw} = V_{DD} - v_R(\omega t) =$$

$$V_{DD} - V_R\sin(\omega t + \varphi) \tag{8}$$

As is the case with other Class E amplifiers, it is possible to eliminate power losses during ON-to-OFF transition by providing the following collector-current conditions:

$$i_{sw}(\pi) = 0 \tag{9}$$

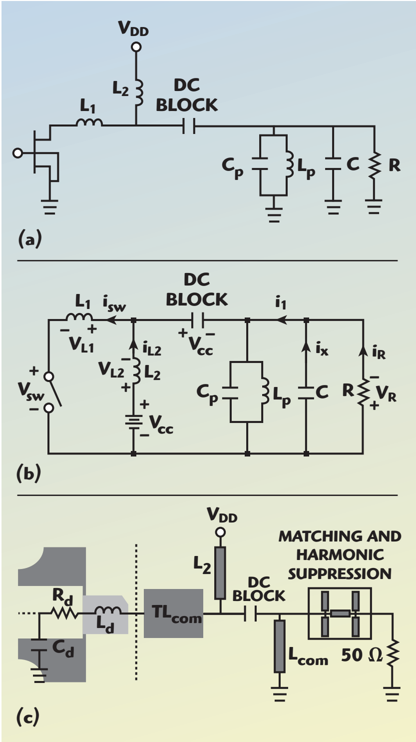
$$\left.\frac{di_{sw}(\omega t)}{d(\omega t)}\right|_{\omega t=\pi} = 0 \tag{10}$$

Applying the zero-current condition in Equation 9 gives

$$V_R = \frac{\pi V_{DD}}{2\cos\varphi} \tag{11}$$

where $-\pi/2 < \varphi < \pi/2$ because $V_R > 0$.

Applying the zero current-derivative condition of Equation 10 and using Equation 11 gives



▲ *Fig. 1 Generalized load network of an inverse Class E amplifier with finite DC-feed inductance ideal circuit (a) equivalent circuit (b) proposed circuit using transmission line (c).*

$$\varphi = \tan^{-1}\left(-\frac{2}{\pi}\right) = -32.4816^\circ \tag{12}$$

and φ falls in the expected range for $V_R > 0$.

As a result, the steady-state switch-current waveform for $0 < \omega t < \pi$ and

the switch-voltage waveform for $\pi < \omega t < 2\pi$ are

$$i_{SW}(\omega t) = \frac{V_{DD}}{\omega L_1}\left(\omega t + \frac{\pi}{2}\cos\omega t + \sin\omega t - \frac{\pi}{2}\right) \quad (13)$$

$$v_{SW}(\omega t) = V_{DD}\left(1 - \frac{\pi}{2}\sin\omega t + \cos\omega t\right) \quad (14)$$

In the time domain, the switch current can be expressed in the form of a Fourier series as follows:

$$i_{SW}(\omega t) = I + \sum_{n=1}^{\infty}\left(a_{in}\cos(n\omega t + \varphi) + b_{in}\sin(n\omega t + \varphi)\right) \quad (15)$$

The DC supply current (I) can be found using Fourier transform equations and 4, 13 as

$$I = \frac{1}{2\pi}\int_0^{\pi} i_{sw}(\omega t)\,d(\omega t) = \frac{1}{2\pi}\int_0^{2\pi} i_{L_2}(\omega t)\,d(\omega t) \quad (16)$$

where

$$i_{L_2}(\omega t) = \frac{1}{\omega L_2}\int_0^{\omega t} v_{L_2}(\omega t)\,d(\omega t) = \frac{1}{\omega L_2}\int_0^{\omega t} v_R(\omega t)\,d(\omega t) = \frac{V_R}{\omega L_2}\left(\cos\varphi - \cos(\omega t + \varphi)\right) \quad (17)$$

The DC supply current is found to be

$$I = \frac{V_{DD}}{\pi\omega L_1} = \frac{\pi V_{DD}}{2\omega L_2} \quad (18)$$

In an idealized inverse Class E mode of operation, there is no simultaneous nonzero voltage and current. That means that there is no power dissipation and the idealized collector efficiency is 100 percent. This implies that the DC power and fundamental output power are equal

$$IV_{DD} = P_{out} = \frac{V_R^2}{2R} \quad (19)$$

By using Equations 11-16, and $P_{DC} = I\,V_{DD}$, the optimum value of L_1 and L_2 can be obtained as

$$L_1 = \frac{V_{DD}^2}{\pi\omega P_{out}} \quad (20)$$

$$L_2 = \frac{\pi}{2}\frac{V_{DD}^2}{\omega P_{out}} \quad (21)$$

At the fundamental frequency f_0, we can write 15 as

$$i_{sw_1}(\omega t) = a_{i1}\cos(\omega t + \varphi) + b_{i1}\sin(\omega t + \varphi) \quad (22)$$

where a_{i1} and b_{i1} are defined as the Fourier coefficients of the switching current

$$a_{i1} = \frac{1}{\pi}\int_0^{\pi} i_{sw}(\omega t)\cos(\omega t + \varphi)\,d(\omega t) \quad (23)$$

$$b_{i1} = \frac{1}{\pi}\int_0^{\pi} i_{sw}(\omega t)\cos(\omega t + \varphi)\,d(\omega t) \quad (24)$$

The coefficients a_{i1} and b_{i1} are found using Equation 13 to be

$$a_{i1} = \frac{\left(\pi^2 - 4\right)}{4\sqrt{\pi^2 + 4}}\frac{V_{DD}}{\omega L_1} \quad (25)$$

$$b_{i1} = \frac{4}{\pi\sqrt{\pi^2 + 4}}\frac{V_{DD}}{\omega L_1} \quad (26)$$

On the other hand, from Figure 1 (b), it is evident that

$$i_x(\omega t) = V_R\omega C\cos(\omega t + \varphi) \quad (27)$$

$$i_1(\omega t) = i_R(\omega t) + i_x(\omega t) \quad (28)$$

$$i_{sw_1}(\omega t) = i_1(\omega t) + i_{L_{21}}(\omega t) \quad (29)$$

Where

$$i_{L_{21}}(\omega t) = \frac{V_R}{\omega L_2}\cos(\omega t + \varphi) \quad (30)$$

Using Equations 2, 11, 12, 22, 25-30, R and C can be obtained as

$$R = \frac{\pi^2 + 4}{8}\frac{V_{DD}^2}{P_{out}} \quad (31)$$

$$C = \frac{\pi^4 + 16}{2\pi\left(\pi^2 + 4\right)}\frac{P_{out}}{\omega V_{DD}^2} \quad (32)$$

The peak values of the switch voltage (V_{swpk}) and switch current (I_{swpk}) can be determined by differentiating the corresponding waveforms given by Equations 13 and 14 and setting the results equal to zero, thus obtaining

$$V_{swpk} = \left(\frac{\sqrt{\pi^2 + 4}}{2} + 1\right)V_{DD} = 2.8621V_{DD} \quad (33)$$

This situation occurs at a phase angle of

$$(\omega t)_v = 180^\circ + \tan^{-1}\left(-\frac{\pi}{2}\right) = 122.4816^\circ \quad (34)$$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For the peak switch current we find

$$I_{swpk} = \pi \tan^{-1}\left(\frac{4\pi}{\pi^2 - 4}\right) I = 3.562I \quad (35)$$

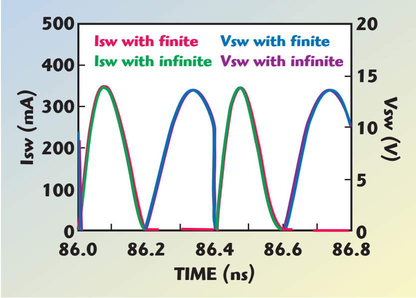
Which occurs at a phase angle of

$$(\omega t)_i = \tan^{-1}\left(\frac{4\pi}{\pi^2 - 4}\right) = 64.9633^\circ \quad (36)$$

The optimum parameters are expressed as functions of a specific output power (P_{out}) and a given input DC voltage (V_{DD}) at a specified operating frequency (f_o) shown in ***Table 1***. Table 1 also shows the optimum parameters of the classical inverse Class E topology.[4]

COMPARISON

In this section, the simulated example of a 500 mW, 5 V Class E PA, operating at 2.5 GHz and having 10 percent bandwidth (Q_{LC} = 10), is provided as a means to verify the theoretical analysis. The values of the circuit elements for topologies with infinite and finite DC feed inductance are presented in ***Table 2***. These quantities are computed based on the equations in Table 2. The active device is modeled as a switch which has 0.01 Ohms ON resistance (used because the Advanced Design System (ADS) simulation algorithm of the switch component does not allow 0 Ohms ON resistance) and 10 kOhm OFF-state impedance. Simulation results are shown in ***Figure 2***. A sinusoidal voltage is used to drive the switch model used in the ADS simulation in such a way that the switch duty



▲ *Fig. 2 Current and voltage waveforms of the inverse Class E amplifier with finite or infinite DC-feed inductance considered.*

cycle is 50 percent. From the voltage and current waveforms, it follows that the waveforms for the circuit modeled with a finite DC-feed almost coincide with the ones for the circuit modeled with an infinite DC-feed. Theoretical

TABLE I

CIRCUIT COMPONENT EQUIVALENCES

Component	Infinite DC-Feed Inductor	Finite DC-Feed Inductor
L_1	$\frac{V_{DD}^2}{P_{out}\pi\omega}$	$\frac{V_{DD}^2}{P_{out}\pi\omega}$
L_2	N/A	$L_2 = \frac{\pi}{2}\frac{V_{DD}^2}{\omega P_{out}}$
R	$\frac{\pi^2+4}{8}\frac{V_{DD}^2}{P_{out}}$	$\frac{\pi^2+4}{8}\frac{V_{DD}^2}{P_{out}}$
C	$\frac{\pi(\pi^2-4)}{2(\pi^2+4)}\frac{P_{out}}{\omega V_{DD}^2}$	$\frac{\pi^4+16}{2\pi(\pi^2+4)}\frac{P_{out}}{\omega V_{DD}^2}$
C_p	$C_p = \frac{Q_{LC}}{\omega R}$	$C_p = \frac{Q_{LC}}{\omega R}$
L_p	$L_p = \frac{1}{(\omega^2 C_p)}$	$L_p = \frac{1}{(\omega^2 C_p)}$

TABLE II

COMPONENT VALUES USED IN THIS DESIGN EXAMPLE OF AN INVERSE CLASS E AMPLIFIER: P_{OUT}=0.5 W, V_{DD}= 5 V, f_0= 2.5 GHz, Q_{LC}=10

Component	Infinite DC-Feed Inductor	Finite DC-Feed Inductor
L_1	1 nH	1 nH
L_2	N/A	5 nH
R	86.7 Ω	86.7 Ω
C	0.85 pF	1.66 pF
C_P	7.34 pF	7.34 pF
L_P	0.55 nH	0.55 nH

Note: The inductance of the RF choke is not included

TABLE III

COMPARISON OF THEORY AND SIMULATION RESULTS

Component	Inverse Class E with Infinite DC-Feed Inductor		Inverse Class E with Infinite DC-Feed Inductor	
	Theory	Simulation	Theory	Simulation
V_{swpk}	14.3 V	13.5 V	14.3 V	13.6 V
I_{swpk}	356 mA	345 mA	356 mA	347 mA
I	100 mA	93.6 mA	100 mA	94 mA
P_o	500 mW	462 mW	500 mW	464 mW
η	100%	98.7%	100%	98.7%

results of the inverse Class E amplifier with infinite versus finite DC-feed topology are also given in ***Table 3***, and compared to the simulation results. From Table 3, it is evident that the theoretical analysis is in good agreement with the simulation results. The same efficiency has been obtained from both power amplifiers.

There are two advantages to using a finite DC-feed inductor (L_2) as opposed to using an infinite one. First is that the size and complexity of the overall circuit are minimized. For this design example, an extra inductor (L_2 = 5 nH) and a larger value of C (1.66 pF) are required for the inverse Class E topology with a finite DC-feed inductor (Table 3). Conversely, realizing a sufficiently high inductance to approach the infinite case would require greater circuit area. The second advantage is that the harmonic components are more thoroughly suppressed; resulting in higher output power and better drain efficiency. The parallel capacitance (C) can be divided into two parts; one part to compensate the phase angle error of the fundamental current, another to resonate with the finite DC-feed inductance at the fundamental frequency. The benefit of resonation at the fundamental frequency is better suppression at harmonic frequencies. This is indicated in the simulated results from Table 3 showing that the output power (464 mW) of the PA with finite DC-feed inductor is larger than the output power (462 mW) of the PA with the infinite DC-feed inductor.

Inverse Class E PA Using Transmission Line

For the experimental validation, a packaged GaN HEMT is used to replace the switch. The device cannot operate as an ideal switch due to the parasitic components caused by the package, interconnections and bond wires.[6] Therefore, several internal parasitic components should be contained or compensated in the design procedure. ***Figure 1(c)*** depicts the proposed output equivalent circuit of the inverse Class E PA. The drain series inductance (L_d) is used as a part of L_1 in Figure 1(a). A series transmission line (TL_{com}) is used as the tuning line to provide additional inductance because the value of L_d extracted by the model in reference Cabral et al[11] is a little smaller than the optimum value of L_1 calculated using equation 1. Meanwhile, C_d simply represents the sum of all capacitance seen at the drain, and is compensated by a short-circuit shunt stub since the inverse Class E PA cannot deal with the output capacitance of the device.

Figure 3 shows the full schematic of the proposed inverse Class E PA. The finite DC-feed inductor (L_2) is realized by a short-circuited shunt stub. The output network is designed to convert the standard 50 Ohm circuit impedance to an optimum matching impedance for the device of 83.9 Ohms using a simple L-type matching circuit. The lumped components are replaced by transmission lines using the Kuroda identity and the Richard transformation as explained in Mury et al.[12] The parallel capacitance (C) is replaced by four open-circuited shunt stubs that are deliberately designed to accommodate the 2nd, 3rd, 4th and 5th harmonic terminations, dispensing with the need for a series-tuned L_pC_p circuit as in Figure 1(a). The input of the device is conjugately matched at the frequency of operation. The values of R_1, R_2 and C_1 are obtained from the stability analysis based on S-parameter simulation in ADS.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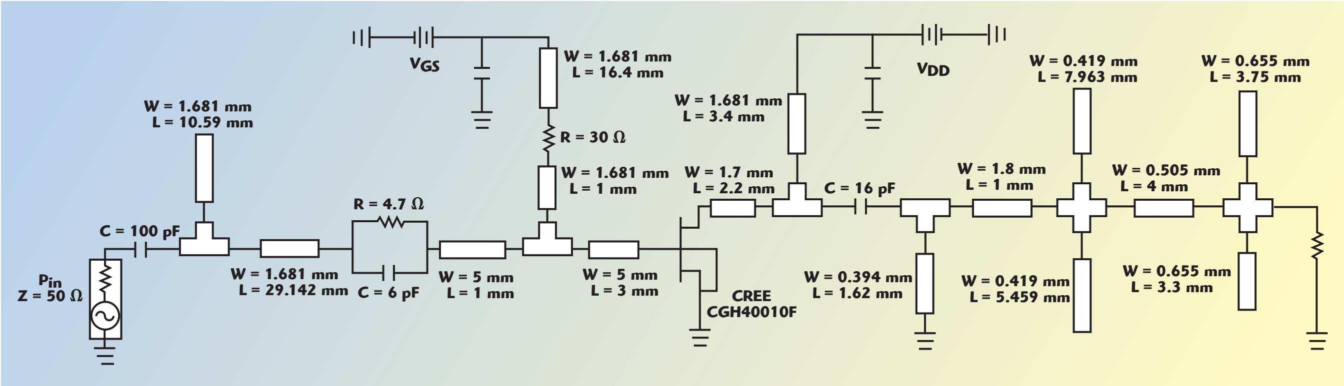
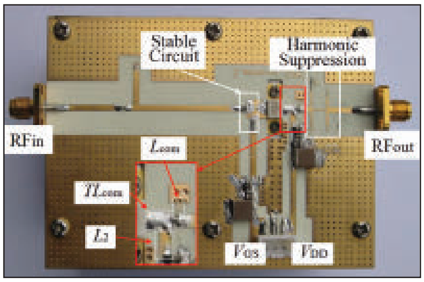


▲ *Fig. 3 Full schematic of the proposed inverse Class E power amplifier.*

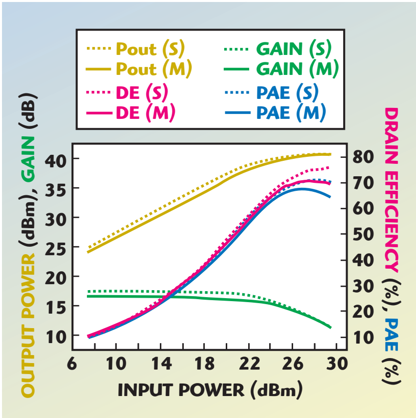
FABRICATION AND MEASUREMENT

The proposed inverse Class E PA was designed and implemented using a 30-mil RO4350B substrate ($\varepsilon_r = 3.5$). The switching transistor is a Cree GaN HEMT power device (CGH40010F). ***Figure 4*** shows the photograph of the fabricated amplifier.

Figure 5 shows the simulated and measured output power, drain efficiency, power-added efficiency (PAE) and gain of the proposed inverse Class E PA versus input power at 2.87 GHz. With the bias condition that $V_{GS} = -3$ V, $I_{DS} = 50$ mA and $V_{DD} = 25$ V, the peak drain efficiency and PAE of 70.6 percent and 67.2 percent with a power gain of 13.2 dB were obtained at an output power of 40.7 dBm. The power gain of over 15 dB is maintained over a wide output power range. The measured harmonic suppression for the 2nd, 3rd, 4th and 5th harmonics are 32.5, 45.6, 42.8 and 60.6 dBc. The measured values are lower than those obtained by simulation (52.7, 57.97, 54.55 and 69.9 dBc) because the measured frequency (2.87 GHz) is shifted from the design frequency (3 GHz). The frequency shift is due to inaccuracies in the large-signal model of the transistor, as well as fabrication tolerances associated with the substrate and surface-mount technology passive components.



▲ *Fig. 4 Photograph of the fabricated power amplifier.*



▲ *Fig. 5 Simulated and measured output power, drain efficiency and PAE vs. input (f_0 = 2.87 GHz, V_{GS} = –3 V and V_{DD} = 25 V).*

Figure 6 shows the simulated and measured output power, drain efficiency and PAE versus drain bias voltage at an input power of 27.5 dBm. It is worth noting that a high efficiency of over 65 percent is maintained over wide range of drain bias voltages (13 to 30 V), be-

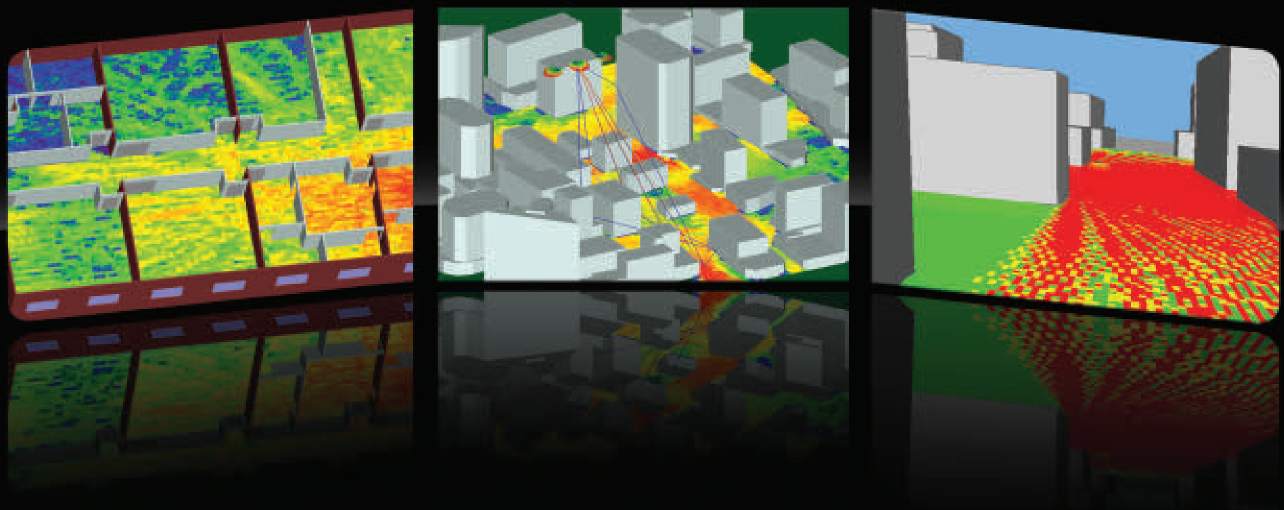
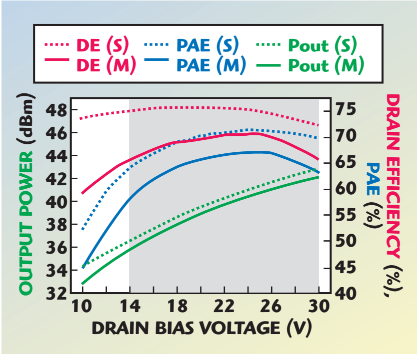


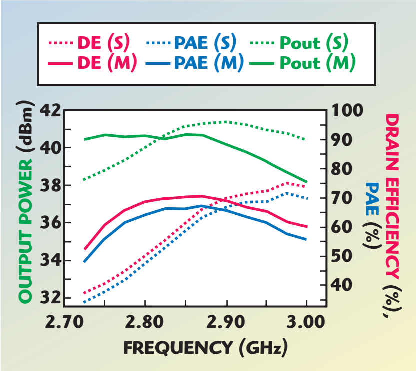
TABLE IV

PERFORMANCE COMPARISON WITH THE PREVIOUSLY PUBLISHED WORKS

PA Mode	Pout (dBm)	PAE/η (%)	f_0 (GHz)	V_{DD} (V)	Device
Class E^{-1} [2]	18	93/95	0.87	2	PHEMT
Class E^{-1} [3]	22	64/69	2.3	3	GaAs MESFET
Class E^{-1} [6]	38.98	68.15/70.98	0.945	20	Si LDMOS
Class E^{-1} [7]	41.03	78.8/79.7	1	22	GaN HEMT
Class E^{-1} [8]	45.6	70.7/79	3.5	28	GaN HEMT
This Work	40.7	67.2/70.6	2.87	25	GaN HEMT



▲ *Fig. 6 Simulated and measured output power, drain efficiency and PAE vs. drain supply voltage (P_{in} = 27.5 dBm, f_0 = 2.87 GHz and V_{GS} = –3 V).*



▲ *Fig. 7 Simulated and measured output power, drain efficiency and PAE vs. operating frequency (P_{in} = 27.5 dBm, V_{DD} = 25 V and V_{GS} = –3).*

cause a flat efficiency response versus drain bias is required for drain voltage modulations such as envelope elimination and restoration (EER).[6]

Figure 7 shows the simulated and measured output power and efficiency as a function of operating frequency at an input power of 27.5 dBm. Output power of greater than 38.2 dBm and drain efficiency better than 60 percent are achieved over a 250 MHz bandwidth (from 2.75 to 3 GHz). Compared to other inverse Class E power amplifiers (***Table 4***), the proposed inverse Class E PA exhibits similar levels of efficiency and output power.

CONCLUSION

In this article, we described the design of a GaN-based PA using inverse Class E topology with finite inductance and harmonic suppression. The design equations are given to determine the values of circuit elements. The peak drain efficiency of 70.6 percent, PAE of 67.2 percent with a gain of 13.2 dB is achieved at

an output power of 40.7 dBm at 2.87 GHz. The measured results demonstrate the validity and advantage of the proposed GaN HEMT inverse Class E PA when used as a solution for high-power transmitters requiring high efficiency. ■

ACKNOWLEDGMENT

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Fully Automated Calibration System

ATE Systems has developed the next generation of microwave instrument calibration technology. This third generation approach is fully automated, virtually eliminating the possibility of user-induced error, while providing accuracy that meets TRL-level verification and significantly reducing the time required for calibration.

The first generation approach, still in common use today, involves connecting mechanical calibration artifacts to the instrument and measuring them to determine systematic error terms. This technique typically involves connecting a series of reflection standards to each test port one at a time, and making through connections between pairs of test ports. Alternate calibration techniques involve some variations on this general approach, but all involve connecting and disconnecting a series of calibration standards at each test port.

The second generation approach was originally developed by ATN Microwave in 1988 and is commonly known today as eCal. The eCal module replaces the mechanical artifacts with electronic impedance standards, and incorporates internal switching to connect each standard to each port at the proper time. When the eCal module is connected to the VNA test ports, the VNA calibration wizard switches through each state, measuring the response as it goes. After the calibration is done, the user disconnects the eCal module and connects the DUT.

ATE's third generation approach, InCal, takes eCal to the next level. Like eCal it utilizes electronic impedance standards. Unlike eCal, though, it can be connected to the

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test system once and does not need to be removed. Calibration can be performed with or without the DUT connected, and measurements are made without removing the calibration system.

IMPLEMENTATION

The InCal system consists of two parts. The Instrument Correction Module is used to perform a fully automated, in-situ calibration of the test instrument. This provides error corrected data at the test ports of the instrument. The Fixture Characterization Module (FCM) is used to perform a fully automated, in-situ characterization of the path between the instrument and the DUT or test fixture (see ***Figure 1***). This brings the reference plane directly to the DUT.

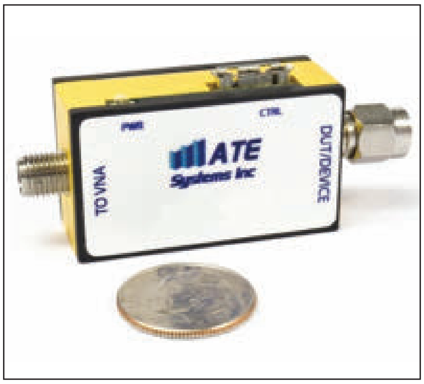
BENEFITS

Using InCal offers some significant advantages over the first two generation techniques. By configuring the system hardware once and not connecting and disconnecting different pieces, the chances of making an incorrect connection or applying an improper torque to a connector resulting in a bad calibration are eliminated. The wear and tear on the connectors is greatly reduced, preserving the electrical integrity of the calibration standards, and virtually eliminating the need to repair connectors or replace worn standards.

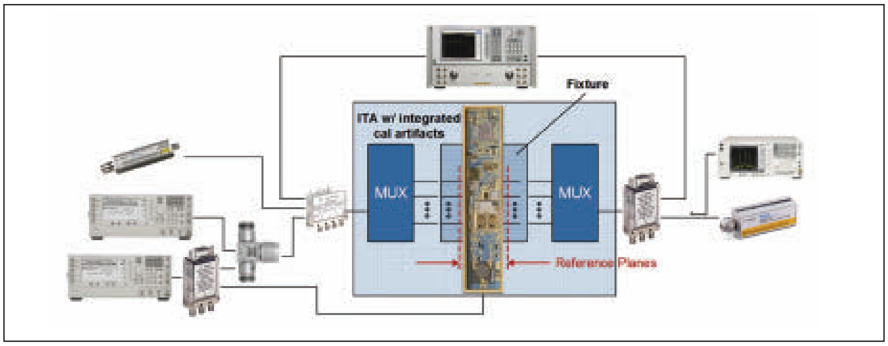
Since the connect/disconnect cycles are eliminated for calibration, the time required for calibration can be dramatically reduced. This is not just a convenience, but it can be a significant cost saver, especially for multiport device measurements or applications where throughput drives cost. Furthermore, InCal is easily expandable to extremely high port-count devices where the time and cost improvements grow exponentially with the number of ports.

The electronic impedance standards of InCal are transfer standards characterized to TRL level accuracy resulting in excellent measurements. If there is suspicion that the instrumentation has drifted during measurement, just press the calibrate button and then make another measurement. This is done without disturbing the measurement setup.

By making the calibration process nearly transparent, the expertise required of the operator is reduced. Making measurements with a VNA using InCal becomes easier than using an oscilloscope while delivering superior accuracy.



▲ *Fig. 1 Fixture characterization module.*



▲ *Fig. 2 The InCal system addressed all of the customer's calibration needs.*

MANUFACTURING ENVIRONMENT CASE STUDY

This calibration technology has been incorporated into custom test fixtures that ATE Systems developed for a customer to address their need to improve operational efficiency and reduce the cost of test. Central to this activity were reducing calibration time and operator error. Throughput is critical to profitability in a manufacturing environment, and time spent calibrating a test system is time when throughput stops since testing is not being performed. Typically, improving throughput requires some combination of additional test systems being purchased, additional operators being hired, overtime being paid or shipments being delayed. All of these options have real, tangible costs associated with them.

