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February 2014

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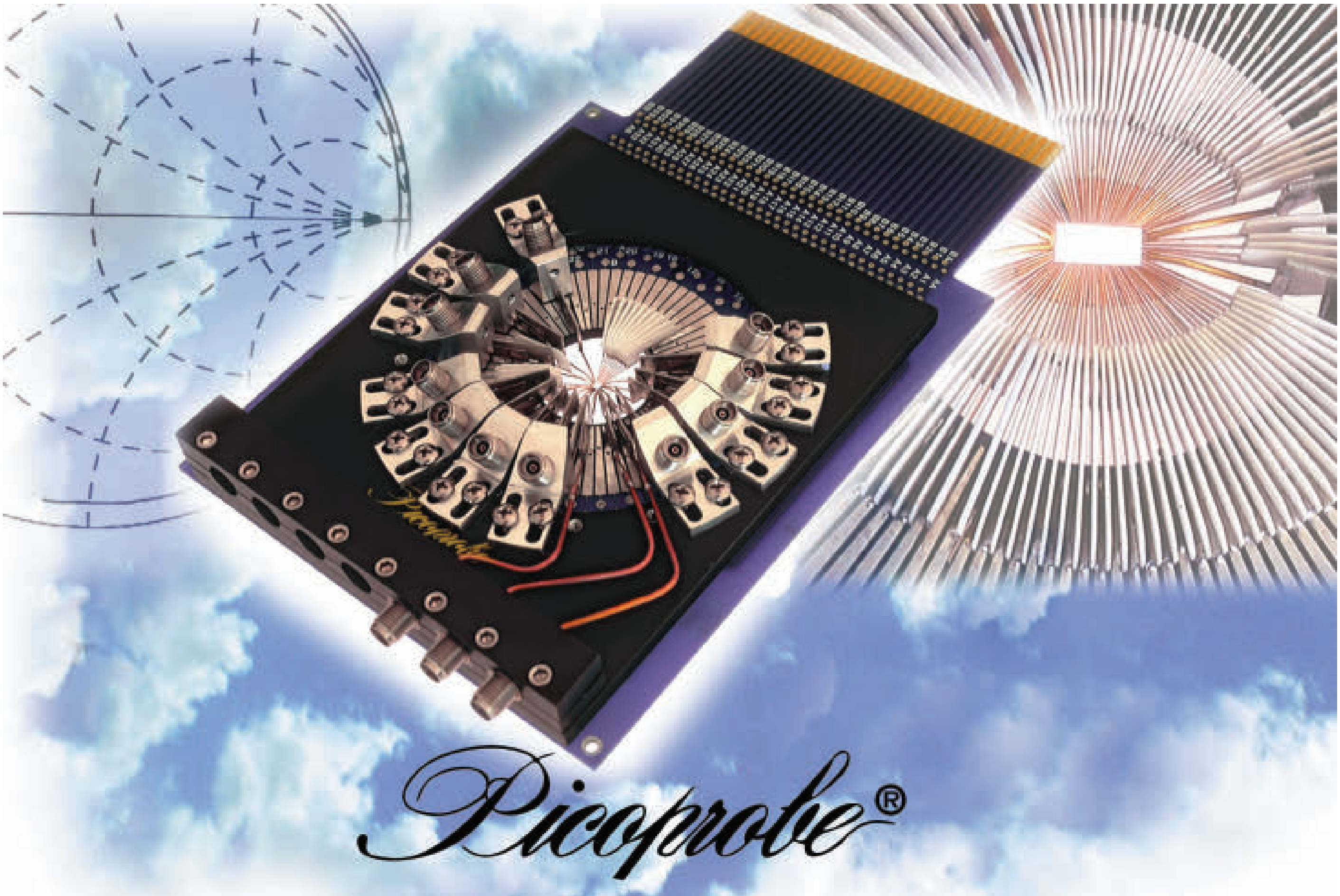

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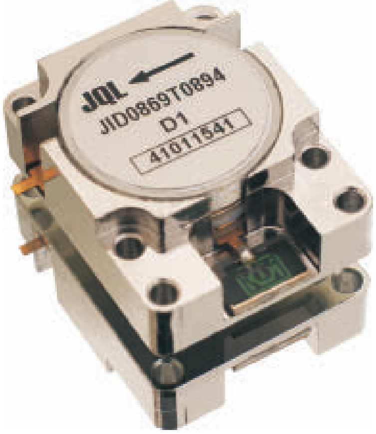

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