Obtaining accurate test data is also important in manufacturing from an overall throughput point of view to ensure that bad parts are screened out, that good parts are not rejected, and that retesting is avoided. Of these, not screening bad parts can be the most costly since it can result in field failures, customer returns, customer dissatisfaction, and potential loss of future business.

These two factors highlight the need for improving system throughput, and this can be done economically by reducing the time required for system calibration, providing a system able to support accurate measurements, and eliminating, to the extent possible, bad data resulting from operator-induced errors. The InCal system addresses all of these issues and has been successfully applied to an existing multiport, multifunctional test system in a flexible manufacturing environment at a customer's facility (see ***Figure 2***). By integrating InCal into the test fixtures, the customer is able to nearly double the throughput, reducing the cost of test in half while achieving excellent accuracy.

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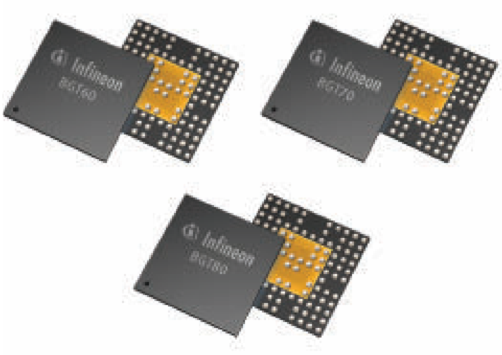

Single-Chip Packaged RF Transceivers for Mobile Backhaul

Infineon Technologies AG has introduced a new transceiver family that simplifies system design and production logistics. Due to their low power consumption the single-chip high-integration transceivers also help to reduce fixed costs in high data rate millimeter-wave wireless backhaul communication systems. The new transceivers address the market for wireless data links with data rates of more than 1 Gbps between LTE/4G base stations and core networks.

Mobile communications and especially LTE is gaining momentum due to the fact that all big carriers and mobile phone manufacturers are investing in the 4th generation ecosystem. The challenge that the ecosystem will face is that LTE will further enhance the video and data exchange to a maximum and the bulk of today's base station infrastructure is not ready to support the required high data throughput. Up until now the connection between the base station has been planned for lower data rates (a few 100 MBit/s) and now needs increased capacity.

This is where the wireless backhaul technology comes into place. A solution using wireless backhaul in the E-Band (71 to 76 and 81 to 86 GHz) will open up a 10 GHz frequency range and in the V-Band (57 to 64 GHz) will open up a 7 GHz frequency range to do so. This enables data rates >1 Gbit/s for video and data services, sufficient for LTE.

A COMPLETE FAMILY

To address this issue Infineon has developed a complete family of packaged RF transceivers for mobile backhaul – the BGT70 and BGT80 for E-Band radio and the BGT60 for V-Band radio. ***Figure 1*** shows E-Band TDD using BGT70 and BGT80 chipsets. The modular approach supports the three backhaul frequency ranges of 60, 70 and 80 GHz with one common architecture. Customers can easily design all three radio versions with the same RF footprint as the package is the same for all three transceivers.

Due to the advanced SiGe technology with a transit frequency of 200 GHz, all relevant RF building blocks can be integrated into a single chip. Chips in the Infineon BGTx0 product family come in a standard plastic package (eWLB, embedded wafer level ball grid array). The highly integrated RF transceivers require no external RF discretes, thereby simplifying the customer design and time-to-market. They replace more than 10 discrete devices used in

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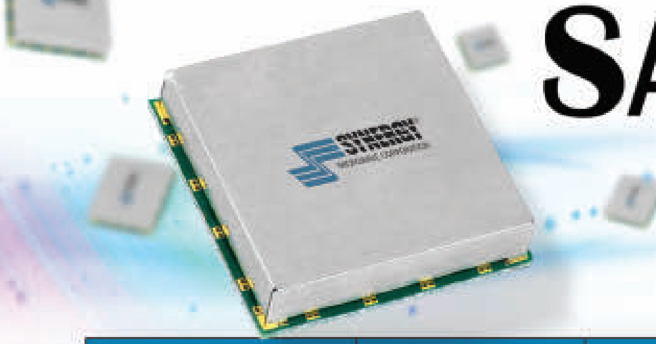

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Model	Frequency (MHz)	Tuning Voltage (VDC)	DC Bias VDC @ I [Max.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]
HFSO640-5	640	0.5 - 12	+5 @ 35 mA	-151
HFSO745R84-5	745.84	0.5 - 12	+5 @ 35 mA	-147
HFSO776R82-5	776.82	0.5 - 12	+5 @ 35 mA	-146
HFSO800-5	800	0.5 - 12	+5 @ 30 mA	-146
HFSO914R8-5	914.8	0.5 - 12	+5 @ 35 mA	-139
HFSO1000-5	1000	0.5 - 12	+5 @ 35 mA	-141
HFSO1000-12	1000	0.5 - 12	+12 @ 35 mA	-141

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current system designs with one single chip. The customers' assembly process is simplified dramatically as they can continue to use a standard SMT assembly flow.

The BGTx0 family provides a complete RF front end for wireless communication in 57 to 64 GHz (BGT60), 71 to 76 GHz (BGT70), or 81 to 86 GHz (BGT80) millimeter-wave bands. BGT60 has identical pinning and the same footprint as the BGT70 and the BGT80. Paired with a baseband/modem, the system solution requires less space, offers improved reliability and lower cost for the critical wireless backhaul links needed in mobile base stations that support LTE/4G networks.

INTEGRATION

The BGTx0 transceivers integrate all of the RF building blocks – I/Q modulator, voltage controlled oscillator (VCO), power amplifier (PA), low noise amplifier (LNA), programmable gain amplifier (PGA), SPI control interface and more – on a single chip in a compact, plastic eWLB package (6 × 6 mm). Validation and calibration of RF performance occurs in production using Built-In-Test-Equipment (BITE), which contributes to the simplicity of integrating the chip into a device builder's production flow and delivers 'known good-die' to the customer. ***Figure 2*** is an application diagram using the BGTx0 family.

The V-Band and E-Band microwave frequencies available for LTE/4G backhaul support data rates three times higher than in earlier generation networks. Correspondingly they need superior RF performance to meet operating requirements. The outstanding RF performance of the BGTx0 family based on SiGe technology – such as deliverable output power of up to 18 dBm from the PA, low noise figure of 6 dB from the LNA and excellent VCO phase noise of better than -85 dBc/Hz at 100 kHz offset – allows system designers to implement high modulation schemes up to QAM64 with a sample rate of 500 Msymbol and QAM32 with 1 Gsymbol at a 10^{-6} Bit Error Rate (BER).

Electrostatic Discharge (ESD) performance of more than 1 kV increases the robustness and eases the system design for customers. The low power consumption of less than 2 W for this backhaul transceiver family also allows network operators to reduce related fixed expenses. Due to the direct conversion architecture of the transceiver, the interface between RF and baseband is simplified significantly compared to currently available discrete millimeter-wave systems.

The technology used is already proven and fully qualified for Infineon millimeter and microwave chipsets (e.g. 77 and 24 GHz automotive radar). Furthermore the offering of these single chip solutions in a plastic package makes a major difference to the market. Up until now, solutions have been bare die and require expensive tools and equipment to build up a radio system. With the packaged chipset, customers can save money and reduce the time-to-market significantly. Engineering samples and evaluation boards (see ***Figure 3***) of the BTGx0 family will be available by the end of September 2013, with production ramp-up planned for early 2014.

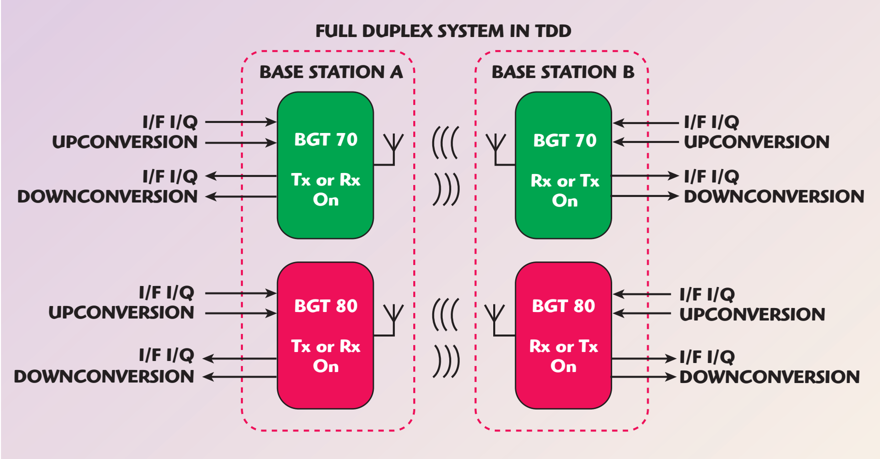

Fig. 1 E-Band TDD using BGT70 and BGT80 chipsets.

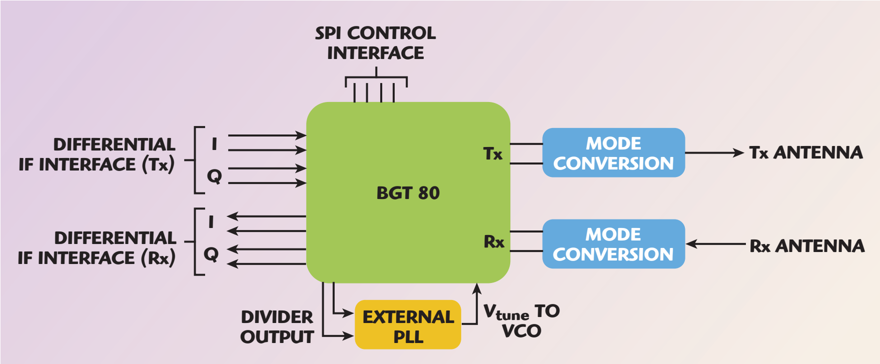

Fig. 2 Application diagram using the BGTx0 family.

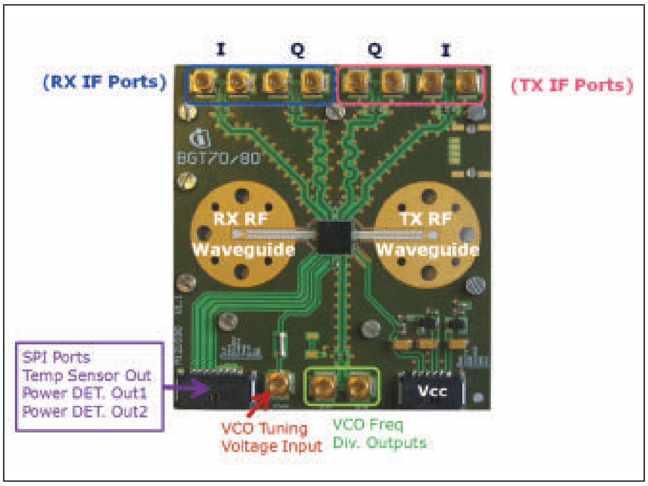

Fig. 3 Evaluation board supporting the BGTx0 family.

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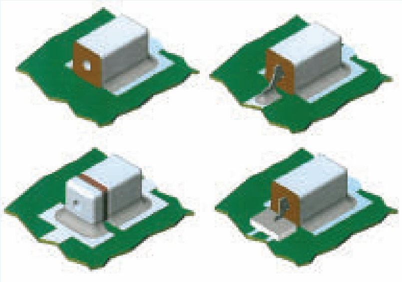

Ceramic Coaxial Resonators

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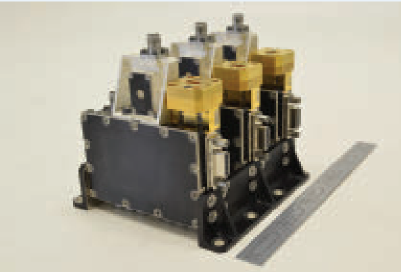

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- Internal bandpass filters: High Q combline filters in RF and IF paths reduce out-of-band signals, spurious and image responses.
- Receiver and downconverter configurations:
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  - D/C: typical 20 to 35 dB gain
- Small footprint
- Low mass (<650 grams)
- I/O options include WR34, WR28, 2.92mm
- Options:
  - Commandable gain
  - LNA RF output
- Qualified to all major satellite bus and environment interfaces.

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- Internal bandpass filters: High Q combline filters in RF and IF paths reduce out-of-band signals, spurious and image responses
- Receiver and downconverter configurations
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  - D/C: typical 20 to 35 dB gain
- Small footprint: 7.2" × 3.8" per 6-pack with integral LO distribution
  - Low mass <300 grams typical per RF slice with integral LO distribution
  - <600 grams typical per RF slice with integral LO distribution and inclusive of MLOs and CPSUs
- I/O options include WR34, WR28, 2.92mm
- Options:
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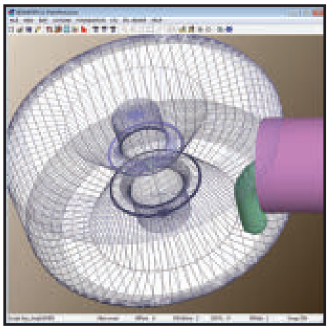

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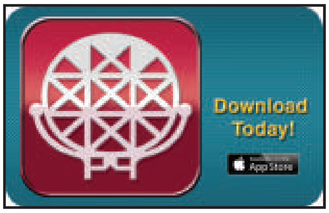
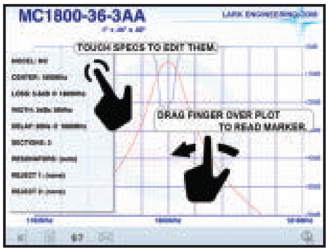
VENDORVIEW



Download Hittite's new mobile app and view the latest products on your iPad or iPhone. Hittite's Selection Guide, Off-The-Shelf Newsletter and Product Solution brochures are available in e-Book and PDF formats for your mobile device. Hittite's 2013 Product Selection Guide summarizes over 1100 products including 22 new products. The June 2013 Off-The-Shelf Newsletter includes 17 new product highlights & articles and company news organized by market application. Hittite's updated Microwave Solutions Brochure is also available.

Hittite Microwave Corp.,
www.hittite.com.

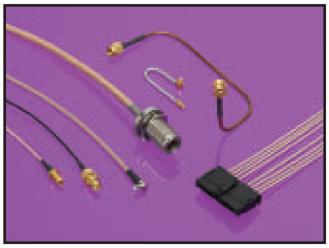
Lark Mobile App



Lark Engineering is pleased to announce its new mobile app guaranteed to make your next design job easier. Go to www.larkengineering.com to get started. Touch specs to edit them and drag your finger over plot to read markers. Lark is a leading (OEM) supplier of RF & microwave filters, multiplexers, and multifunction assemblies for the military, aerospace and commercial markets.

Lark Engineering,
www.larkengineering.com.

RF Assembly Builder



Molex recently launched an online RF Assembly Builder for distributors, customers and prospective customers. The free configurator tool simplifies the design process and allows the user to build a complete assembly and instantly submit an RFQ, without downloading any application or software. The RF Assembly Builder features step-by-step prompts for designing Molex RF cable assemblies. Users specify connectors, cables, options, preferred delivery and any special application instructions.

Molex Inc.,
www.molex.com.

Slide Rule Mobile App

Now available for download to iOS and Android devices, the Slide Rule mobile app from Microwave Development Laboratories enables design engineers to input their own waveguide rectangular (WR) designations to quickly perform complex conversions and determine operating parameters. By entering WR dimensions, a user can generate a range of material specifications including recommended operating frequency rate (GHz), flange type, and waveguide dimensions (in.). Designers requiring assistance with calculations or components purchasing can contact an MDL representative directly from the mobile app.

Microwave Development Laboratories Inc.,
www.mdllab.com/tools.php.

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EUROPEAN MICROWAVE WEEK 2013

REGISTRATION INFORMATION

EUROPE'S PREMIER MICROWAVE, RF, WIRELESS AND RADAR EVENT

EuMA – European Microwave Association

Official Publication: Microwave Journal

Organised by: horizon house

Supported by: IET The Institution of Engineering and Technology

Co-sponsored by: MTT-S

Co-sponsored by: IEEE

Supported by: VDE ITG

EuRAD 2013
The 10th European Radar Conference
Co-sponsored by: AESS

43RD EUROPEAN MICROWAVE CONFERENCE 2013
The 43rd European Microwave Conference
Co-sponsored by:

EuMIC 2013
The 8th European Microwave Integrated Circuits Conference
Co-sponsored by: Electron Devices Society, GAAS

Register online at:
www.eumweek.com

EUROPEAN MICROWAVE WEEK 2013
THE CONFERENCES

Don't miss Europe's premier microwave conference event. The 2013 week consists of three conferences and associated workshops:

- **European Microwave Integrated Circuits Conference (EuMIC): 7th - 8th October 2013**
- **European Microwave Conference (EuMC): 8th - 10th October 2013**
- **European Radar Conference (EuRAD): 9th - 11th October 2013**
- **Workshops and Short Courses from 6th October 2013**

The three conferences specifically target ground breaking innovation in microwave research through a call for papers explicitly inviting the submission of presentations on the latest trends in the field, driven by industry roadmaps. The result is three superb conferences created from the very best papers, carefully selected from over 1,500 submissions from all over the world.
Special rates are available for EuMW delegates. For a detailed description of the conferences, workshops and short courses please visit www.eumweek.com. The full conference programme can be downloaded from there.

Fast Track Badge Retrieval

Register online and print out your badge in seconds onsite at the Fast Track Check In Desk

Conference Prices

There are TWO different rates available for the EuMW conferences:

- **ADVANCE DISCOUNTED RATE** – for all registrations made online until 6th September
- **STANDARD RATE** – for all registrations made online from 7th September and onsite

Please see the Conference Registration Rates table on the back page for complete pricing information.
All payments must be in Euros – cards will be debited in Euros.

Online registration is open now, up to and during the event until 11th October 2013

DELEGATES

Registering for the Conference

- Register online at www.eumweek.com
- Receive a confirmation email receipt with barcode
- Bring your email, barcode and photo ID with you to the event
- Go to the Fast Track Check In Desk and print out your delegate badge
- Alternatively, you can register onsite at the self service terminals during the registration opening times below:

  - Saturday 5th October (16.00 – 19.00)
  - Sunday 6th October (07.30 – 17.00)
  - Monday 7th October (07.30 – 17.00)
  - Tuesday 8th October (07.30 – 17.00)
  - Wednesday 9th October (07.30 – 17.00)
  - Thursday 10th November (07.30 – 17.00)
  - Friday 11th November (07.30 - 10.00)

Once you have collected your badge, you can collect the conference proceedings on USB stick and delegate bag for the conferences from the specified delegate bag area by scanning your badge.

CONFERENCE REGISTRATION INFORMATION

EUROPEAN MICROWAVE WEEK 2013, 6th - 11th October, Nuremberg, Germany

Register Online at www.eumweek.com

ONLINE registration is open from 1st June 2013 up to and during the event until 11th October 2013.
ONSITE registration is open from 16:00h on 5th October 2013.
ADVANCE DISCOUNTED RATE (until 6th September) STANDARD RATE (from 7th September & Onsite)

Reduced rates are offered if you have society membership to any of the following: Eu*M*A, GAAS, VDE, IET or IEEE.

Eu*M*A membership costs: Professional € 25/year, Student € 15/year.

Reduced Rates for the conferences are also offered if you are a Student/Senior (Full-time students less than 30 years of age and Seniors 65 or older as of 11th October 2013).

ADVANCE REGISTRATION CONFERENCE FEES (UNTIL 6 SEPT)

CONFERENCE FEES	ADVANCE DISCOUNTED RATE			
	Society Member (*any of above)		Non Member	
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.
EuMC	€ 420	€ 100	€ 550	€ 130
EuMIC	€ 325	€ 90	€ 430	€ 120
EuRAD	€ 280	€ 80	€ 370	€ 110
2 Conferences				
EuMC + EuMIC	€ 600	€ 190	€ 790	€ 250
EuMC + EuRAD	€ 570	€ 180	€ 740	€ 240
EuMIC + EuRAD	€ 490	€ 170	€ 650	€ 230
3 Conferences				
EuMC + EuMIC +EuRAD	€ 730	€ 270	€ 960	€ 360

STANDARD REGISTRATION CONFERENCE FEES (FROM 7 SEPT AND ONSITE)

CONFERENCE FEES	STANDARD RATE			
	Society Member (*any of above)		Non Member	
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.
EuMC	€ 550	€ 130	€ 720	€ 170
EuMIC	€ 430	€ 120	€ 560	€ 160
EuRAD	€ 370	€ 110	€ 490	€ 150
2 Conferences				
EuMC + EuMIC	€ 790	€ 250	€ 1030	€ 330
EuMC + EuRAD	€ 740	€ 240	€ 980	€ 320
EuMIC + EuRAD	€ 650	€ 230	€ 850	€ 310
3 Conferences				
EuMC + EuMIC + EuRAD	€ 960	€ 360	€ 1260	€ 480

WORKSHOP AND SHORT COURSE FEES (ONE STANDARD RATE THROUGHOUT)

FEES	STANDARD RATE			
	Society Member (*any of above)		Non Member	
	Standard	Student/Sr.	Standard	Student/Sr.
1/2 day WITH Conference registration	€ 80	€ 60	€ 110	€ 80
1/2 day WITHOUT Conference registration	€ 110	€ 80	€ 150	€ 110
Full day WITH Conference registration	€ 120	€ 90	€ 160	€ 110
Full day WITHOUT Conference registration	€ 160	€ 120	€ 210	€ 150

Proceedings on USB Stick

All papers published for presentation at each conference will be on a USB stick, given out FREE with the delegate bags to those attending conferences. For additional USB sticks the cost is € 50.

DVD Archive EuMC

DVD Archive EuMC 1969-2003	FREE
DVD Archive EuMC 2004-2008	€ 10

Partner Programme and Social Events

Full Details and contacts for the Partner Programme and other Social Events can be obtained via the EuMW website www.eumweek.com.

SPECIAL FORUMS & SESSIONS					
Date	**Time**	**Title**	**Location**	**No. of Days**	**Cost**
Tues 8th & Weds 9th October	Tues: 13:50h - 17:40h Weds: 08:30h - 17:40h	The Defence & Security Forum	Room St. Petersburg	2	FREE
Mon 7th & Tues 8th October	08:30h - 17:40h	European Microwave Student School	Room Oslo	2	€ 40
Thurs 10th & Fri 11th October	08:30h - 17:40h	European Microwave Doctoral School	Room Oslo	2	€ 80

Software and Mobile Apps

Filter Synthesis Design

Nuhertz Technologies released version 13.5 of FilterSolutions, its filter synthesis design program. In cooperation with Modelithics and AWR, FilterSolutions 13.5 supports Modelithics measurement-based models that appear as libraries in AWR Corp.'s Microwave Office™. Use of Modelithics models assures that filter responses synthesized in FilterSolutions and simulated in AWR can be manufactured with available parts from leading vendors. Users are encouraged to evaluate FilterSolutions by registering for a free, 30-day license.

Nuhertz Technologies,
www.nuhertz.com.

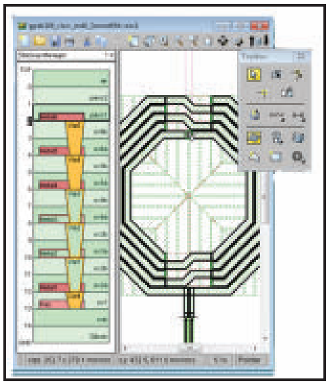
Power Viewer Mobile App

VENDORVIEW

The new Power Viewer mobile app from Rohde & Schwarz transforms Android smartphones and tablets into high-precision base units for power measurements. The USB-compatible R&S NRP power sensors can now display the measured average power value directly on mobile devices with Android 4 operating system. The app can be downloaded for free at the Google Play Store. The app provides users with a mobile solution for situations where minimal weight and size of the measuring instrument are essential yet high-precision average power measurements are required.

Rohde & Schwarz,
www.rohde-schwarz.com.

Sonnet Suites Release 14



Sonnet Software Inc. introduces its latest version of software, the Sonnet Suites Release 14, featuring enhanced speed for Sonnet's 3D planar EM simulation engine, new technology to automate EM model extraction, and GUI enhancements for efficient use in enterprise computing environments. Existing users will see faster simulations, especially on new generation multi-core computing platforms. In addition to allowing more CPU cores to be used in parallel over the previous release, the Sonnet meshing algorithms have been further tuned to yield faster simulations.

Sonnet Software Inc.,
www.sonnetsoftware.com.

The 2013 Defence and Security Forum

At European Microwave Week

EuMA

Microwave Journal
Frequency Matters.

Tuesday, 8th and Wednesday, 9th October 2013 • Room St. Petersburg, NCC Nuremberg, Germany

A one and a half-day Forum focusing on defence and automotive radar.

Programme:

Tuesday, 8th October 2013

13:50 - 15:30 Development and Production Requirements for Automotive and Military Radar
Experts on radar manufacturing will present their view on various volume production aspects and trends for the next generation of radar manufacturing.

16:00 - 17:40 EuMIC Closing Session

Wednesday, 9th October 2013

08:30 - 10:10 *Microwave Journal* Industry Panel Session
An industrial perspective on the key issues facing the defence and security sector and, in accordance with the theme for 2013, the Panel will address: *Defence and Automotive Radar – Differences and Commonalities*.

10:40 - 12:20 EuRAD Opening Session

12:30 - 13:30 Strategy Analytics Lunch & Learn Session
This session will add a further dimension to the Defence and Automotive Radar theme by offering a market analysis perspective, illustrating the status, development and potential of the market.

13:50 - 15:30 Experience and Future Expectations regarding Automotive and Military Radars
This session reports on the experiences obtained with radar sensors in many different applications, with the purpose of identifying the remaining challenges for radar development and production.

16:00 - 17:40 EuMW Defence & Security Executive Forum
Experts and executives from defence and security agencies and leading companies involved in automotive radars will discuss challenges and trends regarding cross-fertilisation, in development and production, between different markets.

17:40 - 19:00 Cocktail Reception

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New Products

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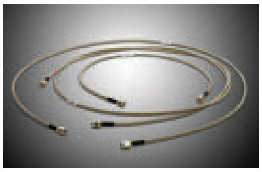
FEATURING VENDORVIEW STOREFRONTS

Components

Cable Assemblies

VENDORVIEW



AtlanTecRF introduced a comprehensive range of fully flexible test cable assemblies which are particularly suited to extensive test set-ups either in the laboratory or automatic test equipment. Grey in colour and only 0.168" in diameter, the standard connector types are SMA male with the well-known and reliable anti-torque feature for which AtlanTecRF assemblies are renowned. Frequency performance is to 26.5 GHz and standard stock lengths range from 2" to 60" with other connector options available.

Atlantic Microwave Ltd.,
www.atlantecrf.com.

Transceiver Modem

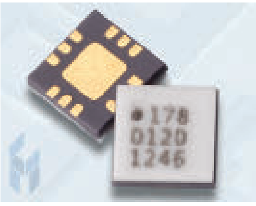
The STD-502-R operates in the 2.4 GHz band available worldwide. Designed to be embedded in equipment, this radio transceiver module was developed for industrial applications that require stable and reliable operation. With battery operation, it achieves line of sight radio communication beyond 300 m. Besides using highly noise-resistant direct-sequence spread spectrum (DSSS) modulation, the module has a true diversity receiver function for preventing signal dropout due to multipath fading. This ensures highly stable and reliable radio communication in the congested 2.4 GHz ISM band.

Circuit Design Inc.,
www.circuitdesign.jp.

Fundamental Mixer

VENDORVIEW

Custom MMIC announced a new general purpose, double balanced fundamental mixer. The CMD178C3 can be used for up and downconverting applications between 11 and 21 GHz.



In terms of performance, the CMD178C3 has typically 6 dB conversion loss, with very low LO leakage to both the RF and IF ports (-25 dBm and -30 dBm, respectively), can operate with an LO drive level as low as +9 dBm, and has a wide IF bandwidth from DC to 6 GHz.

Custom MMIC,
www.custommmic.com.

Upconverters

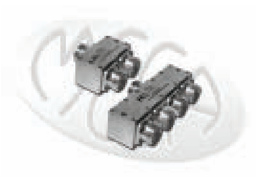
VENDORVIEW

The HMC6787ALC5A and the HMC6146BLC5A are GaAs MMIC I/Q variable gain upconverters which form a competitive and cost-effective microwave radio transmitter solution. The HMC6787ALC5A operates from 37 to 40 GHz and provides a small signal conversion gain of 10 dB with 17 dBc of sideband rejection, and 13 dB of gain control. The HMC6146BLC5A operates from 40 to 44 GHz and provides a small signal conversion gain of 12 dB with 25 dBc of sideband rejection and 17 dB of gain control.

Hittite Microwave Corp.,
www.hittite.com.

Power Combiners

VENDORVIEW



MECA Electronics introduced its H-Series, 100 W, Wilkinson high power combiner/dividers in 2-way, 3-way and 4-way configurations for wireless applications between 0.400 and 2.200 GHz. High isolation (25 dB), VSWR of 1.15:1 and low insertion loss (less than 0.3 dB). Available in 7/16" DIN, Type-N, SMA and TNC connectors. Essential for combining unbalanced inputs. Available STOCK – 4 weeks ARO. Weatherproof models (IP 65) available. Made in the U.S. - 36 month warranty.

MECA Electronics Inc.,
www.e-meca.com.

RF Bypass Capacitors

Passive Plus offers a line of traditional RF bypass capacitors. These dielectric capacitors can be mounted horizontally or vertically and are available in three case sizes for RF/microwave applications. The 0505X series is 0.055" × 0.055" and features WVDC: 50 V, TC: ±25 percent and value range: 47 to 10000 pF. The 1111X series is 0.110" × 0.110" and features WVDC: 50 V, TC: ±25 percent and value range: 4700 to 100,000 pF. The 2225X series is 0.220" × 0.250" and features WVDC: 50 V, TC: ±15 percent and value range: 0.010 to 1.000 uF.

Passive Plus Inc.,
www.passiveplus.com.

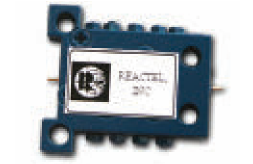
SPDT Switch

Peregrine Semiconductor announced availability of a new SPDT RF switch for harsh environment and space applications. Manufactured on Peregrine's UltraCMOS® technology, the PE95421 switch is highly resistant to total dose and single event radiation effects, resulting in improved product reliability, as well as stable, and predictable, performance over the life of the mission. The switch features HaRP™ technology enhancements for high linearity of 60 dBm IIP3. It has an operating frequency up to and including the C-Band in commercial satellites, manned spacecraft and high altitude aircraft.

Peregrine Semiconductor,
www.psemi.com.

Combline and Interdigital Filters

VENDORVIEW



Reactel offers its flat pack combline and interdigital filters in a bandpass configuration operating in a frequency range of 2000 to 15000 MHz. These extremely small, surface mount packages are perfect for mobile or man-pack systems and are rugged enough to withstand the harshest of environments.

Reactel Inc.,
www.reactel.com.

1P12T Relay

RelComm Technologies compliments its product line by offering a low cost high performance 1P12T relay configured with SMA type connectors providing exceptional RF performance to 18 GHz. The relay measures 2.25" square and is less than 2" tall. It is fitted with standard DA15P header for ease of installation. The relay is available in both latching and failsafe configurations with 12 and 24 V DC operation. Options include TTL control input.

RelComm Technologies Inc.,
www.relcommtech.com.

Broadband Coupler

Response Microwave announced the availability of a new high power, broadband coupler for use in radar and telecommunication transmit applications. The new RMCO5.32-1200Nf covers the 20 to 1200 MHz band offering typical electrical performance of 0.6 dB insertion loss, VSWR of 1.25:1, minimum directivity of 20 dB. Average power handling is 200 W and the unit is operational over the -35° to +85°C range. Mechanical package is 15" × 8" × 1". Connectors used are Type N female on the mainline and coupled ports.

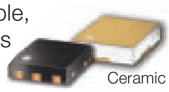
Response Microwave Inc.,
www.responsemicrowave.com.

A perfect fit for almost any PCB!

RCAT/YAT ATTENUATORS DC to 20 GHz from $2.99 ea. (qty. 20)

Our new tiny 2W fixed value absorptive attenuators are now available in molded plastic or high-rel nitrogen-filled ceramic packages. They are perfect building blocks for both broad and narrow-band systems, reducing effects of mismatches, harmonics, and intermodulation, improving isolation, and meeting other circuit level requirements. These units will deliver the precise attenuation you need, and are stocked in 1-dB steps from 0 to 10 dB, and 12, 15, 20 and 30 dB.

The ceramic hermetic ***RCAT*** family is built to deliver reliable, repeatable performance under the harshest conditions having been qualified to meet MIL requirements including vibration, PIND, thermal shock, gross and fine leak and more, at up to 125°C!



The molded plastic ***YAT*** family uses an industry proven, high thermal conductivity case and has excellent electrical performance over the frequency range of DC to 18 GHz. For more details, just go to minicircuits.com – place your order today, and you can have these products in your hands as soon as tomorrow!

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U.S. Patents 7739260, 7761442

IF/RF MICROWAVE COMPONENTS

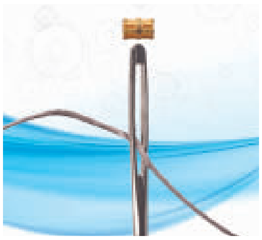
515 rev org

New Products

Latching Switch

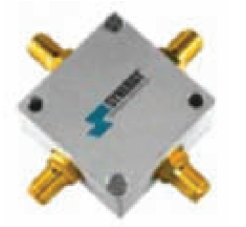
RLC Electronics' 11- and 12-position coaxial switch line provides proven reliability, long life and outstanding electrical performance. The switch also features extremely low insertion loss and VSWR over the entire DC to 18 GHz range, while maintaining high isolation. The switch can be provided in latching self-cutoff or pulse latching mode, in addition to failsafe which is standard on all RLC switches. These switches can either be provided in a terminated (absorptive) or non-terminated (reflective) configuration.
RLC Electronics,
www.rlcelectronics.com.

SMPS Connectors



SV Microwave is proud to announce the release of its SMPS connector series which is the next generation in miniature blindmate connectors. The line is directly compatible with the G3PO interface and is 45 percent smaller than the SMP and 30 percent smaller than the SMPM. The SMPS utilizes SV's threadless design of push-on and blindmate connectors and is capable of frequencies exceeding 100 GHz. Please visit the website or email marketing@svmicro.com for more information.
SV Microwave,
www.svmicro.com.

Ultra-Wideband 90° Hybrid



The 4 port connectorized 90° Hybrid, Model DQK-100-1000S covers ultra wide ratio of 10:1 in the frequency range of 100 to 1000 MHz. A building block for amplifiers, image reject mixers, etc., it has an excellent insertion loss of 2.3 dB (max.) and isolation of 23 dB typical. Outputs are matched for excellent amplitude unbalance (0.8 dB typical) and phase unbalance (±6° typical). Built on a small 1.25" square and 0.750" high package and terminated in SMA connectors.
Synergy Microwave Corp.,
www.synergymwave.com.

Amplifiers

TWT Amplifiers

VENDORVIEW

AR's family of TWT amplifiers covers up to 45 GHz and provides powers to 10,000 W. Both CW and pulse models are available. Features of the amps include "sleep mode" to prolong the life of the TWT, rugged construction for the rigorous treatment in test labs and modular supplies to reduce repair turn-around time.
AR RF/Microwave Instrumentation,
www.arworld.us.

Linear Power Amplifiers

Two new power amplifiers for cellular base station and telecom applications have been introduced. The 8860 PA covers the frequency range from 1.3 to 1.5 GHz, while the 8862 PA covers the frequency range from 2.3 to 2.7 GHz. Both deliver a minimum linear output power (P1) of 19 W, with high gain, ±1 dB gain flatness and excellent phase linearity across the whole frequency range. They are claimed to provide extremely linear output power to ensure the clean and consistent transmission demanded for reliable cellular service.
Amplifier Technology,
www.amplifiertechnology.com.

Driver Amplifier

Centellax announced the release of its new low-cost LiNbO3 Quad Input 32 Gbaud linear modulator driver amplifier for DP to 16 QAM applications. The OA3MMQM has excellent gain, low noise figure, low harmonic distortion and flat group delay, making it ideally suited for advanced modulation formats at 32 Gbaud and beyond, employing Mach Zender interferometer optical modulators. The OA3MMQM addresses the needs of the 400 G optical long haul transponder module manufacturers.
Centellax Inc.,
www.centellax.com.

Solid State Power Amplifier

Comtech PST has announced the release of a solid state Class "AB" linear amplifier which operates over the full 6 to 18 GHz frequency band and delivers a minimum of 20 W. The amplifier uses the latest Gallium Nitride (GaN) technology and is packaged in a standard rack mountable enclosure measuring 19" × 22" × 3.5".
Comtech PST,
www.comtechpst.com.

New Products

Microwave Power Module

L-3 Electron Devices introduced its new Ka-/Q-Band microwave power module (MPM), a combination switchable Ka-Band linearizer/Q-Band high power amplifier for aerospace and defense industry communications terminal builders and system integrators. Featuring a single 2.4 mm coax (0 dBm) input and WR-24 waveguide output, the new Ka-/Q-Band MPM delivers greater than 100 W of saturated CW power, from 29.5 to 31.0 GHz, at greater than 35 percent RF efficiency, and greater than 80 W saturated power from 43.5 to 45.5 GHz.

L-3 Electron Devices,
www.l-3com.com.

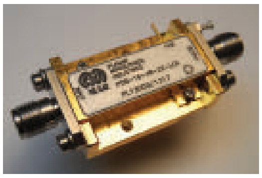
10 W Amplifiers

Microwave Dynamics has released a new line of 10 W amplifiers 6 to 18 GHz. Features include high power output up to 10 W, high gain 30 dB min, compact design (2.75" × 2.125" × 0.812"), low VSWR (2.5:1 max), and low supply voltage (+ 10 V typical). Input limiter model is optional. 2 to 18 GHz to be released soon.

Microwave Dynamics,
www.microwave-dynamics.com.

Low Noise Amplifier

VENDORVIEW



PMI Model No. POB-16-48-22-LCA is a 4 to 8 GHz low noise amplifier which provides 16 dB of gain while maintaining a gain flatness of ±1.0 dB typically over the operating frequency. The noise figure is 3 dB typical and offers a typical OP1dB of +22 dBm. The amplifier requires +12 to +15 V DC and the current draw is 225 mA typical. The unit is supplied with SMA(F) connectors in PMI's standard PE2 housing.

Planar Monolithics Industries Inc.,
www.pmi-rf.com.

Semiconductors/ICs

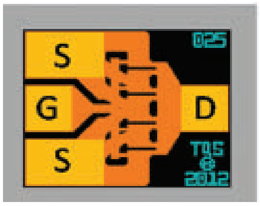
Automotive Transceiver

Infineon Technologies has expanded its portfolio of LIN and CAN automotive communications ICs with its first FlexRay™ transceiver. The TLE9221SX is fully compliant to the most current FlexRay Electrical Physical Layer Specification version 3.0.1. It enables data rates of up to 10 Mbit/s for in-vehicle communication and features best-in-class ESD rating of ±10 kV. As an interface between the communication controller unit and bus wires, the TLE9221SX was developed for use in suspension and chassis control applications as well as for power steering, engine and transmission control units.

Infineon Technologies,
www.infineon.com.

Discrete FET

VENDORVIEW



RFMW Ltd. announced design and sales support for TriQuint Semiconductor's TGF2025 high efficiency heterojunction power FET. This discrete device utilizes TriQuint's proven standard 0.25 um power PHEMT production process featuring advanced techniques to optimize microwave power and efficiency at high drain bias operating conditions. The TGF2025 provides 24 dBm typical output power at P1dB with gain of 14 dB and 58 percent power-added efficiency. This performance makes the TGF2025 appropriate for high efficiency applications in hi-rel circuits and broadband commercial or military subsystems.

TriQuint Semiconductor,
distributed by RFMW Ltd.,
www.triquint.com.

New Products

Sources

Voltage Controlled Oscillator

VENDORVIEW

The ZX95-868+ is a voltage controlled oscillator, designed to operate from 805 to 868 MHz for TV broadcasting application. The ZX95-868+ built using Mini-Circuits' proven unibody construction (size of 1.20" × 0.75" × 0.46") which integrates the RF connectors with the case body to shield against unwanted signals and noise. It features low phase noise (-116 dBc/Hz typical at 10 kHz offset) and a linear tuning sensitivity ratio of 1.2:1 typical.
Mini-Circuits,
www.minicircuits.com.

Band Mechanically Tuned Gunn Oscillator

VENDORVIEW

Model SOM-10401317-08-S1 is a free running F-Band mechanically tuned Gunn oscillator with output power +17 dBm and mechanically tuning bandwidth ±0.5 GHz. The mechanical tuning is accomplished via a self-locking tuning screw or micrometer. The bias voltage and current to operate the oscillator is at +4.5 V DC and 750 mA typically. The semiconductor used on the oscillator is a GaAs Gunn diode. Therefore, no concerns exist in terms of device availability and product continuation ability.
SAGE Millimeter Inc.,
www.sagemillimeter.com.

The 4th Applied Electromagnetics Conference, an initiative of IEEE AP-MTT Joint Chapter, Kolkata section, shall be held during **18 – 20 December 2013** at & in association with the KIIT University, Bhubaneswar. With more than 100,000 temples, Bhubaneswar is known as *City of Temples* and is a junction of Hindu, Buddhist and Jain archeological monuments. The Khandagiri & Udayagiri are rich with partly natural and partly artificial caves of archaeological, historical and religious importance most of which were carved out as residential blocks for Jain monks. A dumb witness of the Kaling War, the Dhauligiri has many rock edicts besides a dazzling white peace pagoda on the hill top built by the *Japan Buddha Sangha* and the *Kalinga Nippon Buddha Sangha* in the 1970s.

The panel of distinguished speakers includes, among others Prof. Raj Mitra, *Penn University, USA;* Prof. Lotfollah Shafai, *University of Manitoba, Canada;* Prof. Mats Gustafsson, *Lund University, Sweden;* Prof. Yahia M. M. Antar, *Royal Military College, Canada.*

As in its previous editions, the AEMC in 2013 aims at providing an opportunity for presentation, discussion and promotion of research on contemporary topics in applied electromagnetics. The AEMC 2013 will focus on new ideas and the latest developments for both academia and industry throughout the international community.

Students are encouraged to participate in Student Paper Contest and Student Project Contest. Free tutorials and short courses are being planned for all interested participants.

Papers are invited in the following 18 tracks: Antennas for Defence and Space Applications (ADS), Antenna Theory and Techniques (ATT), Bioelectromagnetics (BEM), CAD Algorithms and Techniques (CAD), Computational Electromagnetics (CEM), Dielectric Resonator Antennas (DRA), Electromagnetic Compatibility (EMC), EM Education (EME), Electromagnetic Materials (EMM), Electronic Packaging and Interconnects (EPI), Materials for Antenna Technology (MAT), Microwave Devices and Circuits (MDC), Microstrip and Printed Antennas (MPA), Mobile and Wireless Antennas (MWA), Radar and Satellite Technology (RST), Tera Hertz Technology (THT), Transformation Electromagnetism (TREM), Wave Propagation and Remote Sensing (WPR).

For more information please visit: http://www.ieee-aemc.org

Antenna

NFC Antennas

Pulse Electronics announced a new catalog selection of ferrite-loaded, stamp and wire-on-carrier near field communication (NFC) antennas. These products are ideal for integration into point-of-sale terminals, security and access control panels, transportation payment devices, and consumer electronics. The NFC antennas allow for the wireless link between two devices, like a phone or security card; typically with a maximum distance of 100 mm. The antennas operate at 13.56 MHz and are meant for volumetric field strength efficiency rather than antenna gain like traditional antennas.
Pulse Electronics Corp.,
www.pulseelectronics.com.

Base Station Antenna Platform

Radio Frequency Systems (RFS) announced that it has developed a new base station antenna platform that will serve as the foundation for a high-performing line of multi-band base station antennas. Called RF X-TREME, the new antenna platform meets customer demand for multi-band antennas by providing high-performance triple-band capability in a compact dual-band package. By providing the highest gain for triple-band antenna size, RF X-TREME better supports multiple bands, including LTE 700, CDMA 850, PCS 1900 and AWS 2100 with no compromises in electrical performance.
Radio Frequency Systems,
www.rfsworld.com.

Test Equipment

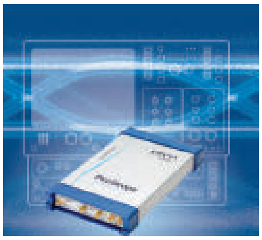
PXI Large Matrix Solutions

The 40-596, 40-597 and 40-598 are all BRIC 1-pole matrices with 2 A current rating, up to 60 W hot switch power and 100 V DC/70 V AC voltage rating – de-

pending on the configuration; these products are available in two-slot, four-slot, and eight-slot PXI modules. Each model sets new standards in the achievable density of PXI matrices with configurations of 6, 12 and 16 Y axis connections and maximum X axis connections of up to 464 (up to 3,072 matrix crosspoints).

Pickering Interfaces Ltd.,
www.pickeringtest.com.

Sampling Oscilloscopes



The compact, two-channel PC-based 9300 Series sequential sampling oscilloscopes offer a combination of portability, price and performance. Their small size allows them to be positioned right next to the device under test, minimizing cable losses and the need for active probes or pull-out sampling modules. There is a built-in signal generator with 4 ns minimum bit interval in PRBS mode and 8 ns minimum period in pulse mode. Specification highlights include over 15 TS/s effective sampling rate and 17.5 ps input rise time.

Pico Technology,
www.picotech.com.

Sweep Trigger

VENDORVIEW

Vaunix announced a new optional feature for its LMS signal generator line. The LMS Sweep Trigger enables the user to synchronize linear frequency sweep functionality with other lab test instruments. The Lab Brick LMS series of USB-compatible, synthesized signal generators features low noise, fast 100-microsecond switching time, and fine 100 Hz frequency resolution, requiring no additional DC supply. Advanced features are phase-continuous linear-frequency sweeping; selectable internal/external 10 MHz reference; and optional pulse modulation.

Vaunix Technology Corp.,
www.vaunix.com.

PXIe/LXI Chassis

VTI Instruments released the CMX34 PXIe/LXI chassis. This combines the horsepower and performance of PXIe with the precision switching capability of VTI's award winning EX1200 series, creating a solution that is uniquely optimized for both instrumentation and switching. It features a PXIe mainframe with high bandwidth PCIe Gen 2 backplane with 2 GB/s bandwidth per slot and 8 GB/s system bandwidth. It is fully integrated including cables and receiver modules, ready to drop into a test system.

VTI Instruments,
www.vtiinstruments.com.

Handbook of Reflector Antennas and Feed Systems Volume 3: Applications of Reflectors

Edited by Sudhakar Rao, Lotfollah Shafai and Satish K. Sharma

This handbook is one of three volumes: Volume 1 covers the theory of reflectors, Volume 2 covers feed systems and this book, Volume 3, focuses on the range of reflector antenna applications. The series is a very comprehensive and up-to-date set on modern reflector antennas and feed sources for diversified space and ground applications as it was recently published.

The intent of this book volume is to provide practical applications and design information on reflector antennas used for several communications systems. This book covers recent developments of reflector antennas used for satellite communications, terrestrial communications and remote sensing applications. New subjects that are introduced for the first time are satellite antennas, terahertz antennas, passive intermodulation (PIM), multipaction, corona, deployable mesh reflector antennas and mechanical aspects of reflector antennas. In addition, this book contains a separate topic on integrated feed assembly for reflector antennas covering analysis, design, fabrication and test.

The book contains pieces from industry antenna experts from Northrop Grumman, MELCO, NASA/JPL, Intelsat, Boeing, CMI, AASC and DUT. It covers new applications such as large deployable reflectors for mobile satellites, multiple beam reflector antennas for high-capacity satellites, multiband reflector antennas covering multiple frequency bands, terahertz reflectors for radar applications, high power antenna payloads with low PIM products, low loss reflector antennas for wide scan applications, reflector antennas for new terrestrial applications and reflector antennas used for remote sensing. The book is very specific to reflector antennas and comprehensive so it is most useful for those directly involved in the industry or related research.

To order this book, contact:

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DRONES OF THE FUTURE

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UAVs Unleashed

They call it the "Hidden War" – the United States' secret use of unmanned autonomous vehicles (UAV) to search out and kill terrorists overseas. It has created a lot of controversy recently and receives increasing mainstream news coverage. Where is the technology heading? What are the risks and business opportunities for RF and microwave companies? This article takes a look at the UAV (or "drone") market, recent progress in the technology and future directions related to the RF and microwave industry.

UAV LANDSCAPE

The most commonly seen UAVs are Unmanned Aircraft Systems (UAS) that include ground stations and other elements besides the actual aircraft. UASs get the most public coverage of all UAVs that also include Unmanned Ground Systems (UGS) and Unmanned Maritime Systems (UMS). The most widely known UAS is the Predator A (see ***Figure 1a***), which began as a reconnaissance platform and was later modified to carry Hellfire anti-tank missiles. The Predator B (Reaper) was a second generation with improved performance capabilities. The third generation Predator C (Avenger, see ***Figure 1b***) is more in line with the fifth generation fighters being deployed by the USAF. The Avenger UAV uses existing Predator ground-based infrastructure so the costs to field it are just the UAV and software itself, avoiding the cost of a full new system. The Avenger has a jet-powered engine and stealth technology that was not used in the previous Predator platforms. The Predator UAV and sensors are controlled from a ground station via a C-Band line-of-sight data link or a Ku-Band satellite data link for beyond-line-of-sight operations. The Avenger is fitted with the General Atomics-developed "Lynx" Synthetic Aperture Radar (SAR) system as well as the AESA Wide-Area Surveillance Sensor.

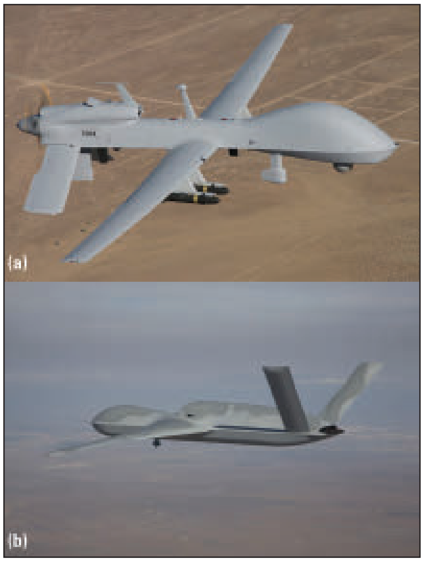

Fig. 1 Predator A (a) and Predator C (b) UAS platforms (courtesy of General Atomics).

Another class of UASs is micro- or mini-UASs. This is a growing area as these are less expensive, easier to deploy and becoming more capable as the software control improves. An example is the Wasp III, which provides real-time direct situational awareness and target information for Air Force Special Operations Command Battlefield Airmen. The Wasp III UAS features the expendable air vehicle, a ground control unit and communications ground station. It is a collapsible lightweight air vehicle with a two-bladed propeller driven by a small electric motor (see ***Figure 2***). It is equipped with an internal GPS and Inertial Navigation System, autopilot and two on-board cameras. The system can function autonomously from takeoff to recovery or be controlled by one operator using a handheld remote control unit.

Fig. 2 Wasp III UAS (courtesy of Aerovironment Inc.).

Patrick Hindle
Microwave Journal *Technical Editor*


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Unmanned Ground Systems (UGS) are an over-looked class of UAVs with many thousands of vehicles used in the Iraq and Afghanistan wars to locate and defuse IEDs or explore potentially dangerous buildings. It has been reported that as of 2011, more than 11,000 IEDs were defeated using UGSs. Other UGSs are designed to go into buildings and provide visual images of what is inside while others are designed to carry equipment to support troops. Many UGSs use treads like a tank for movement but DARPA is working on legged UGSs for carrying equipment like a mule. The DARPA project is called the Legged Squad Support System and is shown in ***Figure 3***. It can carry heavy loads and would therefore be able to support troops by hauling equipment.

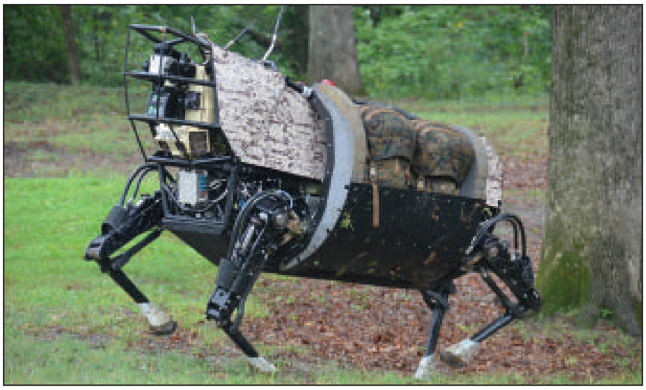


Fig. 3 DARPA Legged Squad Support System UGS (courtesy of DARPA).

Fig. 4 iRobot 110 FirstLook "throwable" UGS (courtesy of iRobot).

Fig. 5 SeaFox USV (courtesy of Defence Talk).

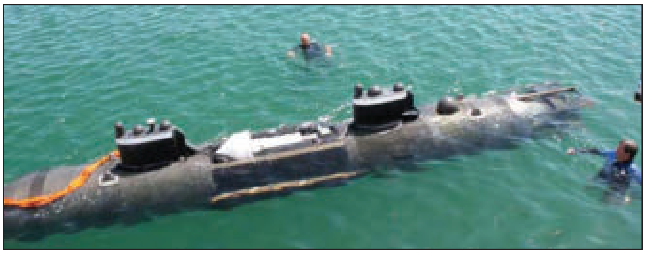


Fig. 6 Sea Maverick UUV (courtesy of Autonomous Undersea Vehicle Applications Center).

For UGS recognizance, there are many kinds of vehicles with cameras and sensors that can enter a building or other areas that pose a risk to humans and take a look remotely at what is there. Some examples are sending UGSs into areas contaminated with chemicals, under bomb threats or radioactive contamination. The UGSs can survey the area for possible problems without endangering humans. An interesting example is the iRobot FirstLook as shown in ***Figure 4***. It is a small, light, throwable robot that provides quick situational awareness, performs persistent observation and investigates confined spaces. One can just toss it into a building (through a window or door) and immediately get images as to what is inside as it is guided around the area. Historically, the emphasis has been on IED and bomb detection and defusing but as the Middle East wars wind down, it is expected that the emphasis will change to other uses such as border security and law enforcement applications.

Unmanned maritime systems (UMS) consist of unmanned underwater vehicles (UUV) and unmanned surface vehicles (USV). The U.S. government's priorities for UMS include mine countermeasures, anti-submarine warfare, maritime domain awareness and maritime security.[1] UMSs have been widely used in mine sweeping operations in several wars. Examples of maritime security UMSs are the SeaFox USV shown in ***Figure 5*** and the Sea Maverick UUV shown in ***Figure 6***. UMSs are used for military maritime security and border security. With large amounts of illegal drugs entering the U.S. coming from underwater or surface vehicles, border security is expected to be a growing area for all types of UAVs, especially UMSs.

UAV MARKET

The UAV sector has recently been called the fastest-growing sector in the aerospace industry by the Teal Group, a defense industry consultant.[2] Current global UAV sales are about $6.6 billion annually and are expected to double over the next decade. The U.S. military UAV market is projected to grow at a CAGR of 12 percent between 2013 and 2018, according to a Market Research Media report.[3] The report says that the U.S. military UAV market will generate $86.5 billion in revenues over the period 2013-2018. Market demand is anticipated to be driven by increased UAV procurement for applications such as persistent surveillance, suppression/destruction of enemy air defense, and communications relays and combat search and rescue.

ASDReports offers another market trend analysis over the next five years. They project that NATO nations (especially the U.S.) will reduce their investment in defense and security UAVs while the non-NATO world will move into those military and police UAVs in a relatively big way. The resultant global market will exceed a cumulative $130 billion over the coming eight years, but the funding profile will change considerably (see ***Figure 7***).[4] The U.S. DoD is changing its focus from Counter Insurgency to a more traditional conflict against a near-peer. That move will reduce the need for expensive UAVs, but will increase the need for fast, stealthy, survivable UAVs.

The U.S. plans to cut spending on unmanned aerial vehicles in fiscal 2014 by one-third of the amount over the previous year, mostly because of the winding down of operations in Afghanistan and the end of the U.S.

military role in Iraq. While the war on global terrorism initially drove the U.S.'s use of UAVs, it is predicted that there are a wide variety of other uses that will allow the growth to continue including civilian uses. Current civilian applications include Homeland Security, disaster management and border surveillance. The AUVSI Economic Report 2013[5] states that the planned opening up of the national airspace to UAVs in the U.S. by 2015 will affect the market potential between 2015 and 2017 by some $13.6 billion, and $82.1 billion between 2015 and 2025. However, it predicts that if the effort is delayed, it will cost the U.S. billions of dollars in potential revenue. For each year of delay, some $10 billion of potential economic impact is lost. So establishing the guidelines for UAVs to operate in U.S. airspace is critical for domestic growth.

Another obstacle to commercial use is privacy issues which are raising objections in the public's eye. It was revealed for the first time in mid-June that the FBI has been using UAVs in the U.S. for law enforcement activities. About a dozen operations were disclosed including surveillance of a man that was holding a young boy hostage in Alabama. The government stated that they are only used on a very limited basis but this immediately outraged some of the privacy advocate groups.

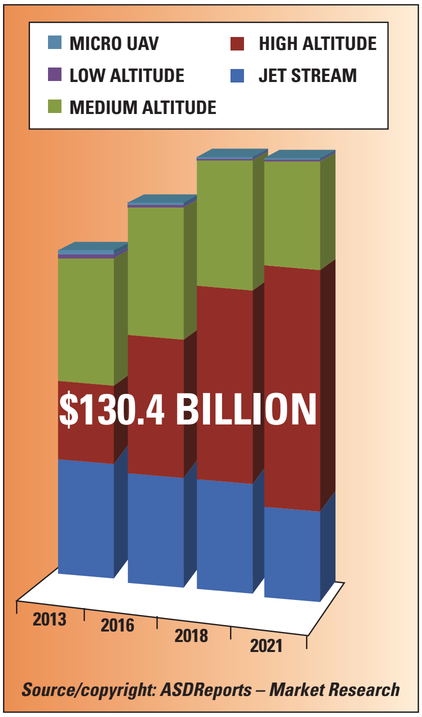


Fig. 7 Projected funding profile for UAV market (courtesy of ASDReports).

While UAVs are already used in a range of civil applications, including wildfire mapping, weather monitoring and telecommunications, the AUVSI report outlined other potential uses that UAVs could carry out, such as precision agriculture and public safety. These applications are thought to make up about 90 percent of the known potential markets. UAVs have many applications in public safety such as search and rescue, surveillance, bomb defusing, surveying dangerous areas (chemical or radiation threats) and following suspects, to name a few. Farmers are already using UAVs to monitor their crops' health from the air to see problems with insects or disease before they become too large to address. This also allows for targeted insectiside application reducing the need to use these chemicals. The report predicts that these two markets will produce approximately 90 percent of the known potential future markets for UAVs.

Outside of the U.S., the demand for UAVs is expected to grow as the technology becomes more widespread. Israel and India are two markets that many analysts are predicting will experience high demand. We have even seen recent use of UAVs by Hezbollah entering into Israeli air space, as they have been shot down by the Israeli defenses. Advanced Defense Technologies Inc. has projected that India is a booming market for micro- and mini-UAVs for civilian and military use.[6] They expect UAVs to be used for reconnaissance and mapping, surveillance, border and maritime patrol.

Israel has been reported to be the largest exporter of UAVs with $4.62 billion from 2005-2012.[7] Britain, India and Brazil are reported to be Israel's leading customers. While the U.S. is constrained with ITAR restrictions that prevent easy export of restricted products, Israel has been able to take the lead in the UAV market. Saudi Arabia recently decided to purchase UAVs from South Africa as the U.S. was reluctant to provide armed UAVs to a Middle Eastern country.

UAV TECHNOLOGY CHALLENGES

There are many challenges to improving UAV capabilities, integrating them into the national airspace and having them cooperate with manned vehicles. These challenges represent opportunities for companies as to the technology needed for future UAV programs. A couple of years ago, the Department of Defense (DoD) released The Unmanned Systems Integrated Roadmap FY2011 — 2036 projecting the U.S. governments priorities and plans for UAVs.[7] It lists the following challenges facing military departments:

- Interoperability: UAVs need to operate seamlessly across domains and with manned systems.
- Autonomy: Pursue technologies and policies that introduce a higher degree of autonomy to reduce the manpower burden and reliance on communications links while also reducing decision cycle time.
- Airspace Integration: Ensure UAS have routine access to the appropriate airspace needed within the National Airspace System working with the FAA.
- Communications: Continue to address frequency and bandwidth availability, link security, link ranges, and network infrastructure.
- Training: Ensure continuation and joint training that will improve basing decisions, training standardization.
- Propulsion and Power: Continue to develop more efficient and logistically supportable sources for propulsion and power.
- Manned-Unmanned Teaming: Continue to implement technologies and evolve tactics, techniques and procedures that improve the teaming of unmanned systems with the manned force.

The interoperability of sensors and improvement in communications bandwidth challenges offer RF and microwave companies the opportunity to develop new technologies that can meet these needs. Standard sensors that can be used across multiple platforms and wideband/high-frequency transmitter/receiver systems are a couple of the solutions that could help meet these challenges.

RF SYSTEM CHALLENGES

Most important to RF and microwave companies, the roadmap discusses many suggested approaches for future developments that are addressed with microwave technology especially in the area of communications. Antennas for UAVs require high-gain, rug-

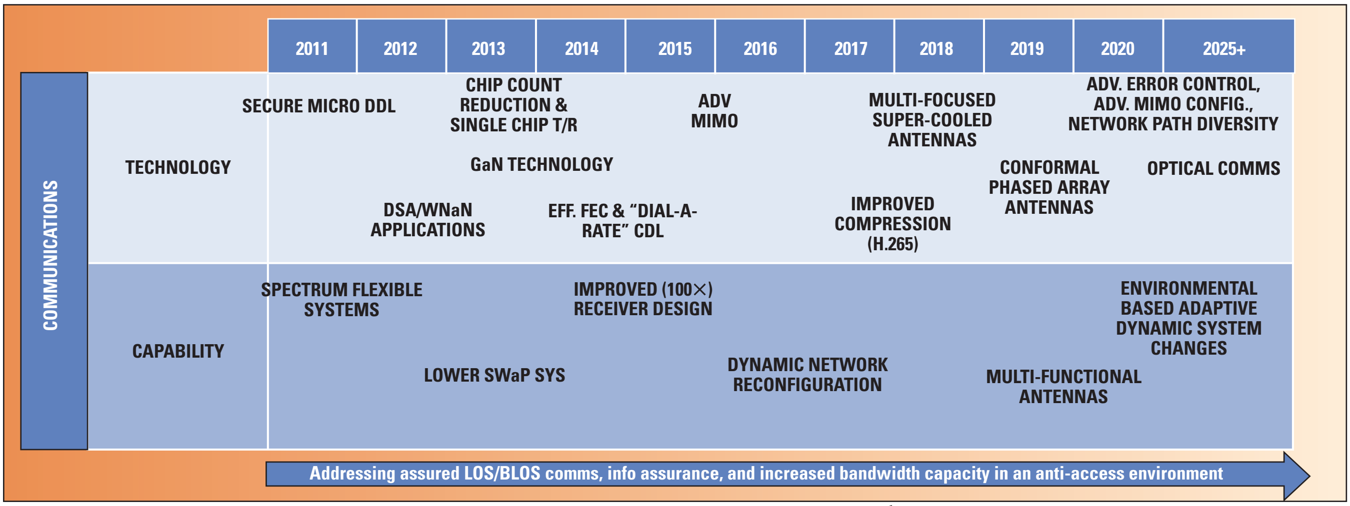


Fig. 8 Projected communications technologies timeline (courtesy of Department of Defense).[1]

ged, and low cost multidirectional antennas. It states that phased array antennas and "smart" antennas offer an alternative to traditional dish antenna, but they require tradeoffs among size, weight and power (SWaP). The industry will need to continue developing such techniques as multi-focused and super-cooled antenna systems. The roadmap explains that future antenna systems need to be able to send and receive signals over a broad range of frequencies. While phased arrays are a viable approach, they need to be conformal (e.g., using metamaterial) so that they will be molded within the vehicle surfaces. The utilization of common apertures requires the development of new interference mitigation methodologies that minimize cosite interference effects and improve the potential for achieving simultaneous transmit and receive operations within adjacent frequency bands.

The report also mentions that MIMO is a proven technology currently being used in commercial 4G wireless systems and would utilize multiple paths (although not necessarily independent) with lower data rates on each path; apply space-time coding and capacity optimization to achieve a total high data rate mission; apply power saving to jammer margin; and evaluate performance in benign and stressed conditions.

For transmitter and receiver systems, GaN SSPAs can offer more than double the efficiency of GaAs amplifiers, increased operational bandwidth, and wider frequency range of operation. The high transmit efficiency of GaN systems reduces the cooling requirements. In order to achieve some of these benefits, amplifier designs need to utilize technologies such as predistortion correction, envelope tracking, etc., to improve efficiency and performance. Some of these GaN technologies are currently available for selected frequency bands and plan to be in service in 2014. Instantaneous bandwidth performance and analog-to-digital converter sampling speeds have continued to improve system performance so this should continue to improve systems. The report mentions that improvements in integrated chip fabrication methods have allowed for significant miniaturization and reductions in part counts and for various transmit/receive and antenna functions and components to be integrated on a single chip this year. Most of these improvements are aimed at

reducing SWaP.

Many U.S. military operations are now taking place in parts of the world where adequate spectrum is not available. Broader bandwidths are needed to deliver timely data to the warfighter and transfer data to UAVs. Additionally, mission areas are becoming more spectrally noisy. DARPA's Next Generation (XG) project and its follow-on Wireless Network after Next (WNaN) program demonstrated the feasibility of dynamic spectrum access (DSA). DSA offers the ability to change frequency band use based on other adjacent spectrum-dependent systems actual use and nonuse of certain bands.

Communication systems need to implement more robust anti-jamming and secure communications techniques. Networking of multiple unmanned systems may be necessary to better ensure connectivity of the systems in non-LOS, urban, hostile, and noisy EMS environments to transfer the collected information. One concept under development with DARPA is the LANdroids program. This program calls for the deployment of small, inexpensive, smart robotic radio network relay nodes that can leverage their mobility to coordinate and move autonomously. ***Figure 8*** shows a summary of the projected communications technologies on a timeline for planned implementation. Most of these improvements involve RF and microwave technology that companies can contribute expertise to developing.

As miniaturization is a growing trend for UAVs, reducing electronics size and weight is becoming more important. RF and microwave companies offering reduced power consumption devices and highly integrated ICs have an advantage in the marketplace. Lightweight cabling and connectors are also an important technology for future systems.

FUTURE DIRECTIONS

Interoperability

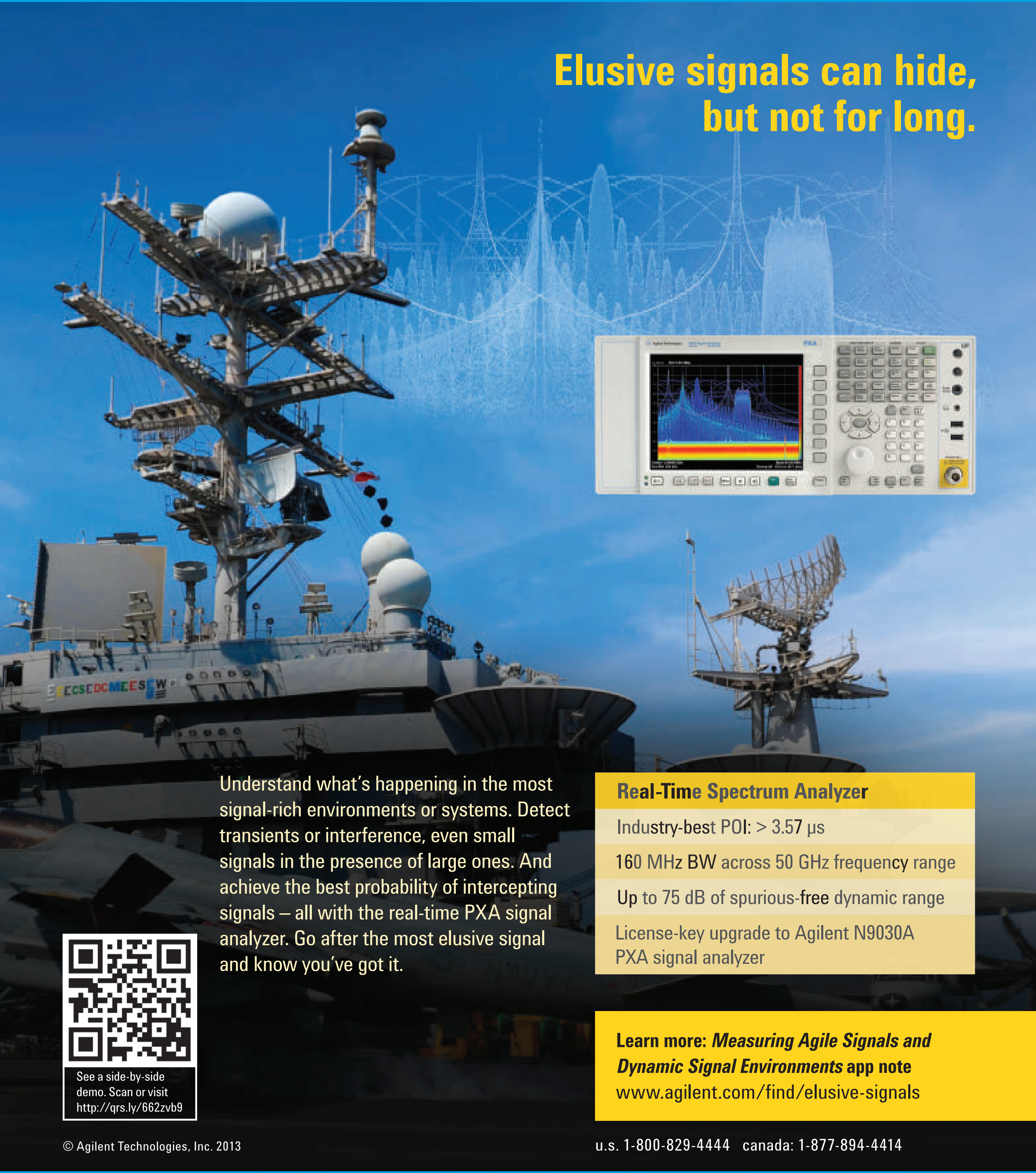
Interoperability is a big challenge to UAVs and the systems that support them. To achieve the full potential of unmanned systems, these systems must operate seamlessly across the domains of air, ground and sea and also operate with manned systems. Initially many of the UAVs were developed as a single system and used as proprietary systems so they are not compatible with each other. Many of them were procured in a rush to meet an immediate wartime need so there was no time to plan for interoperability. Going forward, the U.S. government plans to use an open architecture for systems to operate together and to use common plug-and-play sensors. This extends from sensors to data collection to system controls. Designing sensors and subsystems that can be utilized on many UAV platforms will also be a trend as the government tries to reduce costs and be able to distribute spare parts around the world. These parts could be shared between systems, agencies and maybe even non-military groups.

As a first step in this direction, the Office of Naval Research has recently developed software that can be shared across the range of UAVs in an effort to save money and streamline training. The Unmanned Aerial System Control Segment (UCS) software for the Common Control System has been successfully tested during a dry run on the ground and will be used in a test flight with a UAV later this year.

Airspace Safety

UAVs designers also need to prove that their UAVs can safely operate in the same airspace as piloted aircraft before they will be allowed to fly in commercial airspace. UAVs need to demonstrate a high level of operational robustness and the ability to "sense and avoid" other air traffic. Therefore, NASA has developed the Unmanned Aircraft Systems Airspace Operations Challenge (UAS AOC) that is focused on developing some of the key technologies that will make UAS integration into the National Airspace System possible. This Centennial Challenge will be conducted in two parts: Phase 1 is scheduled to be held in spring of 2014 and Phase 2 will be approximately one year later.[8] Phase 1 focuses on important aspects of safe airspace operations and robustness to system failures, and seeks to encourage competitors to get an early start on developing some of the skills critical to Phase 2.[8]

Another step in this direction of establishing the safety of UAVs in commercial airspace is that the FAA has issued a request for proposal for six ranges that will be used to test UAVs as part of the government's plan to integrate the technology into national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airspace. Establishing the test sites is a component of the FAA Modernization and Reform Act of 2012 with the goal of fully integrating UAVs into the airspace by 2015.

Autonomy

The next evolution in UAVs is autonomy. UAVs currently perform minimal tasks on their own relying on their operators to make most decisions – some behavior is automatic but not necessarily autonomous. An autonomous system has the ability to be goal-directed in unpredictable situations making its own decisions. Some think taking control from humans and giving it fully to machines is a bad idea (especially after watching Terminator or The Matrix), but in order to take UAVs to the next level to perform more tasks in an efficient manner, autonomy is needed. While many of the challenges to autonomy are software related, inputs to the software regarding the surrounding environment come from sensors. Higher resolution and improved sensors with fast response time will help enable autonomy.

Some UAVs are already starting to incorporate this type of technology into their designs. Britain's new stealth bomber UAV, Taranis, is being designed to self-evade without input from a controller. It can also independently identify targets and would only check back with a human controller before initiating an attack. This UAV is relatively large at with a wingspan of 30 ft and has a shape similar to the B-2 and stealth design (see ***Figure 9***). The UK hopes to replace manned bombers with UAVs such as this one. Some have said that the day of the manned fighter platform is gone after the current fifth generation fighters end their service.

Recently, a similar U.S. designed UAV achieved a very significant milestone. The X-47B (see ***Figure 10***) was catapult launched from the aircraft carrier USS George H.W. Bush for the first time and later made an arrested landing on the carrier. The X-47B design took into account the corrosive saltwater environment, launch and recovery on deck, integration with command and control systems, and operation in an aircraft carrier's high-electromagnetic-interference environment, as well as the ability to perform reconnaissance missions in its design. UAVs are now able to be fully integrated into the Navy on carriers – one of the harshest environments for aircraft to land on and take off from. This marks one of the last areas for UAVs to fully penetrate the armed services and provides better coverage around the world.

Micro- and Mini-UASs

An intriguing aspect of the micro- and mini-UAS space is UAS platforms that are hidden or blend into the environment. Some designs look like birds that sit perched on a tree and survey the area or track a target. Others are insect-like and so small that they are very difficult to observe. As the UAVs become smaller, their agility increases so that they can easily maneuver through small spaces. This allows them to move around inside of buildings without hitting any obstacles.

Researchers have also been working on software that allows these small UAVs to cooperate and fly together in formation and even break formation to go through a small space and then regroup automatically. A February 2012 Technology, Entertainment, Design (TED) video, featuring Vijay Kumar from the University of Pennsylvania, shows the results of cooperation between UAVs as they fly in formation sensing each other to keep a minimal distance in a set pattern.[9] Then as they come to an obstacle too small for the formation, they cooperate by passing through one by one, regrouping in formation after they have each passed through the small space. Developing systems that allow these UASs to communicate with each other and make their own decisions is a big area of research that could allow these vehicles to take the next leap in capability. With this technology, many UAVs can work together to accomplish tasks that a single UAV would not be able to do such as lift a heavy object or perform a coordinated attack from many directions.

Imagine several small UAVs communicating with each other as they fly through a structure and automatically map out the inside using radar sensors and sending the layout information to those that need it. The UAVs make their own decision about which way to roam around the building steering toward the areas that are the most unmapped at the time and communicating which areas they have covered to the other units.

This quickly accomplishes the task without inputs from a controller.

Improved Radars

New radars that can perform through-the-wall sensing and mapping are being developed to improve UAV capabilities. An example of this technology is found at TiaLinx which designs UAVs with sensors that operate at 5 GHz, giving them substantial penetrating capability, even at extremely low power. Some models are designed to detect motion, even a heartbeat or breathing. The company has previously stated that the device can detect people or animals more than 20 feet behind an 8" thick concrete slab. They have models that operate in the V-Band to produce sharper images. But the atmospheric attenuation at 60 GHz means this model cannot penetrate as deeply. Because these devices transmit ultrawideband (UWB) signals, they are able to obtain a more complete view of hidden objects. UWB signals are less affected by environmental factors such as rain, snow and fog that degrade the performance of many radars plus operate at low power (see ***Figure 11***). These types of UAVs' roles could be expanded into internal surveillance as very small form factors that can fly around virtually undetected.

Global Activity

Many other countries are putting a lot of resources into UAV design and development. During the AVIC Cup-International UAV Innovation Grand Prix ceremony (a contest for industry professionals) at the Zhuhai Airshow in China last November, a video was shown of the futuristic "Blue Shark" UUV (see ***Figure 12***) diving for an attack on Russia's Kuznetsov aircraft carrier.[10] Many of the contestant submissions were of near-space UUVs and hovering ground-attack heavy UAVs.[10] A recent report states that China uses UAVs for intelligence, surveillance, and reconnaissance (ISR) missions and communications relay, but likely is developing and operating UAVs for electronic warfare (EW) and lethal missions.[11] China, like the U.S., is incorporating UAVs into non-defense missions such as border security, maritime surveillance, and humanitarian assistance/disaster relief. The Chinese presence is expected to grow in the international market as they have far fewer restrictions than the U.S. for military exports.

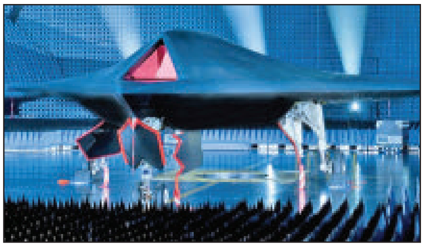

Fig. 9 British UAV Taranis (courtesy of BAE).

Fig. 10 U.S. UAV X-47B preparing for carrier launch (courtesy of U.S. Navy – photo by MC2 David R. Finley, Jr.).

Israel is a major operator and producer of UAVs, with three air force squadrons equipped with Heron, Hermes 450 and Searcher craft, as well as the giant Eitan[12] and as stated previ-

ously, probably is the largest exporter of UAVs globally. Israel is considered to be second to the U.S. in UAV technology. UAVs play a key role in battling Gaza rocket launchers as they perform surveillance and identify rocket launcher positions. They are working on UAVs to take over many tasks that are currently performed by manned aircraft.

CONCLUSION

UAVs are an exciting area of development that is progressing quickly. While the overall market is growing, the U.S. military market will decline in the next few years as the U.S. pulls out of Iraq and Afghanistan. However, the U.S. commercial market is expected to grow significantly as military sales decline providing that legislation is passed to incorporate UAVs into the national airspace. New commercial applications such as border security, public safety and farming are expected to find many benefits from the use of UAVs. Growth is also expected in

Fig. 11 TiaLinx UAV with UWB radar sensor (courtesy of TiaLinx).

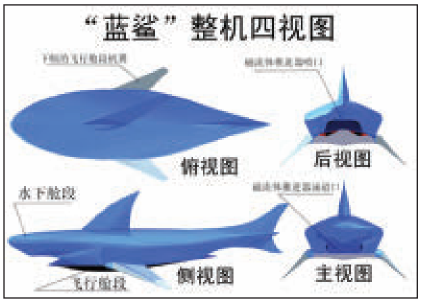

Fig. 12 Blue Shark UUV Chinese concept (courtesy of Defense News).

foreign military markets as the technology becomes more widespread.

RF and microwave companies can participate in this market growth with technologies that reduce SWaP such as GaN amplifiers, highly integrated radio transmitters and receivers, MIMO and conformal antennas, light weight cables/connectors, plug-and-play sensors and low power systems. The market for smaller mini- and micro-UAVs will demand further miniaturization of electronics and other key components as the commercial market expands. ■

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Envelope Tracking in Next Generation Military Radios

Existing narrowband military communications systems offer minimal battlefield capability beyond voice communications and relatively low data rate services. The desire for increased combat effectiveness is driving the need for improved interoperability and battlefield communication system features – combat units and individuals are now integrated into a network of data services providing features such as integrated command and control, mapping, real-time video and location-based services providing situational awareness.

Realistically, these services can only be delivered using modern complex high peak to average power ratio (PAPR) modulation schemes that provide high spectral efficiency. For systems supporting both these and legacy constant envelope or low bandwidth/PAPR waveforms, the traditional fixed-supply PA becomes very inefficient when using the new modulation schemes, requiring large power sources for even small RF output powers. The increased peak power needed by a fixed-supply PA to support high-PAPR waveforms also compromises the efficiency when operating with legacy waveforms, resulting in decreased battery life compared with legacy equipment.

Recent advances in envelope tracking (ET) techniques are leading to their adoption for commercial LTE-based 4G cellular systems, enabling insertion into next generation military radio designs. The use of an ET-enabled PA is an effective solution for modern high modulation rate air-interfaces, especially for dismounted soldiers. ET PAs offer improved efficiency and lower power consumption resulting in reduced cooling requirements thereby allowing smaller, lighter batteries to be used or longer battery life to be achieved from a given battery. Less obvious benefits include improved linearity performance, improved tolerance of mismatched antennas and increased output power from a given PA device compared with fixed-supply operation. ET PAs fit in well with software defined radios (SDR) as they are capable of being configured in real time to suit the differing operating modes required under battlefield conditions. In addition, they are forward-compatible with yet to be announced future waveform developments.

This article explains how the key benefits of ET PAs for modern battlefield communications systems – improved PA efficiency and linearity – are achieved, and the types of ET modulator

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Nujira Ltd., Cambridge, UK
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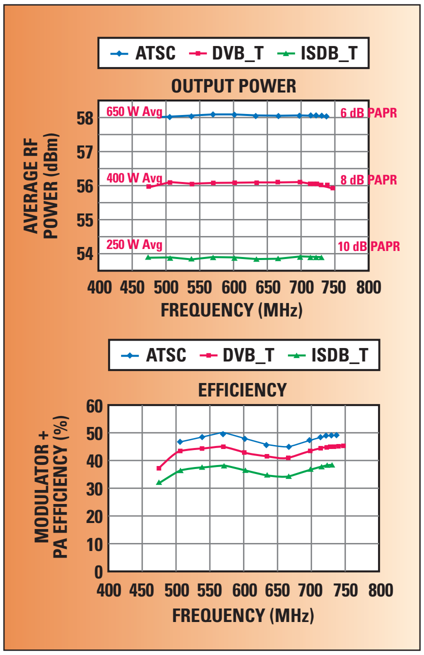

Fig. 1 Broadband high power ET PA example.

technology being developed to enable them. The move to networked combat data services is driving demand for higher data rates and there is currently no real alternative to ET-modulated PAs for next generation military radio use.

WHY USE ET FOR MILITARY APPLICATIONS?

Military success has always depended on effective battlefield communications and with the emerging proliferation of radios, sensors and unmanned assets, this has proved to be an increasing technical challenge. In this environment, it is essential to integrate all battlefield communications within a single integrated network to provide seamless access to voice and data traffic. This objective has been pursued in the U.S. under the JTRS program with the result being a complete networking concept enabled by SDR and several new networking waveforms. In order to understand the benefits ET brings to radios operating in this environment, it is useful to review the top level network architecture and associated waveforms.

In concept, the evolving military communications network has three distinct levels; lower, mid-level and upper, with each level having specific functionality and waveforms commensurate with this functionality. The lower level is intended to support the

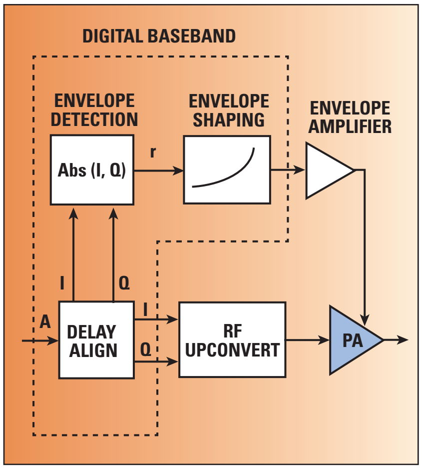

Fig. 2 ET-enabled system architecture.

tactical edge and provides voice and low capacity data services including connectivity to other edge devices. Network domains are formed using the Soldier Radio Waveform (SRW) which fully supports self-forming ad hoc IP networking. At this level, domains are generally small geographically and are supported by small form factor handheld radios with RF transmit powers typically in the range 2 to 5 W.

Networking at the mid-level is by means of the Wideband Networking Waveform (WNW) which again supports self-forming mobile ad hoc networks with each radio being a node on an IP-based mesh. The purpose of the mid-level is to provide effective high capacity backhaul. It provides connectivity between the lower level local networks at the tactical edge and integrates all data over a large geographical area. Radios for use in mid-level communications must therefore have an extended range and simultaneously be able to interconnect to both lower and upper levels. Interconnection with the lower level uses SRW whilst upper level interconnection uses the Mobile User Objective System (MUOS) satellite system. Mid-level radios today are generally man portable or vehicle mounted with RF transmit powers in the 20 to 50 W range. Support for SRW, WNW and MUOS waveforms is therefore required in addition to a range of legacy waveforms. Planned upper level integration of the total networked battlespace will use assets that include WIN-T, the MUOS satellite constellation and GIGBE, and consequently, will be global in scale. See JTNC Newsletter for further background on the communications networks and waveforms discussed here.[1]

For the emerging military communications strategy to succeed, next generation radios require certain features which are challenging for the radio designer. Each radio is required to support one or more high PAPR waveforms operating over an extended frequency range. Depending on whether the radio is assigned for operation on the lower or mid-level networks, these modern waveforms may have to operate alongside a range of legacy waveforms, imparting additional demands. These considerations create significant challenges for the transmit chain where efficiency and linearity are crucial. In the future, these challenges will be compounded with the move toward cognitive radios required for the DARPA Wireless Network after Next (WNaN) program.

ET exhibits attributes well suited to meeting these requirements. An example of ET's ability to deliver high efficiency, broadband PAs capable of operating with a wide range of signal PAPRs is shown in ***Figure 1***. This allows the efficiency of broadband PAs to be significantly improved without the inherent RF bandwidth restrictions of RF phasing techniques such as Doherty and Chireix.

ET SYSTEM ANATOMY

A typical ET-enabled transmit system is shown in ***Figure 2***. At the heart of the system is the envelope amplifier (also known as an envelope modulator) that must provide a high efficiency, low noise and high bandwidth dynamic power supply to the PA. Envelope detection and shaping functionality needs to be added to the digital baseband processing in an ET system to generate a reference signal for the envelope amplifier. The envelope shaping determines the relationship between the instantaneous RF power and the PA supply voltage and influences many key metrics of the ET system. Lastly, accurate, stable timing alignment between the RF and envelope signals is necessary to achieve low PA distortion and this function is also typically implemented in the digital baseband.

MODULATOR ARCHITECTURES

Examples of basic ET modulator architectures are shown in ***Figure 3***. The

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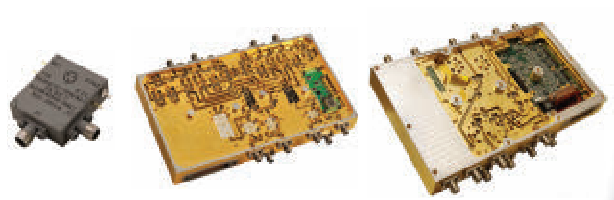

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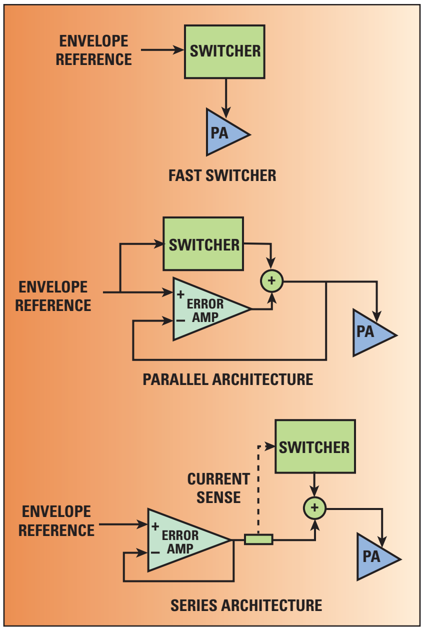


Fig. 3 Modulator architectures.

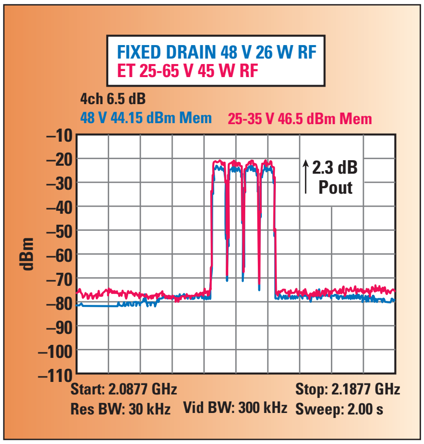


Fig. 4 Increased O/P power capability using ET.

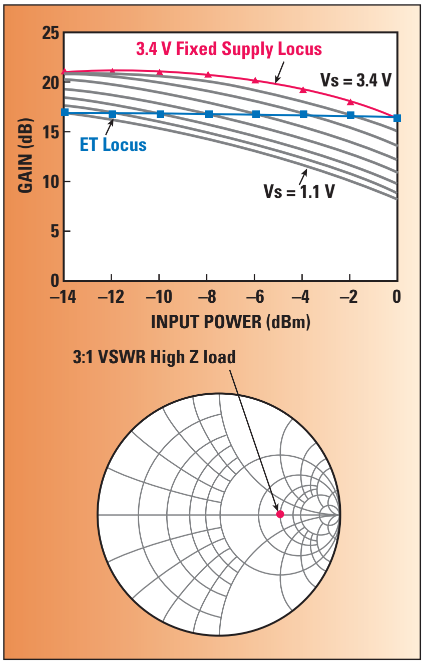


Fig. 5 ET and fixed supply operation into mismatched load.

first is a fast switcher-only architecture. This simple scheme can achieve ~90 percent efficiency with low power and low bandwidth signals but is difficult to scale up in bandwidth and power. To achieve good TX linearity, the bandwidth of the envelope path has to be 2 to 3 times the RF bandwidth. Furthermore, to achieve good stability margin and switching noise suppression, the ratio between switching rate and modulation bandwidth for a single phase buck converter is typically 10×, resulting in a switching frequency to RF bandwidth ratio of 20 to 30:1. This means that to achieve an RF modulation bandwidth of only 2 MHz, a switching frequency of ~50 MHz is required. Increased switching frequency results in excessive semiconductor switch and inductor losses. Multi-phase/multi-level switch mode techniques can be used to reduce the ratio between switching rate and modulation bandwidth, at the expense of increased complexity.

The second architecture is the hybrid parallel switcher-error amplifier architecture. The switcher 'leads' by creating a crude approximation of the desired waveform, and a linear amplifier 'follows' by cleaning up the output of the switcher. An efficient but relatively low bandwidth switch-mode power supply provides 80 to 90 percent of the power at DC and low frequencies, and the less-efficient but high-bandwidth linear error correction amplifier provides the remaining HF power. In addition to providing the modulator's HF signal content, the error amplifier also suppresses high frequency switcher noise by comparing the switcher output with the desired reference. Feedback loops around the error amplifier and switcher ensure that the modulator exhibits low output impedance across a wide frequency range – a feature critical to achieving high tracking accuracy and good transmitter linearity. The overall efficiency of the modulator architecture is typically >80 percent and is almost flat with increasing bandwidth – a highly desirable characteristic.

The third is the hybrid series switcher-error amplifier architecture. This comprises a 'leading' error amplifier driving the PA supply and a 'following' switcher. Current sensing detects when the current drawn from the error amp exceeds a pre-determined threshold and a hysteretic switcher is used to efficiently supply additional current to the PA. At low bandwidths, the overall efficiency of this architecture is similar to the parallel architecture, but the efficiency tends to fall with increasing signal bandwidth as delays in the switcher loop result in the switcher working against the linear amplifier. In addition, the switcher ripple current has to flow into the low impedance output of the linear amplifier, resulting in increased linear amplifier dissipation.

More complex derivatives of both the parallel and series hybrid architectures are possible. These generally use multi-phase and/or multi-level switchers to increase modulator efficiency, provide voltage boost capability or increase bandwidth. Low power (~750 mW average RF) handset modulator ASICs providing high efficiency and voltage boost capability are becoming available. One such ET IC uses a single phase buck converter to provide the DC and LF power, and a multiphase, multilevel converter to provide the bulk of the remaining power. A linear error amplifier is used to clean up the switching noise of the switch-mode converters. Such ASICs operate with standard 2.5 to 5.25 V Li-ion batteries and generate a 4.5 V peak/1.2 A peak PA supply capable of supporting RF bandwidths up to 20 MHz.

High-density IC components incorporating all necessary ET functions for medium-power mobile applications (~5 to 25 W average RF) are also emerging. For instance, all signal processing and DAC functions may be integrated on one IC whilst a second IC may integrate several switcher controllers. At this power level, external O/P stages may be used to allow the power and voltage range of the modulator to be optimized to suit the PA voltage and power. Compact scalable ET modulators fit into satcoms and higher-power handset applications, in addition to low-power vehicle-mounted terminals. At this power level, a typical modulator may operate from 10 to 30 V supplies to generate a 10 to 30 V peak/1 A peak PA supply capable of supporting RF bandwidths up to 20 MHz.

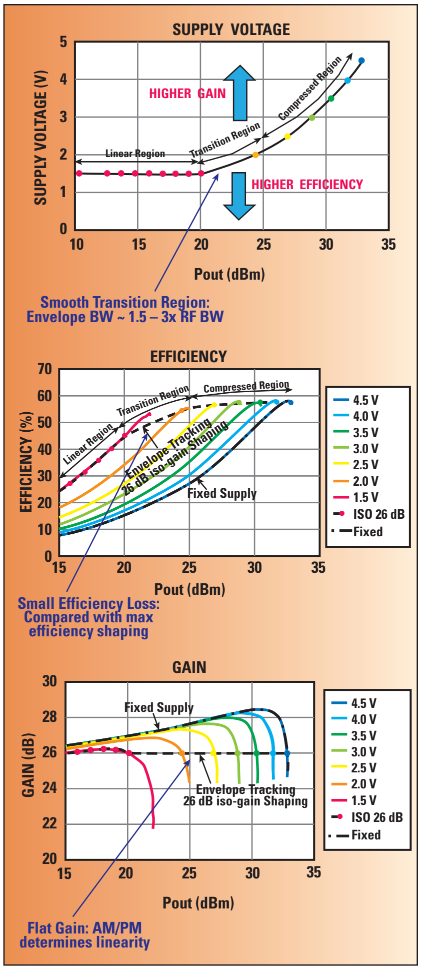
BENEFITS OF ET-ENABLED PAs

A fixed-supply PA only operates in compression during infrequent waveform peaks, whereas an ET PA operates in compression most of the time. This results in ET PAs operating more efficiently and with lower die powers, enabling smaller PA devices and smaller, lighter batteries to be used for a given system capability.

The PA die size is primarily determined by the system peak power requirements and is in principle the same for both fixed supply and ET having the same peak voltage. However, the use of ET greatly reduces die power dissipation and temperature which often results in further increased peak power capability. In addition, for GaN devices the peak power capability may be significantly increased by operating in ET mode, allowing a higher peak supply voltage than could be sustained in fixed supply operation. This is possible because the output power in fixed supply mode is often limited by thermal issues rather than voltage considerations. In the example shown in ***Figure 4***, the peak output power of a fixed drain 48 V GaN PA increased by 2.3 dB when operated in ET mode with 25 to 65 V swing range. Despite the increased RF output power, the die power dissipation actually decreased from 45 to 32 W.

The reduction in PA die power dissipation reduces heat sinking requirements, simplifying the thermal design. This can eliminate the need for fans, heat pipes, heat sink fins, etc., reducing product size, weight and cost.

A perhaps unexpected benefit of ET is increased VSWR tolerance compared with fixed supply PAs. The increasing use of wideband PAs and wideband antennas means that the antenna match is often not ideal and may vary dynamically in use. In these situations, a fixed-supply PA would need to operate with significant power back-off to maintain linearity. But it is



▲ *Fig. 6 ISOgain shaping.*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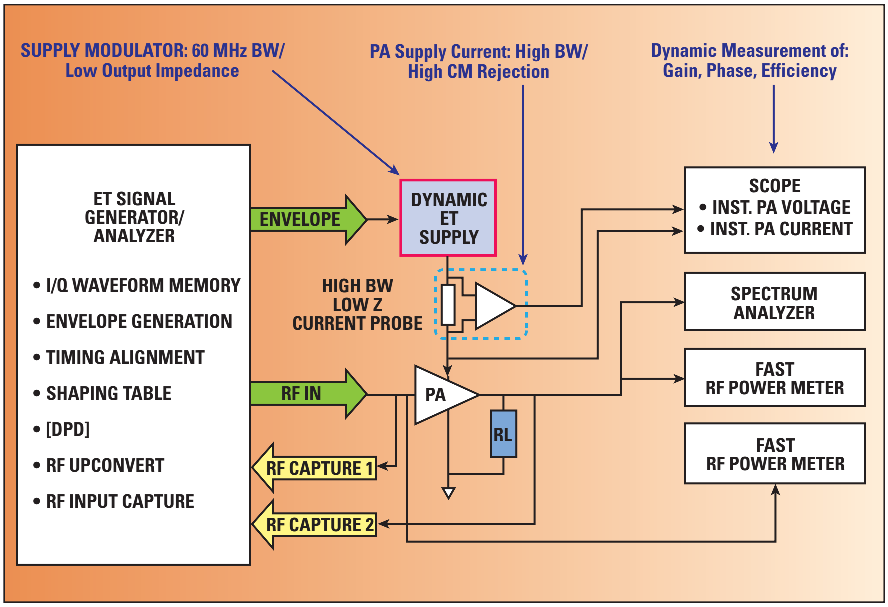
found that ET PAs can work into high VSWR loads with significantly less ACPR degradation. The explanation for this initially surprising finding may be found in the fact that an ET PA operates in compression over much of the envelope cycle by design, using a shaping table chosen to achieve flat AM-AM characteristics. If exposed to a VSWR phase angle that results in a significantly higher load impedance, it operates in even heavier compression, but the shaping table still results in approximately flat AM-AM characteristics – i.e., the PA linearity does not alter dramatically. In contrast, the AM-AM characteristics of a fixed supply PA will be considerably altered when working into load impedances higher than intended (see ***Figure 5***).

The provision of a fall-back Average Power Tracking (APT) mode means that ET PAs can also offer high efficiency when operating with legacy low bandwidth, constant envelope or low PAPR waveforms, or when operating at low power with backed-off high PAPR waveforms. This APT mode is generally accomplished by disabling the linear amplifier of a hybrid modulator and running only the switcher. This then generates a variable voltage fixed DC output with an efficiency of 90 to 95 percent so that the PA runs with the minimum fixed-supply necessary to reproduce the legacy waveform with adequate linearity.

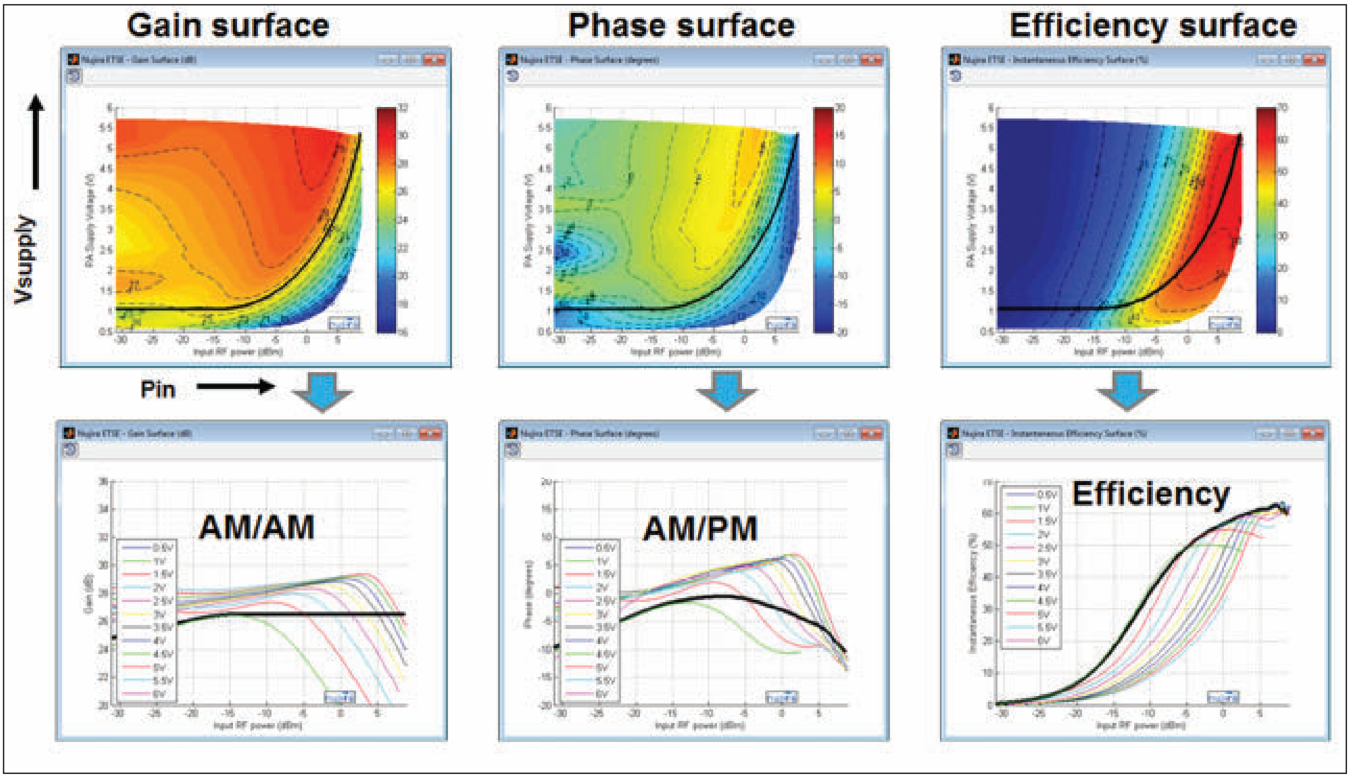
ET PA CHARACTERISTICS

As previously noted, the shaping function plays an important role in determining many key metrics of an ET PA system. To understand why, it is necessary to appreciate some of the fundamental efficiency and linearity characteristics of the PA itself.

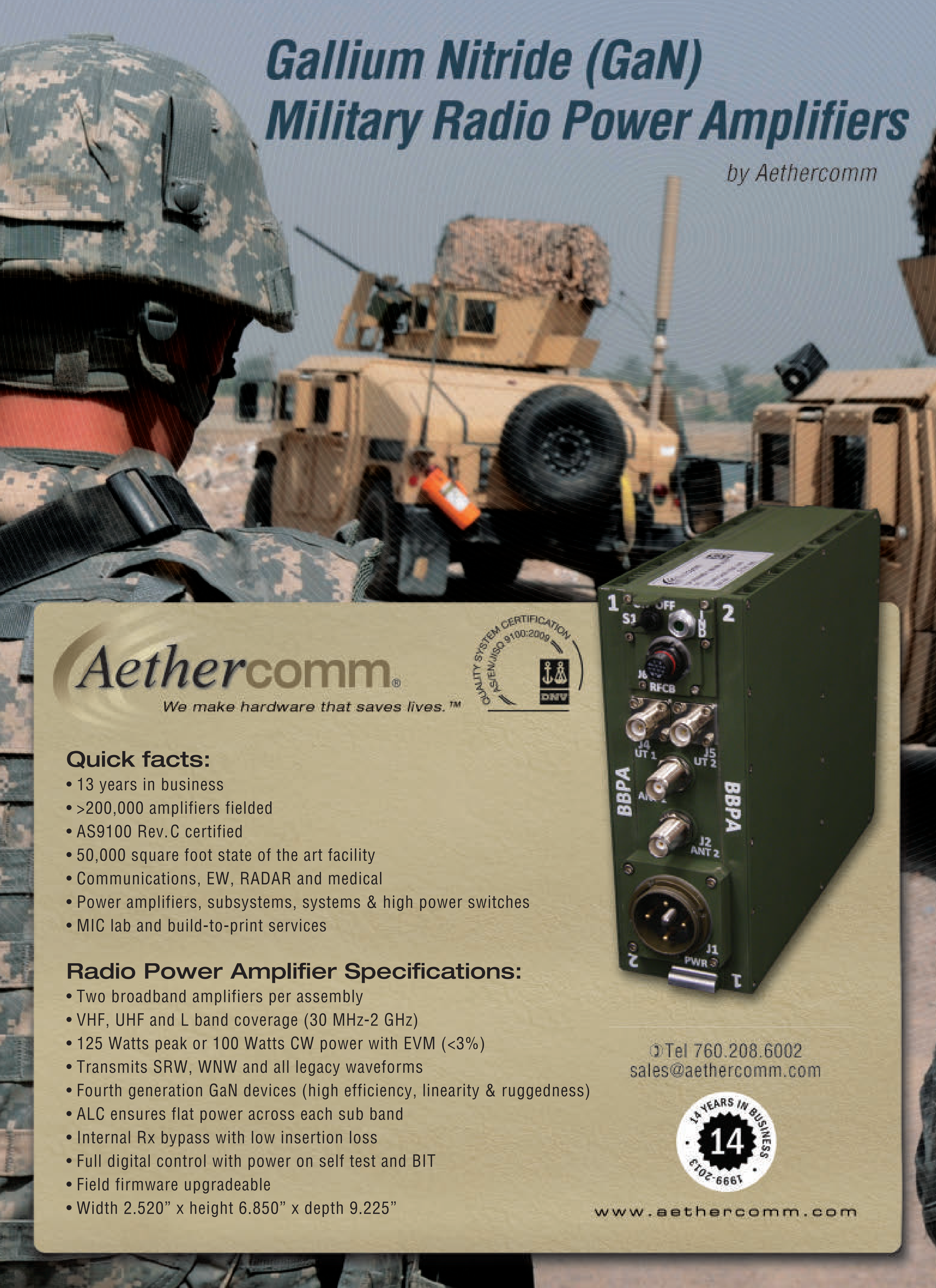
A traditional fixed supply is usually considered to be a two port device whose fundamental output characteristics (efficiency, gain, phase, etc.) are a function of only a single input variable, the instantaneous input RF voltage. An ET PA may be considered to be a three port device whose output characteristics are determined by both instantaneous input power and supply voltage. Surface plots are therefore required to properly understand its



▲ *Fig. 7 PA characterization.*



▲ *Fig. 8 ET PA characterization and shaping function derivation.*



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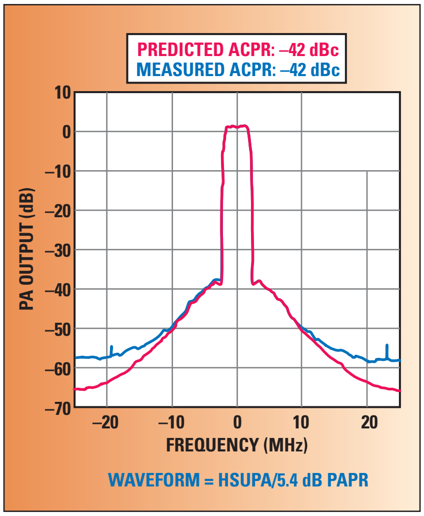
ET mode behavior. The operating trajectory across the output surfaces is determined by the shaping function, which determines the nonlinear mapping between instantaneous input RF voltage and supply voltage.

Three operating regions may be identified for a typical ET PA as shown in ***Figure 6***. At high instantaneous power, in the compressed region, the PA's output characteristics are determined by the supply voltage. At low instantaneous power, in the linear region, the PA operates as a conventional fixed supply PA and its output characteristics are determined by RF input voltage. In between these, in the transition region, the PA's characteristics depend on both supply voltage and RF input voltage. The choice of shaping function determines the trade-off between the efficiency and compression characteristics of the PA and determines the transition points between operating regions.

Figure 6 illustrates that it is possible to select a shaping function that results in a flat PA gain characteristic (ISOgain), with only a slight impact on its efficiency. Hence ET offers the possibility of a simple method for linearizing the AM characteristics of a PA whilst simultaneously raising its efficiency. The AM-PM characteristics are not directly controllable by the shaping function in the same way, so to fully exploit this linearization benefit, the PA should be designed to show low intrinsic AM-PM.

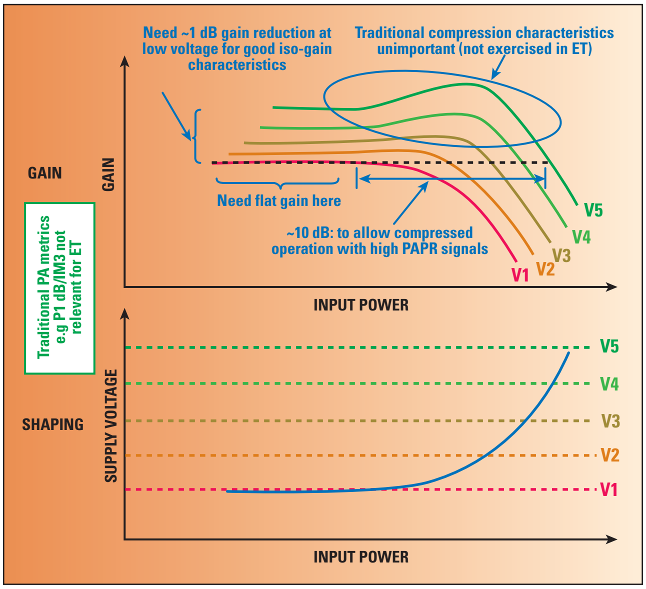
To determine the ET shaping function, the PA must first be characterized under representative operating conditions. So how can the PA be measured? It might initially be thought that a VNA power sweep to capturing AM-AM and AM-PM data across a range of supply voltages would be adequate. Unfortunately, data captured in this way results in poor ET performance prediction on account of die heating effects due to the slow CW sweep. A better characterization can be achieved using a setup like that shown in ***Figure 7***. The key elements of this setup are an ET signal source which generates time synchronized RF and envelope waveforms, and a dynamic power supply which generates the PA supply voltage. Simultaneous captures of the instantaneous input and output RF power, together with instantaneous supply voltage and supply current, enable the key PA characteristics to be captured under representative operating conditions.

Once this raw data has been captured, it may be post-processed in



▲ *Fig. 9 ET performance prediction from ET PA characteristics.*

many ways to examine different aspects of ET PA performance. Three particularly useful surfaces (gain, phase and efficiency) are shown in ***Figure 8***. In these plots, color-mapped contours of constant gain, phase and efficiency are represented by the z direction. The shaping function – the mapping between instantaneous input power and supply voltage – is overlaid as a black line on all three plots. Once this is determined, more familiar 2D plots of the PA's AM-AM, AM-PM and instantaneous efficiency may be derived, as shown in Figure 8.



▲ *Fig. 10 ET PA – ideal characteristics.*

These metrics are useful as they give considerable insight into mechanisms that may be limiting linearity or efficiency performance. Typically, however, PA specifications are defined by system level parameters such as ACPR, EVM and average efficiency. Further post-processing of the instantaneous AM-AM, AM-PM and efficiency data together with knowledge of the target waveform may be used to predict these parameters also. This is shown in ***Figure 9*** which shows a comparison of predicted ACPR based on PA characterization and waveform data, and measured results using the actual waveform.

This begs the question of how a PA should be designed to achieve good ET performance, particularly where the target application cannot support the complexity and power overhead of sophisticated closed loop DPD linearity correction. ***Figure 10*** shows the AM-AM or gain characteristics of an ET optimized PA. To achieve flat gain as shown by the dotted black line, the PA operates in moderate compression at high instantaneous power and gradually comes out of compression as the instantaneous power reduces. It is important that the gain at very low powers and low supply voltage is flat, and that the low supply voltage small signal gain is less than the high supply voltage small signal gain. If this is not the case, the ET PA will exhibit gain recovery at low instantaneous power, resulting in wideband TX distortion due to the high rate of change of signal at low power. It is interesting to note that the PA compression characteristics of a traditional fixed supply PA are of little relevance to an ET PA, as the PA never operates in this region.

ET SYSTEM PERFORMANCE OPTIMIZATION

Murphy's Law for PAs dictates that there is always some trade-off between system efficiency and linearity, hence it usually makes sense to trade linearity for efficiency to just meet the TX linearity target with adequate margin. In high power systems, this can be achieved through use of baseband crest factor reduction (CFR). However, this is computationally intensive, and ET allows a crude form of CFR to be implemented simply by modifying the contents of the shaping table as shown in ***Figure 11***. The level and 'sharpness' of the soft clipping may be used to provide a degree of control over how far from carrier the inevitable distortion products lie. By reducing the PAPR of the PA output signal, this technique enables the PA to operate at high average power, increasing system efficiency.

It has been shown that ET may be used to linearize a PA in addition to improving its efficiency; however, this may necessitate use of a wider supply voltage swing range than is needed to achieve best efficiency from the PA/

supply modulator combination, particularly if the PA has not been well optimized for ET operation. Where this is the case, it can make sense in low and medium power systems to include simple RF pre-correction – a cut-down version of traditional DPD – allowing the minimum supply voltage to be optimized for best efficiency. In this architecture, shown in ***Figure 12***, envelope shaping is used to control AM at high instantaneous powers and RF path pre-correction is used to provide AM correction at low instantaneous powers and PM correction across the entire power range.

CONCLUSION

With the move to networked combat data services driving the demand for higher data rates, envelope tracking satisfies the diverse requirements of next generation military radio transmitters. ET-enabled PAs allow for the use of smaller power sources or longer battery life, together with lower cooling requirements resulting in lighter, smaller radios. They can handle the range of waveform types from legacy voice to high-capacity data, offer broadband RF capability, and have improved linearity and antenna mismatch tolerance. ■

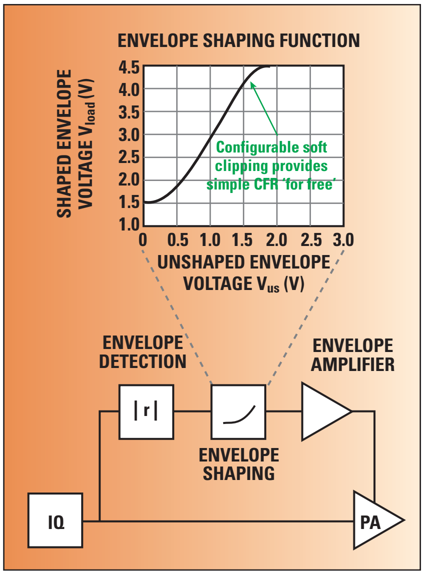


Fig. 11 Shaping table based crest factor reduction.

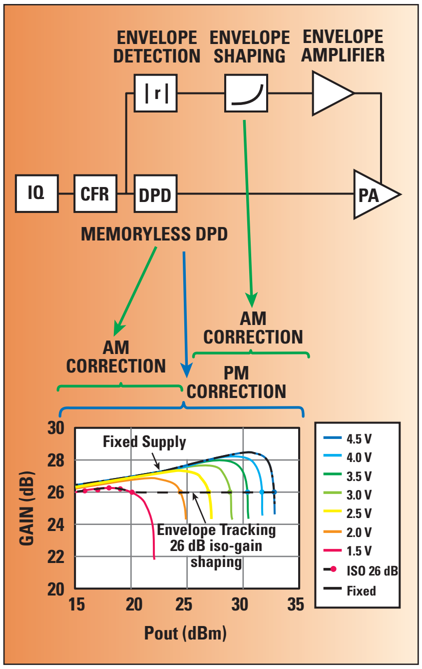


Fig. 12 Combined RF pre-correction + shaping function linearization.

Reference

1. JTNC Newsletter Vol. 1, Issue 1, March 2013.

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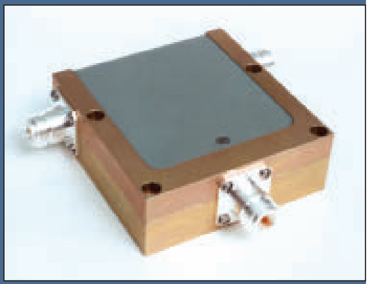

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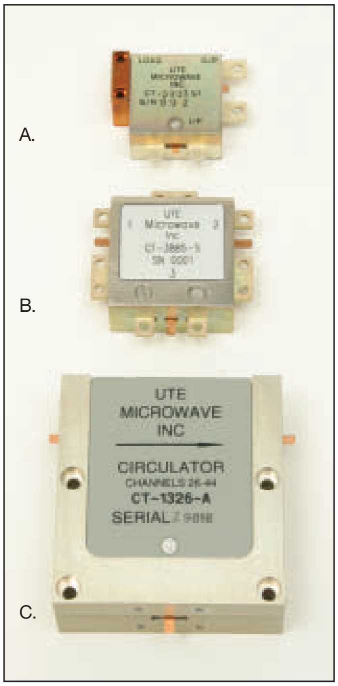

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Receiver Protection in S-Band Radars for Mitigation of 4G Signal Interference

Spectral proximity of 4G communication signals to S-Band radar frequencies can result in the introduction of false target signals into a radar sensor system. Furthermore, the magnitude of 4G communication signal levels (when radiated in the vicinity of a radar) can cause the radar receiver to begin to limit then fully activate the receiver protector, and so cause any synchronous target signal to be lost.

An updated pre-TR limiter receiver protector (RxP) has been designed to tolerate high levels of 4G signal interference, and enables the use of a low-power filter at the RxP output to minimize 4G signals before they enter the radar receiver. This approach has preserved the operational performance characteristics of the legacy pre-TR limiter design, and presents a robust alternative to high-power filtering at the radar antenna.

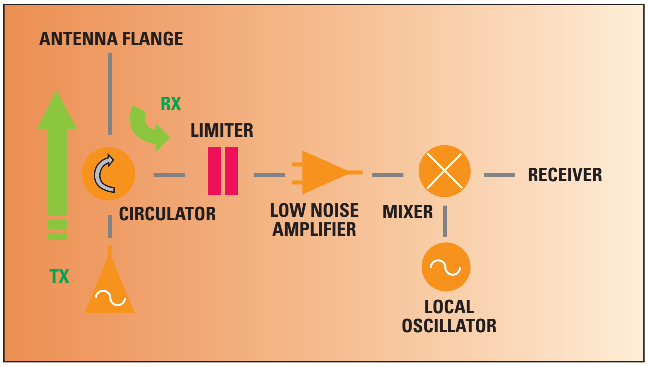

Fig. 1 Surveillance radar transceiver functional schematic.

Allocation of communication frequency bands close to existing radar frequencies[1-3] has seen study of potential interference and disruption effects in surveillance radar systems.[4-7] As the margins between allocated frequency bands narrow, there is a growing demand for precision in the requirements for band-edge filtering of transmitted signals and out-of-band rejection of any extraneous received signal frequencies[1-7] which otherwise threaten the mission reliability of the radar system.

4G interference signals can reach and activate the limiter causing it to compress and attenuate all in-band incoming signals (including target echo returns), as illustrated in the radar system schematic shown in ***Figure 1***. These 4G signals can also pass through the RxP and generate false signal returns or saturate the receiver.

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Amplitude Variation, Narrow Band	±0.5dB across any 50MHz (100MHz to 500MHz) ±0.5dB across any 100MHz (500MHz to 18GHz)		
Phase Variation, Narrow Band	±2° over any 50MHz (100MHz to 500MHz) ±2° over any 100MHz (500MHz to 18GHz)		
Phase Resolution	0.8° max.		
Return Loss (Input / Output)	10dB min.		
Input Power, Operating Max.	+7dBm		
RF Input Power (CW) Damage Threshold	+30dBm CW max.		
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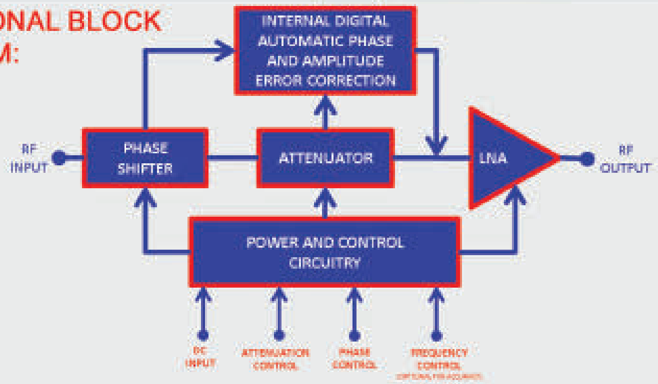

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IF FILTERING OF 4G SIGNALS

Radar receivers generally incorporate filtering within the IF stages; however, it may not be practical to reduce the impact of 4G interference by introducing narrowband filtering at this point because the desired signal and all interfering signals must pass through the receiver protector into the low-noise microwave amplifier (LNA) and frequency converting mixer before reaching the IF amplifier. Consequently this "downstream" IF filtering approach can lead to:

- Limiter compression and impeded target signal reception due to the attenuation from the receiver protector
- Harmonic generation from the 4G signal; saturation and potential damage of the LNA
- In- (radar) band products of the mixing process; third-order intermodulation can generate products at frequencies up to 2.81 GHz from base station signals in the 2.6 GHz 4G communications band
- Saturation of the IF amplifier leading to missed and erroneous target returns.

RF INPUT FILTERING OF 4G SIGNALS

The solution of filtering the received signal before the receiver protector and gain stages[8,9] relies on a filter capable of handling the high-level antenna reflection signals and potential high-power fault conditions and having a sufficient number of high-Q elements to attenuate the 4G signals.

With this "up-stream" approach, incoming RF power levels could exceed the filter's electric field rating and cause internal arcing, leading to long-term filter degradation – this is especially a problem when the system is specified to operate at high altitude without waveguide pressurization.

Alternatively, a power-compliant filter design can prove excessively large in size, leading to accommodation issues with a retro-fit filter installation.

MODIFICATION OF THE RECEIVER PROTECTOR

Receiver LNAs have been optimized to operate in radar receivers close to 4G communication signal bands.[10] It is also feasible to enhance the behavior and operation of the duplexer and receiver protector to mitigate any signal interference, and avoid further modification of the receiver LNA.

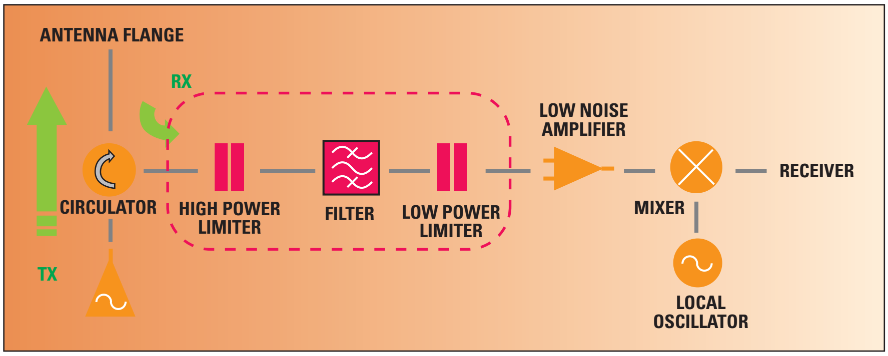


Fig. 2 Functional concept for a 4G-resilient surveillance radar transceiver.

An updated receiver protector design is presented for S-Band (2.8 GHz) applications, which accommodates a higher input compression level to mitigate attenuation in the radar receive chain from the ingress of 4G signals. This updated RxP was designed for use with a low-power filter and secondary low-power limiter (included in front of the receiver LNA) to allow reliable filtering of 4G interference signals and maintain robust protection of the LNA as shown in ***Figure 2***.

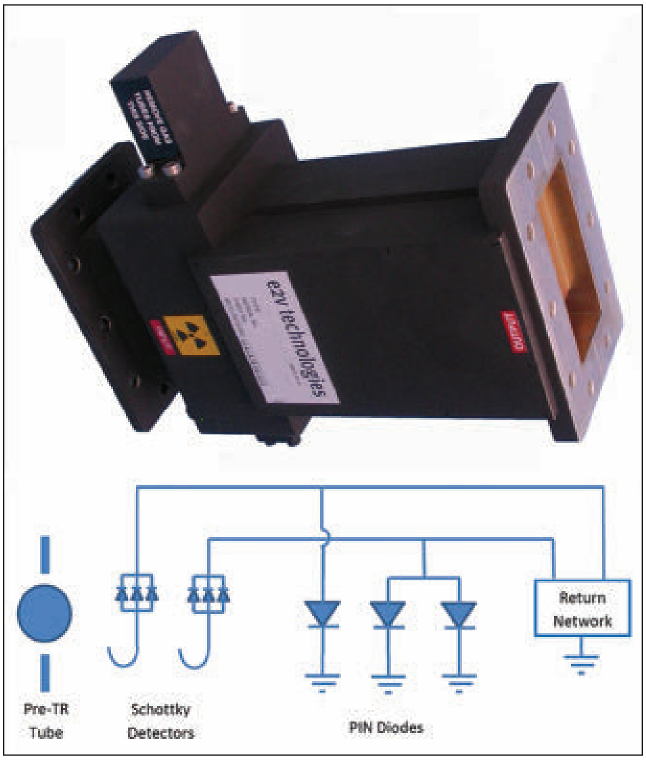


Fig. 3 General arrangement of a legacy S-Band pre-TR limiter receiver protector.

4G signals within the frequency bands 2.5 to 2.69 and 3.4 to 3.6 GHz, at +23 dBm peak power, can be incident on an S-Band radar limiter receiver protector.[12] The existing pre-TR limiter design (see ***Figure 3***) did not meet this interference specification owing to too low a compression point: the limiter was therefore redesigned to increase its compression threshold, and to replace the pre-TR gas cell filling with a non-radioactive fill.[11] The limiter redesign approach was to conserve the fit, form and function of the original unit, whilst optimizing the PIN diode arrangement for higher compression operation.

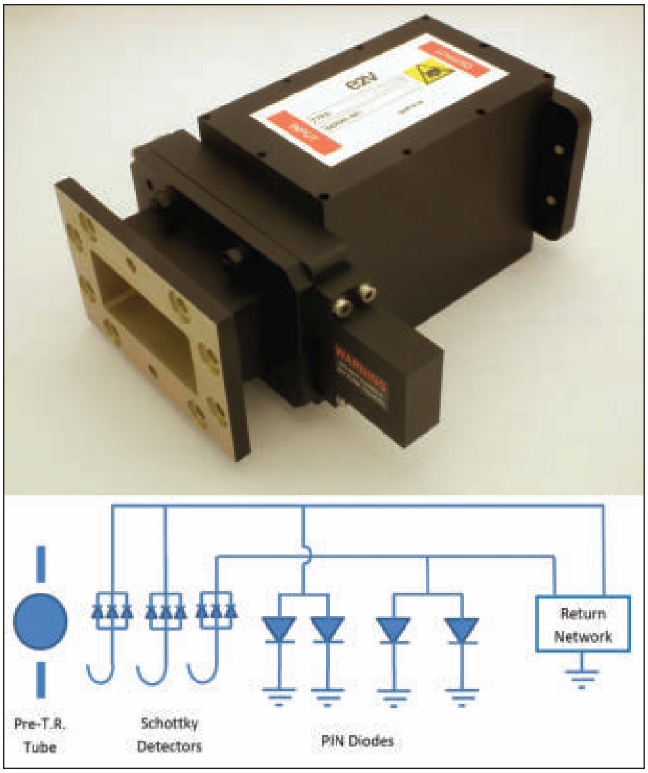
UPDATED RECEIVER PROTECTOR DESIGN

Modifications were made in the waveguide structure and PIN diode configuration of the limiter design:

- PIN diodes with a thicker I-region and reduced sensitivity that therefore require a higher level of incident RF before limiting starts
- Modification of the return DC current path, to impede the flow of the self-generated current sufficiently to raise the limiting power value
- Modification of the tuning structure to reduce the level of coupling, reducing the power present at the PIN diode for a given power level, and improving operational reliability under high-power conditions.

The present unit (in Figure 3) had a pre-TR mount located at the input to protect the limiter section diode from higher, potentially damaging levels of incident RF power (typically > few hundred watts). Routinely a non-radioactive device solution is preferred in new and upgraded radar installations.

The use of the radioactive gas (tritium, H_3) within the pre-TR tube improved the pre-TR performance by enhancing the avalanche breakdown process with the onset of a high-power RF input level, assisting the formation of a plasma discharge in the gas tube. With the tritium removed, the statistical time period to activate the pre-TR tube therefore increases, and can expose the solid-state limiter section to higher incident power levels for longer periods.



▲ *Fig. 4 General arrangement of an updated S-Band pre-TR limiter receiver protector.*

The updated limiter design therefore had a dual PIN diode stage incorporated into the input: this arrangement offered increased power handling capability (with minimal insertion loss increase) for robust limiter operation in conjunction with a non-radioactive pre-TR input stage. Increased power handling of the input diode stage was augmented with a more robust detector (a Schottky diode assembly lightly coupled into the input waveguide that outputs a DC bias current to the PIN diodes). This updated pre-TR limiter design is shown in ***Figure 4***.

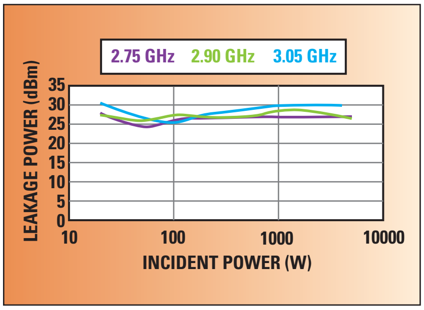
RECEIVER PROTECTOR PERFORMANCE

The specification for the updated limiter was identical to that of its legacy predecessor with the following modifications:

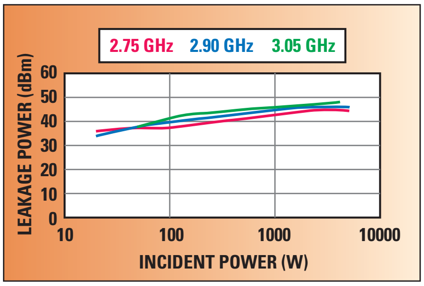
- Addition of the requirement for the limiter to function unimpeded by the presence of the close proximity of the new 4G signal bands
- Change to the flat and spike leakage power levels (1 and 6 W increased to 10 and 100 W, respectively).

The small-signal test results are very similar to the existing device, achieving an insertion loss better than 0.4 dB and return loss of 20 dB (VSWR approximately 1.25:1) over 2.75 to 3.05 GHz at 20°C. Similarly, the biased attenuation performance of the limiter was retained at > 60 dB over the operating frequency band.

Flat and spike leakage were measured up to a peak input power of 5 kW; the pulse rise-time of the test equipment was typically 20 ns, in line with typical transmitter system specification requirements. The flat leakage maximum was just over 1 W, and the curves shown in ***Figure 5*** have no indication that the flat leakage level would rise rapidly at power levels beyond a 5 kW peak incident power level. At this 5 kW incident power level, the pre-TR gas tubes had fired and the level of leakage will typically remain



▲ *Fig. 5 Flat leakage performance – updated S-Band pre-TR limiter.*



▲ *Fig. 6 Spike leakage performance – updated S-Band pre-TR limiter.*

constant for a wide range of increasing incident power levels. The spike leakage maximum measured was 48 dBm (> 60 W) and the curves shown in ***Figure 6*** indicate that the increase in the spike leakage to be leveling-off at the 5 kW incident power level. The spike leakage pulse was typically 10 ns wide at the –3 dB point: for a 48 dBm peak leakage level this equated to a maximum spike leakage energy of ~600 nJ per pulse.

The minimum power level at which the device compressed by 0.2 dB was 16.5 dBm, a 21 dB improvement over the legacy device design. Typical 4G input signal levels into a surveillance radar are dependent on a number of factors, not least being local proximity of a 4G antenna. For a close-in base station, a nominal value for 4G peak power levels incident on the receiver protector could be +13 dBm mean power, with a ~10 percent probability of peak power spikes at +10 dB above this within a 7 µs period.[12]

These spikes of peak power can be sufficient to cause cone breakdown in legacy TR Cell equipment, leading to high-attenuation states with significant recovery periods. The full effect of charge generation in the high-power diodes of the proposed high power limiter is under further investigation, specifically the 'pre-energizing' and 're-energizing' effect on the solid-state limiter PIN diode stages owing to 'pumping' from close-range 4G interference signals where this may slow the rate of RxP recovery.

The updated, non-radioactive pre-TR gas tube breakdown level demonstrated no change in the breakdown threshold with the legacy (radioactive content) pre-TR tubes. Gas tube breakdown (with the maximum RF pulse width) was between 200 and 400 W: the variation with frequency was due to the position of RF standing wave maxima in relation to the pre-TR tube mount iris. Monitoring the leakage pulse behind the receiver protector unit showed no signs of instability pulse-to-pulse: constant recovery time values and steady leakage pulse amplitudes were consistently measured with no detectable jitter. Comparison between breakdown activations with a 40 and 1 µs pulsewidth gave the expected approximate doubling of the peak power level required to initiate breakdown; nominally the breakdown power at 1 µs being twice the value at 40 µs.

FILTERING AND LIMITING AT LNA INPUT

Existing receiver filter and input protection on the LNA can be used in conjunction with the updated receiver protector. The updated RxP clearly has an elevated compression threshold, requiring the LNA input protection to work harder, and in general this may require an additional low-power limiter at the LNA input.

Previous sections describe the vulnerability (due to RF breakdown under fault conditions) of a bandpass (BP) filter to reflected RF energy. The solution presented here is the integration of a receiver protector at the input to the receiver, a key requirement of the updated receiver protector being that it must not be driven into compression by an incident 4G communications signal.

Unattenuated by the receiver protector, predicted levels of 4G signal power are expected to exceed the dynamic ranges of the receiver LNA typically used in S-Band radars.[12] It

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is therefore essential that a BP filter is integrated within the receiver protector assembly. With the threat from damaging levels of reflected RF energy now mitigated by the receiver protector, it becomes possible to design a BP filter which attenuates the 4G signal without needing to consider the contra design requirement of minimizing peaks in field strength; a less-challenging BP filter requirement specification also realizes a cost benefit for the radar system.

A PIN diode receiver protector requires a finite time to react to damaging levels of RF energy. Typically, PIN diodes designed to handle higher levels of RF power tend to be slower to switch from 'through state' to 'limiting state.' During the transition from 'through state' to 'limiting state,' a spike of RF energy will leak through a receiver protector: the energy contained in the spike may be sufficient to damage the LNA input stage. A second, fast reacting, low-power limiter to attenuate residual levels of spike leakage energy may therefore be included at the input to the LNA, as shown in Figure 2.

SYSTEM DESIGN CONSIDERATIONS

High power testing was performed over an incident peak power range up to 5 kW, covering the range of typical incident power levels the device will experience under normal operating conditions. Spike leakage was closer to the specification limit in the updated unit, however, the spike leakage energy remains comparatively low and the spike level measurement is heavily dependent on the incident RF pulse conditions.

More information on the failure mode of downstream modules and components in the radar receiver chain would be needed in order to determine if the leakage should be specified (a) as a peak power level or (b) the energy content per pulse.

An operational assessment of the updated receiver protector in an S-Band surveillance radar system will provide extremely useful information and guidance on the effects of the receiver protector to incoming 4G signals, when tested in the actual operating environment. Assessment of the updated RxP has already demonstrated no loss of performance characteristics when compared with the legacy unit.

The ultimate performance of the receiver protector/filter combination is achieved by integration of the limiter stages with the filter: this leads to providing the full level of fault protection afforded by the high level gas switch, operating at a level well above the received 4G signals, but capable of limiting incoming signals to a level compatible with a high-Q filter design.

Following this limiter-filter arrangement comes the lower-level limiter, providing low leakage levels into the LNA and (due to the preceding filter) only attenuating in the presence of in-band antenna reflections (and unaffected by the filtered-out 4G signals), described in the limiter-filter arrangement shown earlier in Figure 2. Integration of the

filter with the final low-power limiter further reduces the likelihood of any internal breakdown within the filter, since the standing wave position within the waveguide assembly is now well-defined. This alternative arrangement, together with modern LNA offerings with lower noise figures, leads to a receiver solution with a positive effect on the overall noise figure of the receive chain, enabling a measurable improvement in minimum detectable signal levels.

CONCLUSION

The small-signal performance of a legacy radar receiver protector has been reproduced in an updated high power pre-TR limiter design, to be used in conjunction with (i) an output filter and (ii) low-power limiter at the LNA input. This arrangement provides a retrofit solution into S-Band radar systems to mitigate interference effects from 4G communications signals, and avoids the need for a high-power filter at the antenna. ■

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Simplifying Signal Analysis in Modern Radar Tests

The evaluation of direct digital synthesis (DDS)-based radar systems is challenging for traditional signal analysis test techniques. This is especially true when it comes to pulse compression analysis, pulse trend analysis over time and frequency agility verification. The test tools used to simplify the testing of modern radar systems are evolving, like the systems they must test. This article focuses on the evolution of spectrum analyzers from relatively basic instruments used for measuring traditional pulsed signals to the advanced test system architectures required for signal analysis of leading-edge radars.

Sophisticated, next-generation radar systems benefit from advances in digital technology and computational power. The trend is toward the use of DDS to enable powerful wideband waveform generation capabilities and digital signal processing in radar baseband electronics in order to create software-defined radar. When used along with active electronically scanned antenna (AESA) technology, this offers the following potential radar system benefits:

- Frequency agility – the ability to operate over a wide frequency band to account for atmospheric effects, jamming, interference and detection avoidance.
- Waveform agility – the ability to operate pulse compression (PC) techniques such as frequency and phase modulation on pulse (FMOP and PMOP) to improve target resolution.
- Mode agility – the ability to change waveforms and sequences on a pulse-to-pulse basis, including turning PC on and off, changing the pulse repetition interval (PRI) and staggering PRI to avoid range ambiguities.
- Multifunctionality – the ability to operate as a radar, a communications system (radio) and an electronic warfare (EW) asset.
- Rapid technology insertion – the ability to change the function and performance of the radar through software.

The same DDS technology is also appearing in the EW assets used to deceptively jam these radar systems. In addition to evaluating radar performance in a benign environment, the anticipation of DDS-generated radar countermeasures warrants enhanced receiver testing to assess radar system vulnerabilities.

Spectrum analyzers have long been used for analyzing radar signals. To perform even

Darren McCarthy
Rohde & Schwarz Inc., Beaverton, OR

basic pulse measurements, however, users must have a thorough knowledge and understanding of the signal parameters and the operation of the spectrum analyzer in order to obtain valid results. With advancements in DDS technology, the pulse characteristics and pulse sequences produced by radar waveform generators and radar test signals are becoming more complex. For the measurement of these waveforms, conventional swept-tuned spectrum analyzers may not be adequate.

BASIC PULSE MEASUREMENTS

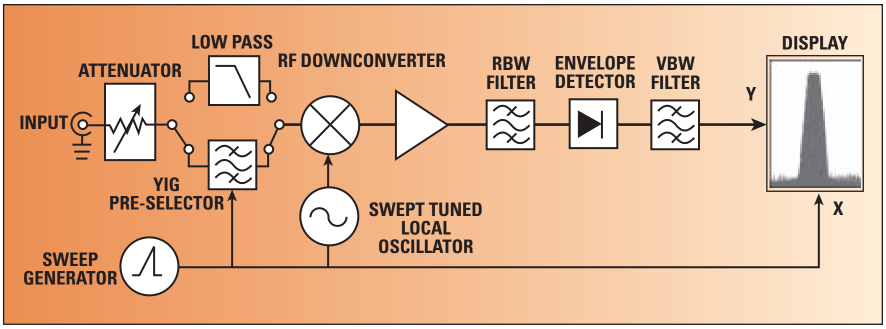
The main advantage of a traditional spectrum analyzer is that it can be used to test frequency-dependent power components over a wide dynamic range. Simple measurements, such as checking the symmetry of the pulse spectrum, are useful in verifying radar transmitter operation. An asymmetrical spectrum, for example, can waste power, generate unwanted spurious emissions and degrade overall radar system performance.

When making measurements using a spectrum analyzer, especially on signals with low duty cycles, one must be familiar with the waveform parameters. The proper resolution bandwidth (RBW), span and sweep time must be set to correctly measure the signal under test in order to yield informative results.

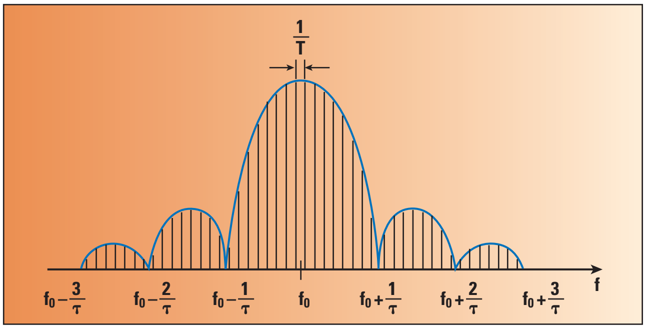
Figure 1 shows the swept-tuned architecture of a traditional spectrum analyzer. A signal is filtered and downconverted to an IF frequency by applying various resolution bandwidth (RBW) and video bandwidth (VBW) filters to the signal while the local oscillator is swept across a frequency span. Energy versus frequency is plotted on the display.

Since a pulsed signal is not on at all times, its energy will not completely 'fill' the spectrum on a single sweep. ***Figure 2*** shows the spectral characteristics of a simple pulsed RF radar waveform with a pulse width τ and the pulse repetition interval T; the amplitudes of the spectral lines are determined by the envelope about the center frequency, f_0.

When measuring the frequency spectrum using a spectrum analyzer, it is possible to display the individual spectral lines or the envelope of the pulse spectrum, depending on the instrument settings. To display the spectral lines, the RBW should be set to a value significantly less than the pulse repetition frequency (1/T). The line spacing is equal to the inverse of the pulse period (pulse repetition interval) and is independent of the setting for the sweep time on the analyzer. The amplitude of the spectral lines is also independent of the RBW.



▲ *Fig. 1 Traditional swept-tuned spectrum analyzer architecture.*



▲ *Fig. 2 Typical display of a pulse signal showing pulse width τ and pulse interval T.*

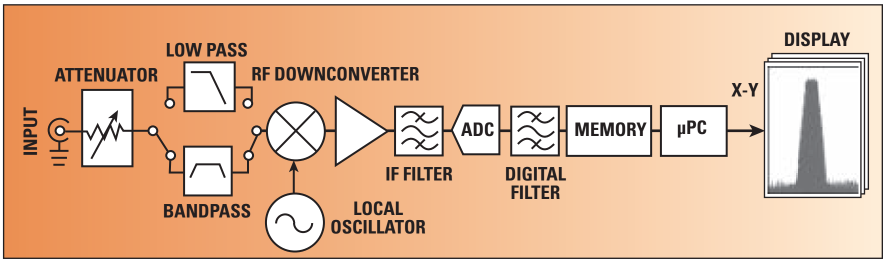
While this technique can help characterize a relatively stable, and repetitive pulse signal that does not contain other forms of complex modulation, there are additional challenges for the assessment of DDS-based radar systems that employ more complex and dynamic modes such as frequency agility, variable PRI, pulse compression (modulation inside the pulse), and dynamically variable pulse trains.

In addition, a swept-tuned analyzer typically provides a zero span function or a video output such that an oscilloscope can capture the time-domain signals. The bandwidth of the time-domain signal is constrained, however, by the maximum RBW of the spectrum analyzer. This could be a limitation if the frequency content of the pulse waveform being analyzed exceeds the RBW.

SPECTRUM ANALYZER ARCHITECTURES FOR TESTING RADARS

Analysis of modern radar signals requires a spectrum analyzer architecture that exceeds the limited capabilities the traditional swept-tuned spectrum analyzer. State-of-the-art spectrum analyzers now incorporate fast Fourier transform (FFT) acquisition and vector signal analysis operating modes. This class of spectrum analyzer is also called a signal analyzer. When signal analyzers incorporate run-time sequential processing of FFTs for functions such as persistency display and triggering, they are also known as real-time spectrum analyzers.

A real-time spectrum analyzer includes a dedicated processing function between the analog-to-digital converter (ADC) and the memory to provide sequential processing of incoming sampled data. One of the benefits of sequential processing and real-



▲ *Fig. 3 Vector signal analyzer architecture.*

time display technology is the ability to see very fast events with 100 percent probability of intercept (POI). A figure of merit for a real-time spectrum analyzer is the minimum event duration for 100 percent POI. As the radar pulse compression technique tends to reduce pulse widths below 4 μs, high-performance real-time technology can improve test confidence.

As shown in ***Figure 3***, a vector signal analyzer has a front end similar to that of a traditional swept-tuned spectrum analyzer with filtering and downconversion. Once the signal is downconverted to an intermediate frequency (IF), however, the entire spectrum is digitized by an ADC and placed into memory. The time-sampled data can then be converted through FFT and waveform processing, where the spectrum, time and phase information is extracted and stored for analysis.

Unlike the swept-tuned analyzer, the bandwidth of a vector signal analyzer is not limited by resolution bandwidth, but by its IF bandwidth defined by the ADC, the sampling rate and associated IF filtering. Typical vector signal analyzers have bandwidths ranging from tens to hundreds of MHz. Acquisitions are seamlessly captured into memory, and subsequent FFT processing and analysis can be performed on the acquired signals. The wider IF bandwidth enables analysis of much faster rise/fall times (and narrower pulse widths), wider bandwidth signals (e.g. chirps), and the analysis of frequency-agile radar waveforms across a much wider band.

Figure 4 shows the spectrum of a frequency hopping sequence over a 160 MHz span. There are two displays shown for comparison. The lower display (Frequency Sweep) is what is measured using a traditional swept-tuned spectrum analyzer, with the trace set at Max Hold while the parameters of the sweep are set to 50 kHz RBW and 6.4 ms sweep time. The five hopping frequencies are displayed and there appears to be some level of spurious emission across the band of interest. The upper display (Persistence Spectrum) in Figure 4 is what can be seen using the features of a vector signal analyzer. It shows a color gradient scale based on the accumulated occurrence of the pulse signals. Since the real-time display is based on vector analysis techniques, the entire sequence of the pulse events is captured instantaneously. Observing the difference between the two acquisition techniques, there appears to be a distinctly different spectral shape appearing infrequently in this operating mode on the lowest of the five hopping frequencies.

Because the spectrum of this event is different from that of the other pulses, a frequency mask trigger (FMT) function can be used to isolate the signal (see ***Figure 5***). Once isolated, a spectrogram display shows that this event appears to be faster than the other frequency hops. Shown in the bottom of the spectrogram display in Figure 5 the adjacent event also appears to be ON for a longer period of time than the triggered spectrum event.

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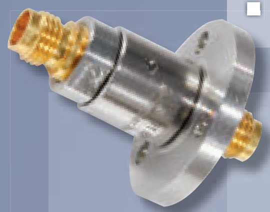

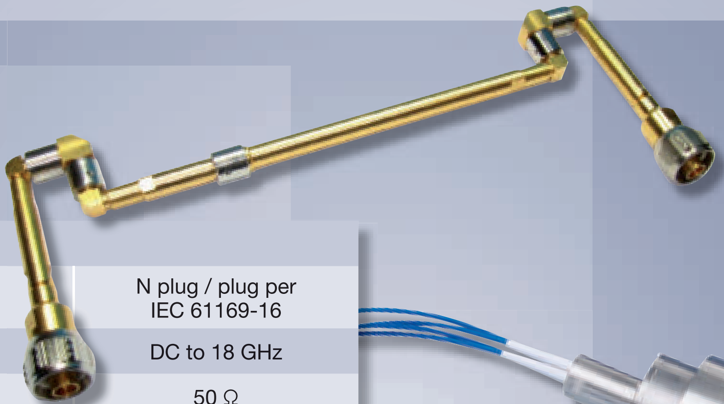

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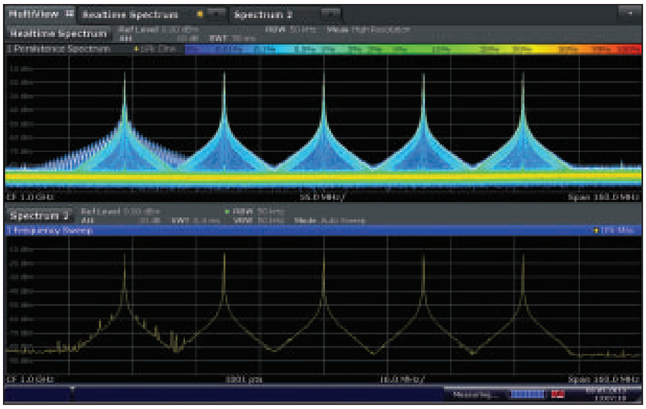

Fig. 4 *The Real-time Spectrum display (top) shows a different spectrum on the lower frequency event, while on the Frequency Sweep display with Max Hold (bottom) it is not as visible.*

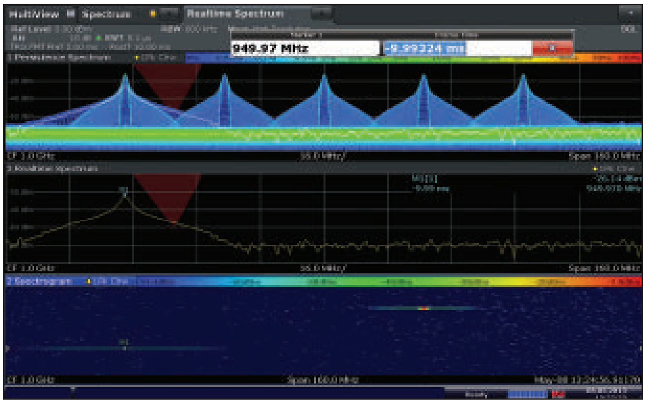

Fig. 5 *Triggering on the spectrum enables event isolation and spectrum vs. time viewing in the spectrogram.*

Fig. 6 *The unique pulse signal can be isolated and analyzed completely using the R&S FSW-K6 pulse measurements option.*

ory, state-of-the-art vector signal analyzers can now provide pulse measurement options to completely analyze the pulses and pulse trend sequences of modern DDS radar signals. For example, the R&S FSW signal and spectrum analyzer with the R&S FSW-K6 pulse measurements software option can be used to analyze over 100,000 pulses with time-correlated views of the spectrum, timing, modulation and statistical properties of the signal. These are useful functions not readily available on traditional swept-tuned spectrum analyzers.

Furthermore, based on the performance of the analyzer and independent time synchronization, important

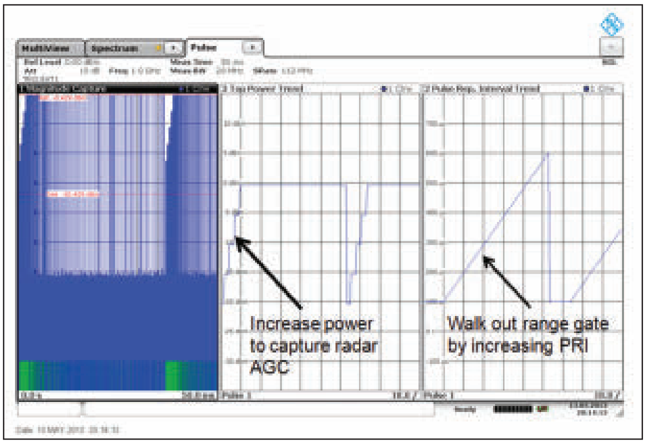

Fig. 7 *RGPO test signal including power trend and PRI trend.*

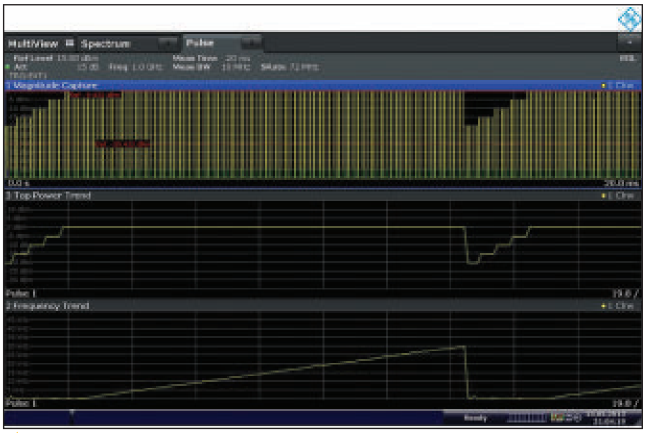

Fig. 8 *VGPO test signal including power trend and frequency trend.*

pulse-to-pulse parameters can be measured. The accuracy of the analysis depends on several of the signal and performance features of the spectrum analyzer: the signal-to-noise ratio of the signal, the signal bandwidth and measurement filters applied, the reference clock jitter, and the phase noise accumulated during the measurement pulse period.

An example of automatic pulse measurement analysis is shown in ***Figure 6***. For this analysis, the pulse width trend, the results table and the pulse information are displayed for several hundred pulses captured over a 250 ms period. The ratio of the signal is 128:1, meaning there are 128 events with a 20 μs pulse width to a single event with a 1.0 μs pulse width as shown in the upper right pulse width trend display. The selected pulse from the results table (the upper right display in Figure 6), selects the pulse waveform of interest to be displayed for the two trace display windows at the bottom of the figure (Pulse Phase and Pulse Frequency). It can now be seen that the demodulated pulse waveform has changed from a pulsed continuous wave signal to a polyphase pulse compressed Barker 13 waveform for the 1 μs pulse period. This dramatically changes the radar's resolution on a repetitive basis, but only for a very short period of time. By utilizing a combination of real-time technology to isolate the signal of interest and pulse measurement analysis of a single pulse, a complex pulse signal is easily characterized.


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VALIDATING ELECTRONIC PROTECTION (EP) WAVEFORMS

Traditionally, radars that needed EP required a substantial amount of testing to evaluate their effectiveness against likely deceptive jamming techniques. As new threats evolve, the test profiles for DDS radars must also evolve. It is also important to validate the test signals used to evaluate radar receiver vulnerabilities. Range gate pull-off (RGPO) is a classic deceptive jamming technique where a jammer tries to confuse the radar's range tracking system. As shown in ***Figure 7***, during RGPO the power of a jammer will increase in an attempt to capture the automatic gain control (AGC) of the target radar. Once captured, the jammer will then attempt to push or pull the range gate in time by varying the PRI, forcing the radar to break track with the target.

Pulse compression techniques can be used to reduce the effectiveness of RGPO, since the radar can sense the type of signal being processed in the receiver as a foreign (bogus) return and respond either by ignoring the jammer temporarily or by switching modes and/or frequencies.

One of the more advanced DDS jammer techniques, and potentially much more troublesome for the radar, is digital RF memory (DRFM). DRFM directly captures, modifies and retransmits a response that is much more difficult to detect as a foreign return. DRFM typically modifies the delay or Doppler of the return to attempt to deceive the velocity gate of the target radar system.

Figure 8 shows an example of the velocity gate pull-off (VGPO) deceptive jamming technique, which is similar to the range gate technique. VGPO employs a similar increase in power to capture the radar AGC, and then gradually shifts the frequency of the return such that the velocity tracker system breaks with the target.

As DDS-based radars encounter new EW capabilities and tactics, radar receiver testing will continue to evolve in order to keep pace. Many of these threats are based on a thorough understanding of the radar signals in order to provide realistic target speeds (Doppler walk), for example, to deceive the radar processor. Having the tools to perform trending and timing analysis of various parameters can provide confidence in the test process.

CONCLUSION

Modern radars have evolved and capitalized on the improvements in DSP processing and wideband digital converters. This evolution has dramatically improved the functionality and utility of DDS radars. At the same time, the test methods and tools have had to evolve in order to keep up with the requirements for testing these radars. State-of-the-art spectrum analyzers based on vector signal analysis architectures can provide the building blocks for simplifying the testing of DDS radars. By combining real-time functions and automatic pulse software, the sophisticated new spectrum analyzers are up to the task of simplifying testing and analysis. ■


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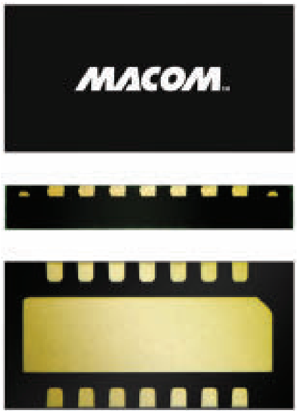

High Power GaN in Plastic Transistors

Radar and communications designers are continuously challenged to strike the optimal balance of size, weight and power profiles for their unique radar system designs, from military applications spanning ground/air surveillance and target tracking, to civilian radar systems including air traffic control and weather observation. The ever exacting performance, reliability and ruggedization requirements associated with this new generation of mobile radar systems are straining the limits of conventional Si- and GaAs-based power transistor components. The challenge facing radar system designers – accommodating higher power with smaller components – is accelerating the pace of innovation in power transistor packaging technology. But with each incremental gain in component power density, the resulting thermal management issues grow increasingly problematic.

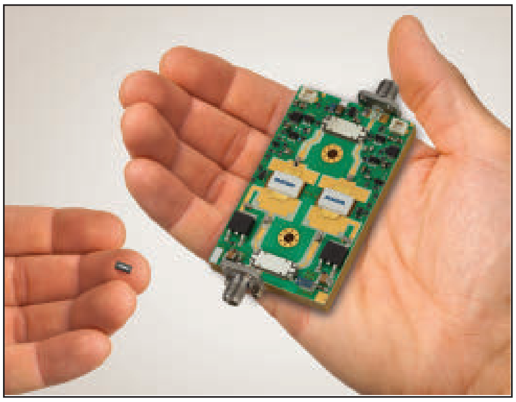

Fig. 1 Size comparison of plastic vs. ceramic packaging.

Indentifying these system requirements early, M/A-COM Technology Solutions Inc. (MACOM), introduced its GaN in plastic packaged power transistors for high-performance civilian and military radar and communications systems. The first entries in MACOM's GaN in plastic power transistor product portfolio include 90 W (MAGX-000035-0900P), 50 W (MAGX-000035-05000P) and 15 W (MAGX-000035-01500P) transistors, all of which are available in standard 3 × 6 mm dual-flat no leads (DFN) packaging. The devices can be mounted on PCBs via ground/thermal arrays. Internal stress buffers allow the devices to be reliably operated at up to 200°C channel temperature. The GaN in plastic series also includes a 5 W device in an even smaller SOT-89 package, measuring 2.5 × 4.5 mm. All of these transistors are capable of operating at frequencies up to at least 3.5 GHz. ***Table 1*** shows a

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TABLE I

TYPICAL PERFORMANCE FOR MACOM'S GaN IN PLASTIC TRANSISTORS

Parameters	Units	MAGX-000035-0900P	MAGX-000035-05000P	MAGX-000035-01500P	MAGX-000040-00500P
Frequency	GHz	DC-3.5	DC-3.5	DC-3.5	DC-4.0
Pout	W	95	50	17	5.3
PAE @ 1 GHz	%	65	65	68	65
Duty	%	10	10	10	10
Gain	dB	17.5	18	19.5	14
Size	mm	3 × 6	3 × 6	3 × 6	SOT-89

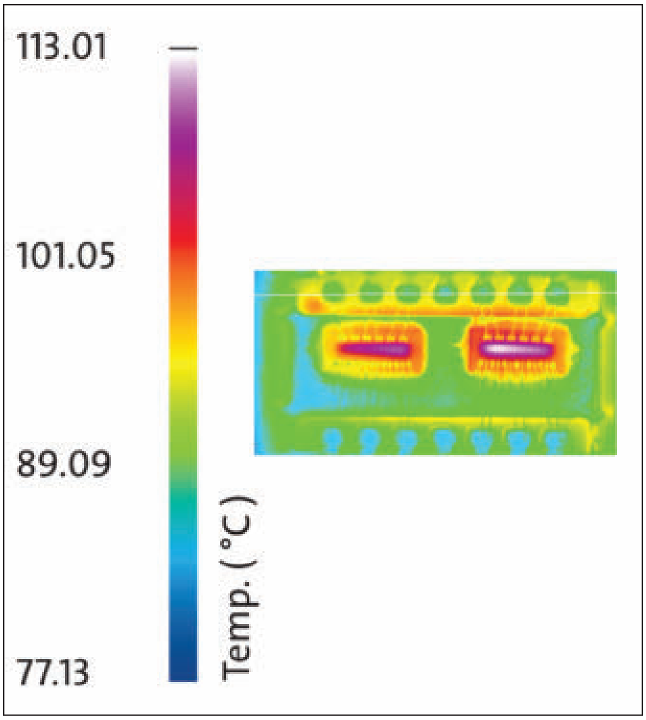


Fig. 2 93 W output power shows 113°C junction temperature.

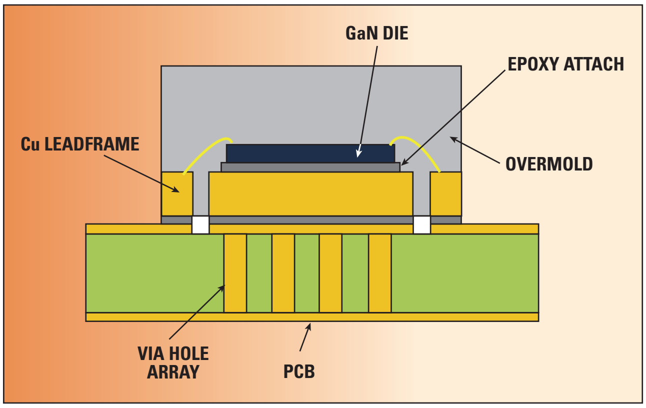


Fig. 3 MACOM's plastic packaging construction.

summary of the GaN in plastic devices and key performance data.

Scaling to peak pulse power levels of 100 W, MACOM's GaN in plastic transistors exceed the power, size and weight limitations of competing ceramic-packaged offerings to enable a new generation of high performance, ultra compact military and civilian radar systems (see ***Figure 1***). As a result, customers can use these products to provide new capabilities and take advantage of the total system cost reductions associated with size, weight and cooling requirements. MACOM's GaN in plastic builds on the company's 60+ years of packaging innovation, and rich heritage of expert engineer-to-engineer customer support, ensuring that radar system designers are best equipped to harness the highest power in the smallest possible size.

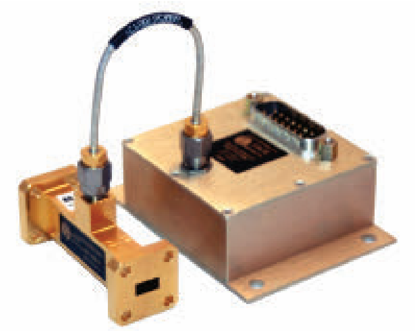
Packaged in miniature 3 × 6 mm DFN and standard small outline transistor (SOT-89) packages, MACOM's GaN in plastic transistors operate at 50 V drain bias resulting in outstanding power density and performance, higher efficiency, and smaller impedance matching circuits due to improved device parasitics. The high voltage operation also benefits overall system design with smaller energy storage capacitors and lower current draw.

To achieve this new standard, MACOM leverages over six decades of radar design experience to pioneer sophisticated, proprietary thermal dissipation techniques to ensure that its GaN in plastic power amplifiers offer comparable reliability to conventional ceramic-packaged GaN-based offerings. MACOM's approach optimizes the transistor die layout and uses advanced heat sinking and die attachment methods. Utilizing some of the most stringent thermal imaging testing methodologies in the industry, the 90 W transistor demonstrates less than 115°C junction temperature (80°C baseplate) for a pulsed power output of 93 W, using a 100 µS pulse, 10 percent duty cycle on standard Rogers board material (see ***Figure 2***).

MACOM's GaN in plastic-based power transistors are also lightweight compared to the existing ceramic-packaged GaN-based offerings. Measured in aggregate across the hundreds of power amplifiers within a typical modern radar system, this can reduce overall system weight considerably. The resulting weight reduction ensures greater ease of movement for mobile radar systems.

MACOM's high performing GaN in space saving plastic enables radar system designers to take full advantage of GaN technology and achieve new levels of power density while reducing system size and weight significantly. Utilizing sophisticated packaging (see ***Figure 3***) and thermal management techniques to maximize design efficiency and component reliability, MACOM is working hand-in-hand with designers to overcome challenging development hurdles and pioneer a new generation of high-performance, rugged radar systems that transcend the capabilities of systems based on conventional GaN in ceramic packages. GaN in plastic test fixtures are available and datasheet are available online.

MACOM,
Chelmsford, MA,
www.macomtech.com/gan.



Ka-Band Digital Attenuator

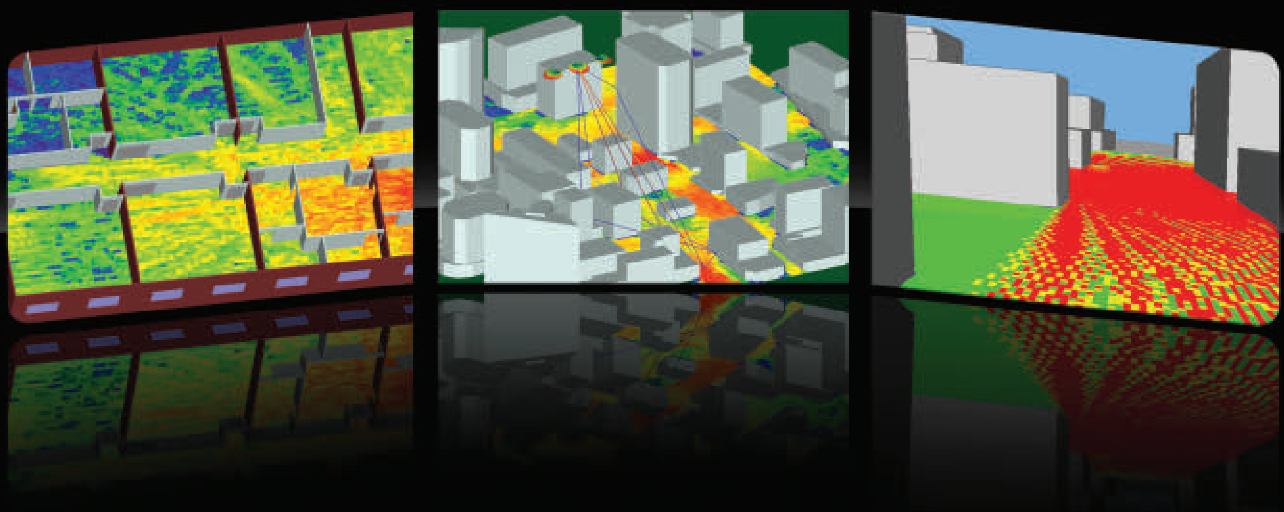
Digitally controlled attenuators are the key components in communication, radar, instrumentation and automatic test systems. Broad bandwidth, high dynamic attenuation range, low insertion loss, high control resolution and fast control speed are key considerations in nearly all applications. SAGE Millimeter has introduced a new line of digitally controlled attenuators offering the best of these parameters in Ka- through W-Band waveguide bands. These attenuators are configured with an analog PIN diode attenuator and a programmable digital driver that provide up to 8 bits of input control.

Fig. 1 *Programming board for programming attenuator driver.*

Over the entire Ka-Band frequency range from 26.5 to 40 GHz, the SAGE Millimeter model SKA-2734033040-2828-D1 digitally controlled attenuator offers 3.0 dB insertion loss and 40 dB dynamic range. The attenuation flatness is ±2.0 dB across the band with a CW power handling capability of +23 dBm. The attenuation level is controlled by a digitizing driver which features TTL control with up to 8 bits of resolution. The bias voltage required is ±10 VDC/90 mA. The RF interfaces of the attenuator are with standard WR-28 waveguide with UG599/U flanges. Without the digital driver, the attenuator can be used as an analog attenuator with control voltage from 0 to 5 V DC and current up to 25 mA.

The digital attenuator driver is fully programmable and can be configured to operate with 1 to 8 bits of digital input data for the standard version, and up to 12 bits for custom versions. This allows the driver to be easily configured for different attenuation ranges and resolutions. Switching speed for the driver is under 80 nsec from the digital input to the analog voltage output from the driver. Overall digital-to-RF switching time is dependent upon the specific bias circuit design within the attenuator, but overall switching times under 100 nsec are achievable. The programmable digital driver consists of a digital input buffer that drives a static, non-volatile memory with 12 bit output that drives a high-speed DAC. Internally, the digital input word is sampled every 10 nsec to provide very fast update rates for the driver. A differential current-to-voltage converter transforms the DAC output and provides a single-ended drive to the PIN attenuator. A current-limiting resistor within the

SAGE Millimeter Inc.
Torrance, CA



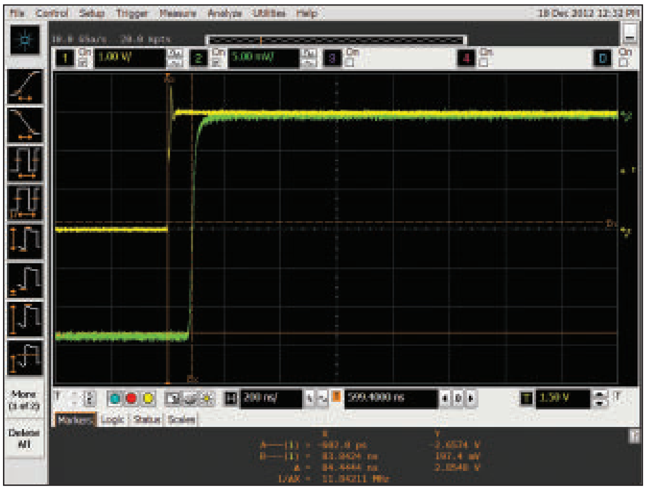


Fig. 2 Attenuator switching time to 30 dB attenuation.

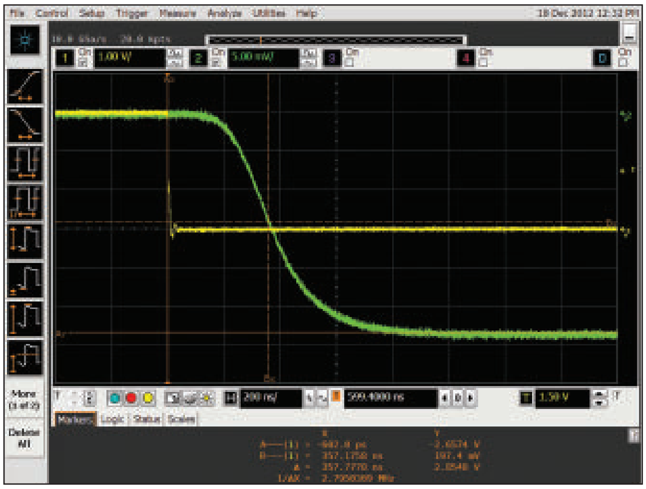


Fig. 3 Attenuator switching time to low insertion loss state.

attenuator limits the overall current to the PIN diodes, but the 80 mA output capability of the driver will easily handle wide dynamic range attenuator designs with multiple PIN diodes.

Figure 1 shows the custom developed model SKA-WC-E01-P programming board for programming the attenuator driver. The programming board is a standalone product designed for connecting directly to a programming header inside the driver enclosure, along with a ribbon cable to the driver sub-D connector. Programing the attenuator is a simple procedure that involves measuring the insertion loss of the attenuator on a network analyzer or power meter while dialing the setting knobs for a specific data address and output voltage. The programmer can set the 8 bit digital input word to the driver and then allow the attenuator drive voltage to be set to any desired value with 12 bit resolution. Values are saved in the non-volatile driver memory by simply pressing a STORE button on the programmer. Once the programming is completed, the programmer is removed and the attenuator is ready for remote control or system use.

The featured digitally controlled attenuator was designed to provide over 40 dB of dynamic range with 1 dB attenuation resolution. Only a 6 bit digital input word was required for this resolution; however, due to the 12 bit DAC resolution within the driver, the accuracy of the attenuation could be set to within 0.25 dB of any desired attenuation value. The attenuator exhibits ±0.25 dB attenuation accuracy and a switching time from the low insertion loss state to 30 dB attenuation in 84 nsec, as shown in ***Figure 2***. Conversely, the switching time from 30 dB attenuation to the low insertion loss state was 357 nsec, as shown is ***Figure 3***.

While the featured Ka-Band digitally controlled attenuator is packaged with a separate driver enclosure, an integrated version is available as a custom design. The attenuators are available in frequency bands from Ka- to W-Band under various model numbers.

VENDORVIEW

SAGE Millimeter Inc.,
Torrance, CA
(424) 757-0168,
info@sagemillimeter.com,
www.sagemillimeter.com.

RF Simulators for Next Gen Phased Array Radar

The next generation of phased array radar systems currently being developed by military research laboratories and major defense contractors is expected to eliminate shortcomings in older systems for faster target detection, higher detection sensitivity and clutter mitigation. As a result, this research and development is concurrently driving demand for commercial testing and quality assurance products designed to simulate RF signals as they would appear in the field at varying distances and in more crowded urban environments.

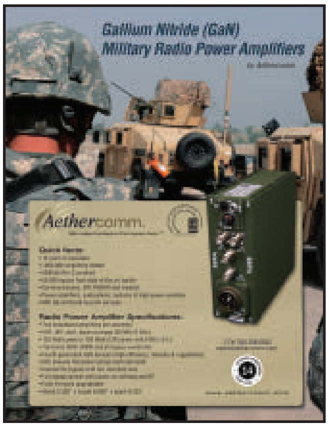
With more sophisticated receivers comes the need to test them during the research and development phase. Although custom one-off testing units are a possibility, the market is beginning to respond with commercial testing devices that simulate an RF signal as it travels and bounces off objects. Renaissance Electronics Corp., a manufacturer of RF and microwave subsystems and components, is now offering a 6 × 6 (REC part number 18A6NAD) and 12 × 12 (REC part number 18A6NAC) matrix with programmable delay lines (PDL) and attenuators designed to simulate RF signals for next generation systems.

The units synthesize both amplitude and phase to replicate a variety of phase array RF signals at different distances. Each of the available inputs can be programmed to synthesize a 30 to 2500 MHz RF signal that is electronically attenuated up to 91 dB in 1 dB steps and to simulate signal propagation and absorption loss, along with delays up to 5 ns to simulate the natural effects of distance. Armed with such RF signal simulators, military research laboratories and defense contractors will be able to move past the "proof of concept" phase and verify the sensitivity and accuracy of the next generation of receivers.

VENDORVIEW

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

LITERATURE SHOWCASE



GaN Military Radio PAs Flyer

Aethercomm designs and manufactures sophisticated RF and microwave hardware for the military and commercial electronics marketplace. Aethercomm hardware falls into five product categories: systems, subsystems, RF modules, medical and high power switches. Aethercomm is housed in a new 50,000 square foot facility and are also AS9100 Rev C certified. The company's manufacturing and test capabilities is top in the industry. Aethercomm manufactures typically 30,000 RF products per year with outstanding results.

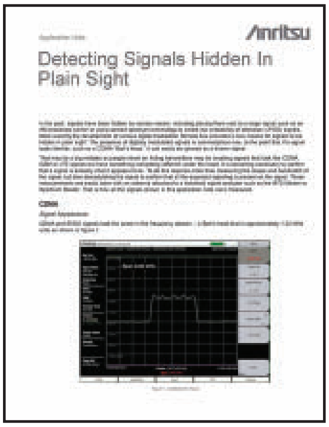
Aethercomm,
www.aethercomm.com.

EW Measurement Application Notes

VENDORVIEW

Agilent's new radar and EW measurement application notes help you keep pace with the latest technology. Get an overview of both the transmitter and receiver sides of the radar block diagram with "Agilent Radar Measurements" and "Agilent Radar, EW & ELINT Testing: Identifying Common Test Challenges." Learn how to build flexible test environments inexpensively in "Creating Realistic Multi-Emitter Signal Scenarios." Order the "Radar Fundamentals" poster for great reference information and the latest products from Agilent.

Agilent Technologies Inc.,
www.agilent.com.

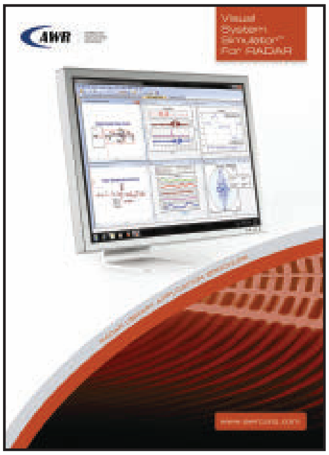


Signals Application Note

VENDORVIEW

In the past, signals have been hidden by various means. Recently signals have been hidden by making them look like an CDMA, GSM, or LTE signal, while they could be something completely different. It is becoming necessary to confirm that a signal is actually what it appears to be. This application note will discuss and provide examples of the importance of not only measuring the shape and bandwidth, but demodulating to confirm the signal type.

Anritsu,
www.anritsu.com.

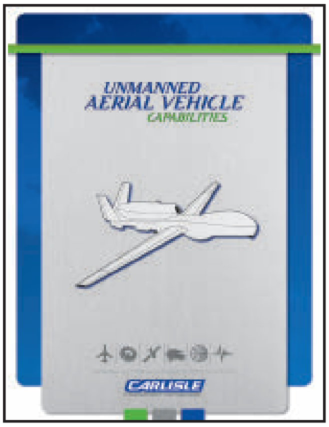


VSS for Radar

VENDORVIEW

The new AWR Visual System Simulator Advanced Radar System Design Brochure details the capabilities of the software for behavioral modeling of radar RF and signal processing systems and 3D antenna patterns derived from synthesis or measurement. VSS Radar offers a wide variety of waveform options, as well as RF modeling, antenna and phased array models, DSP modeling, third-party connected verification solutions and a complete radar design library. Read more about VSS Radar online and download the brochure at www.awrcorp.com/VSS.

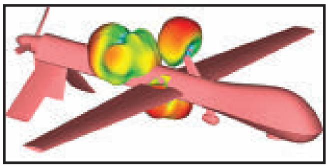
AWR Corp.,
www.awrcorp.com.



Unmanned Aerial Vehicle Capabilities Brochure

When performance matters, Carlisle Interconnect Technologies (CarlisleIT) is a global leader in interconnect solutions for unmanned aerial vehicle (UAV) and unmanned combat air vehicle (UCAV) systems featuring aerospace grade wire; high-speed digital cable, fiber optic cable; high density interconnect solutions; integrated racks and structures; lightweight trays; antenna doublers; RF/microwave cables and connectors; contacts and a complete offering of custom interconnect solutions perfect for limited space and harsh environments to ensure mission success.

Carlisle Interconnect Technologies,
www.carlisleit.com.



EMIT Brochure

VENDORVIEW

Aircraft, ships, land vehicles and satellites have demanding and complex electromagnetic (EM) environments. EMIT, a product of Delcross Technologies distributed worldwide by CST, is a simulation tool that provides rapid identification and root-cause analysis of EMI issues in complex environments. This brochure details the advantages of cosite interference simulation and outlines the features, analysis methods and results views available in EMIT, showcasing how specific causes of interference can be identified. Download the brochure at: www.cst.com/EMIT.

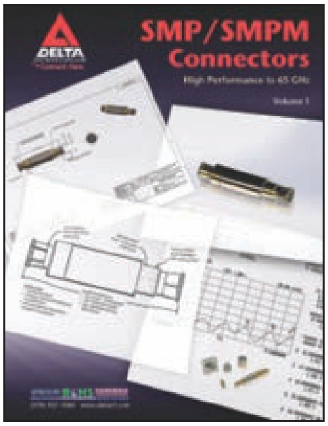
CST-Computer Simulation Technology AG,
www.cst.com.

LITERATURE SHOWCASE

Power Amplifiers Catalog

CTT announces a new four-page power amplifiers short form catalog that was introduced at IMS 2013 is Seattle, WA. The catalog features more than 75 models developed for radar, EW and multi-function systems design. The amplifiers feature Narrowband CW, Narrowband Pulsed, Wideband (CW) and Ultra-Wideband (CW) coverage. Frequency coverage is from 0.1 to 18 GHz. CTT's family of solid-state amplifiers are finding applications in many of the next generation of high-performance communications, instrumentation and medical systems where high power is required.

CTT Inc.,
www.cttinc.com.



SMP/SMPM Catalog

Delta Electronics Manufacturing Corp.'s new 24 page SMP/SMPM series catalog details 167 part numbers that span 37 different connector configurations in these two series that operate from: SMP: DC to 40 GHz/SMPM: DC to 65 GHz. These connector interfaces are developed for applications in phased array radar systems, airborne radar, ground radar, shipboard radar and active antennas. The SMP/SMPM series address the High Density Modular packaging requirements of the aerospace, defense, telecom and instrumentation markets.

Delta Electronics Manufacturing Corp.,
www.deltarf.com.

Filter Catalog

This new short form catalog features a sampling of the company's RF and microwave filter products to 40 GHz utilized in military, commercial and wireless applications. The catalog also highlights some of the company's diverse filter design and manufacturing capabilities.

Eastern Wireless TeleComm Inc.,
www.ewtfilters.com.

Cable Assemblies Catalog

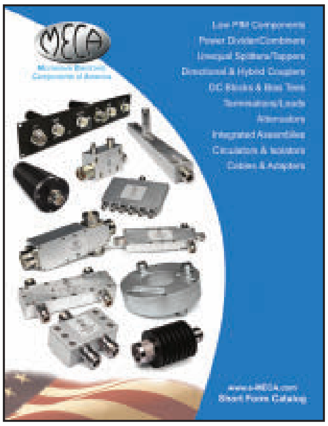
Emerson Network Power Connectivity Solutions has a wide range of cable assemblies suited for RF and microwave signal transmission. Emerson Connectivity Solutions is a vertically integrated supplier of custom, fixed length and semi rigid cable assemblies from DC to 50 GHz. The company can create custom cable assemblies to satisfy your specific application requirements, also with manufacturing in the United States, United Kingdom and China; it has a cable assembly to meet any price requirement.

Emerson Network Power Connectivity Solutions,
www.emersonnetworkpower.com.

RF Portfolio

This 36-page brochure by HUBER+SUHNER offers a clear-cut overview of the company's versatile range of RF cable and connector families. The brochure supplements its comprehensive catalogues, *RF Cables* and *RF Connectors*, which are continuously updated as online versions. The brochures *RF Portfolio*, *RF Connectors* and *RF Cables*, along with another hundred brochures, can be downloaded as e-papers or PDFs from the download section of the website.

HUBER+SUHNER AG,
www.hubersuhner.com.



Components Catalog

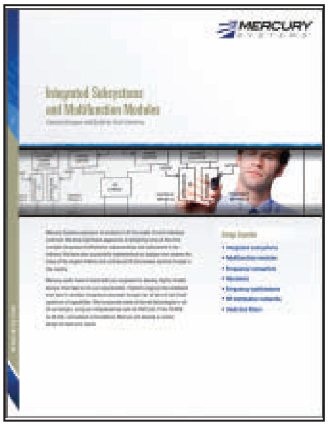
VENDORVIEW

Celebrating its 52nd anniversary, MECA (Microwave Electronic Components of America) designs and manufactures an array of RF/microwave components with industry leading performance, most recently low PIM products. MECA is recognized worldwide as a primary source of supply for rugged and reliable components to commercial and military OEMs, service providers and installers by only providing products made in the USA. Download the company's components catalog at www.e-meca.com/pdfs/MECA_Short_Catalog2013.pdf.

MECA Electronics Inc.,
www.e-MECA.com.

MILITARY MICROWAVES

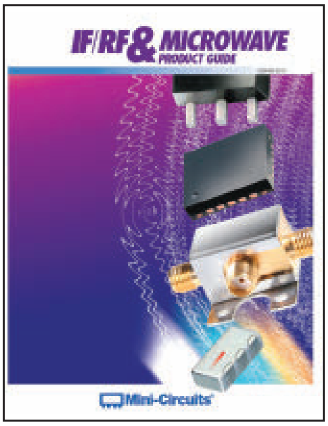
LITERATURE SHOWCASE



Integrated Subsystems Flyer

Mercury offers a broad spectrum of design, manufacturing and testing services for complex integrated multifunction assemblies and subsystems. Working hand-in-hand with your engineers, the company helps develop highly reliable designs from 10 MHz to 40 GHz for narrowband or broadband. Manufacturing capabilities include vacuum lamination of substrates, surface mount solder assembly, chip and wire assembly, and hermetic sealing. Test capabilities include static and dynamic phase noise measurements and detailed automated test routines to ensure compliance to all of your requirements.

Mercury Systems,
mrcy.com/engineering.



IF/RF & Microwave Product Guide

VENDORVIEW

Mini-Circuits' 24-page IF/RF & Microwave Product Guide provides details on 18 hot new products plus established and custom offerings. Innovative new products include the 10 MHz to 6 GHz CMA high-IP3 MMIC amps, 100 W SYBD 400 MHz to 6 GHz bi-directional couplers with directivity up to 35 dB, and 15 more exciting new products including cables, switches, limiters, transformers and mixers. The guide also features custom products that meet unique application requirements. Custom designs range from 300 W rack-mount base station combiners to three-way active GPS splitters.

Mini-Circuits,
www.minicircuits.com.

RF and Microwave Filters and Assemblies

NIC celebrates 27 years of uninterrupted service to the military and space markets. This catalog features NIC's design and manufacturing capabilities from DC to 40 GHz and showcases a broad range of filter technologies including: LC, crystal, ceramic, cavity, delay equalized and phase matched filters, as well as NIC's integrated assemblies such as: switch filter banks, filter/amplifiers, and phase shifters. NIC is ISO 9001:2008 certified and AS-9100C certified for aerospace applications.

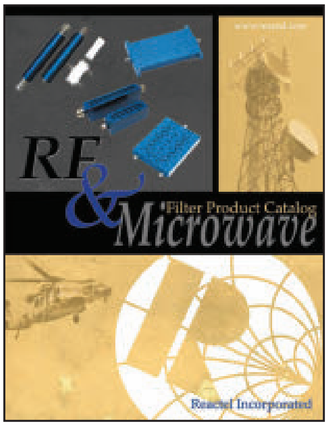
Networks International Corp.,
www.nickc.com.

Overview and Capabilities Brochure

VENDORVIEW

Planar Monolithics Industries (PMI) has released its latest product Overview and Capabilities Brochure. The brochure contains a listing of various RF components and RF module product types up to 40 GHz, including amplifiers, attenuators, phase shifters, detectors, DLVA/SDLVAs, filters, limiters, switches and switch matrices.

Planar Monolithics Industries,
www.pmi-rf.com.

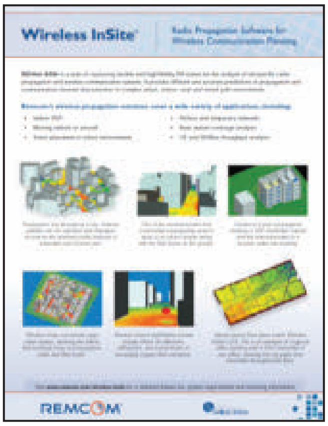


Filters, Multiplexers and Multi-function Assemblies

VENDORVIEW

When being first to react makes all the difference in the world, choose Reactel for your mission-critical filter requirements. This catalog features RF and microwave filters, multiplexers and multi-function assemblies for the military, industrial and commercial industries. To request your copy, please email reactel@reactel.com, or visit www.reactel.com.

Reactel Inc.,
www.reactel.com.



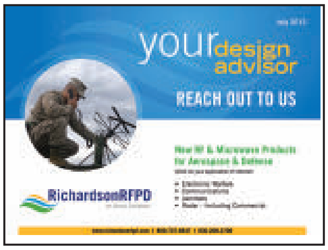
Radio Propagation Software Flyer

VENDORVIEW

Wireless InSite is a suite of ray-tracing models and high-fidelity EM solvers for the analysis of site-specific radio propagation and wireless communication systems. This new wireless propagation application flyer gives a brief tour of some of Wireless InSite's key features and provides a comparison of the models that are included in the standard, real time and professional versions.

Remcom,
www.remcom.com.

LITERATURE SHOWCASE



A&D Selector Guide

VENDORVIEW

Richardson RFPD's July 2013 A&D Selector Guide includes the latest RF and microwave products for electronic warfare, communications, jammers and radar (including commercial) applications. Featuring more than 70 new products from the world's leading suppliers, the Selector Guide is organized by application and frequency bands. It is updated monthly and features links for data sheets and online shopping. You can find it on the Richardson RFPD website, in the new and improved Design Resource Center. Download it at: www.richardson-rfpd.com/AD-SelectorGuide.

Richardson RFPD Inc.,
www.richardsonrfpd.com.

Precision Microwave Components Catalog

RLC Electronics is a leader in the design and manufacture of RF and microwave components. In this catalog, you will find standard RLC products, including coaxial switches and filters up to 65 GHz, as well as power dividers, couplers, attenuators and detectors up to and beyond 40 GHz. As you will see, many of these components are available in surface mount or connectorized packages. RLC can also provide customized designs to meet specific customer requirements not shown in the catalog.

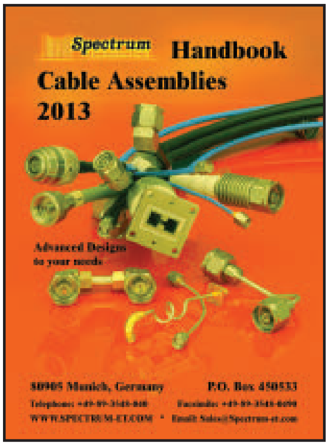
RLC Electronics,
www.rlcelectronics.com.

Value Instruments Catalog

VENDORVIEW

Whatever your job is, you are not always performing complex measurements and do not always need the ultimate high-end T&M equipment. What you need are precise, reliable, universal measuring instruments. That is exactly what you get with value instruments from Rohde & Schwarz: they combine practical features with excellent measurement characteristics; they are easy to use and easy on the budget. Find out more in the Value Instruments Catalog 2013 from Rohde & Schwarz.

Rohde & Schwarz GmbH & Co. KG,
www.rohde-schwarz.com.



Cable Assembly Handbook

Spectrum Elektrotechnik GmbH is issuing a new comprehensive handbook, covering the following products: high performance cable assemblies, operating to 71 GHz; phase matched cable assemblies, showing also phase adjustable connectors to 40 GHz; multipin/multiport cable assemblies; phase king assemblies with limited phase shift over temperature; phase stable assemblies to 26 GHz; push on and quick connection assemblies; assemblies with interchangeable connectors; SpectrumFlex assemblies; commercial cable assemblies; semi rigid cable assemblies; handy form cable assemblies; delay lines; and details on connector outlines.

Spectrum Elektrotechnik GmbH,
www.spectrum-et.com.

ATC Catalog

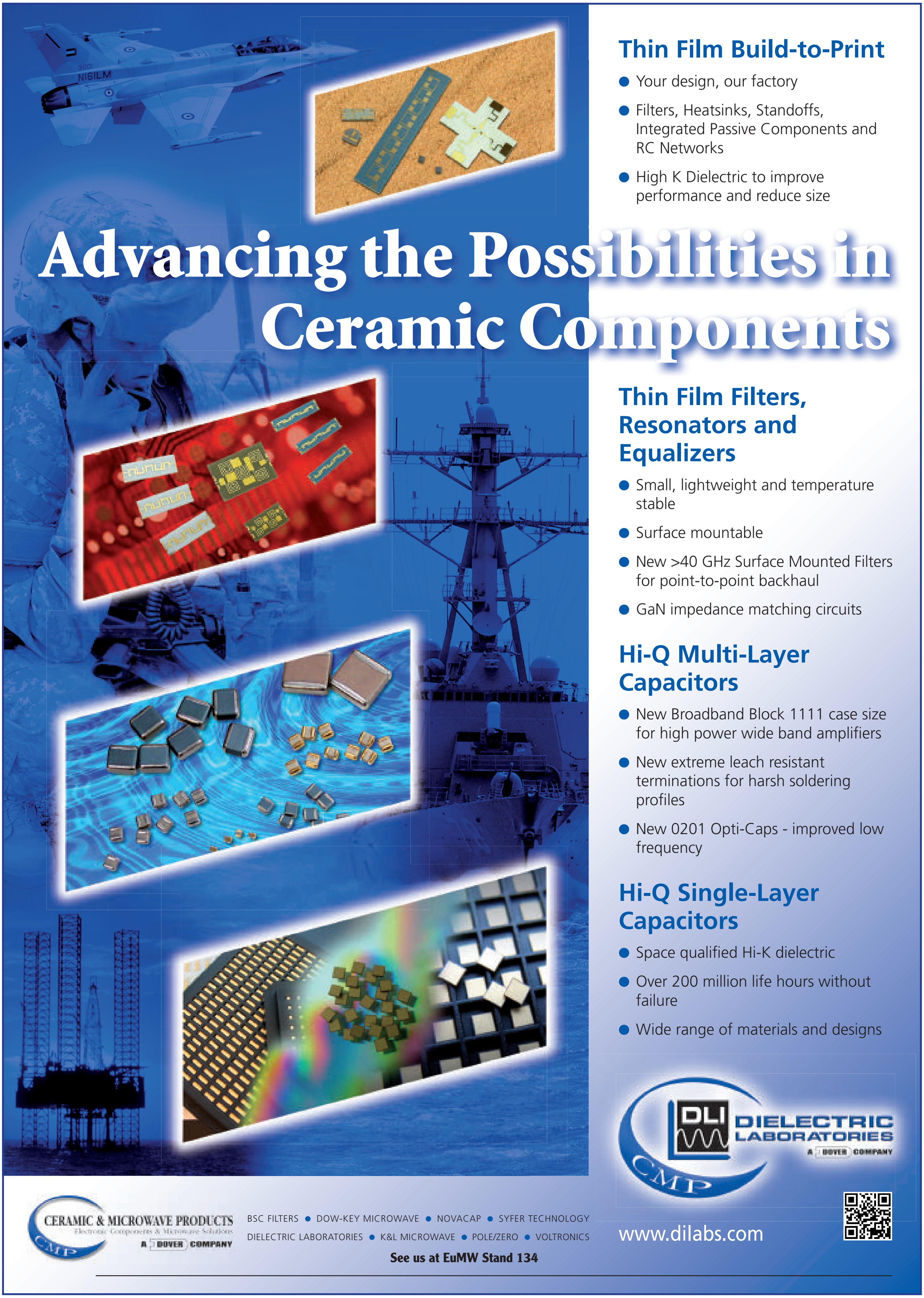
SPINNER is a reliable supplier of advanced components for radar systems – especially rotary joints. These include the broad field of air traffic control (ATC) radar systems like surface movement radar (SMR), precision approach radar (PAR), air surveillance radar (ASR), en-route radar or Doppler weather radars (DWR). When it comes to application in ATC, all major customers in Europe already trust in SPINNER rotary joints. With this new catalog, the company wants to put a special focus on this market.

SPINNER GmbH,
www.spinner-group.com.

Millimeter Wave Connector Series Catalog

SV Microwave has released a new catalog for its millimeter wave connector series. SV's line has the precision, quality and performance needed for the millimeter wave spectrum through 67 GHz. Products include 2.92 mm, 2.4 mm and 1.85 mm and are available as connectors, terminations, attenuators, cable assemblies and customized solutions. To obtain the new catalog, please visit www.svmicrowave.com/ProductLiterature or email marketing@svmicro.com.

SV Microwave,
www.svmicrowave.com.



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Your design, our factory
Filters, Heatsinks, Standoffs, Integrated Passive Components and RC Networks
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Thin Film Filters, Resonators and Equalizers
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New 0201 Opti-Caps - improved low frequency
Hi-Q Single-Layer Capacitors
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Wide range of materials and designs
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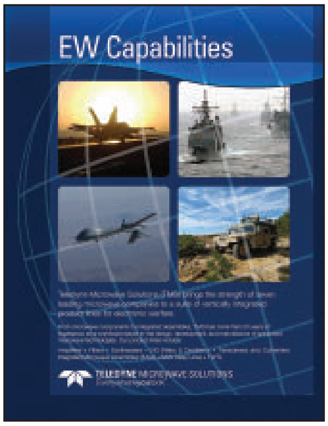
See us at EuMW Stand 134
www.dilabs.com

LITERATURE SHOWCASE



Teledyne Microwave Solutions EW Capabilities Brochure

For more than 50 years, Teledyne Microwave Solutions (TMS) has provided advanced microwave technologies for the demanding requirements of electronic warfare. From components to sub-systems, the company's vertically integrated product lines include the design, development, and manufacture of amplifiers, filters, synthesizers, YIG filters & oscillators, transceivers and converters, integrated microwave assemblies (IMA), BAW delay lines and TWTs. These products are detailed in this brochure, which can be downloaded from the company's website.

Teledyne Microwave Solutions,
www.teledynemicrowave.com.

Harness Capabilities Brochure

The Teledyne Storm Microwave Multi-Channel Microwave Solutions brochure details the company's capabilities in the design and manufacture of both standard and custom multi-channel microwave harness assemblies. The harnesses, found in a wide range of airborne, ground and sea-based military and commercial applications, are backed by Teledyne Storm's more than 30 years of microwave cable design and manufacturing expertise. The brochure includes a case study.

Teledyne Storm Microwave,
www.teledynestorm.com.

Crystal Oscillators Flyer

Ultra low phase noise and excellent spectral purity are the main characteristics provided in Wenzel Associates' Multiplied Crystal Oscillator (MXO) Series of products at fixed frequencies between 200 MHz and 12 GHz, detailed in this flyer. This versatile product line allows the customer to specify the exact frequency needed and select specific options such as phase locking with an external or internal reference, high output level, base oscillator output and multiple outputs along the multiplier string.

Wenzel Associates Inc.,
www.wenzel.com.

2013 Catalog

VENDORVIEW

Werlatone is a leading supplier of high power, broadband RF coaxial components to include (uni, dual, bi) directional couplers, 90° hybrid couplers, RF combiners/dividers and 180° hybrid RF combiners/dividers. The company's Mismatch Tolerant® directional couplers and combiners/dividers are designed to operate continuously, at rated power, into high load VSWR conditions without damage. This new catalog highlights some of its new products as well as several of its most popular designs. Please note that 65 percent of Werlatone's business revolves around custom designs.

Werlatone Inc.,
www.werlatone.com.

AD INDEX

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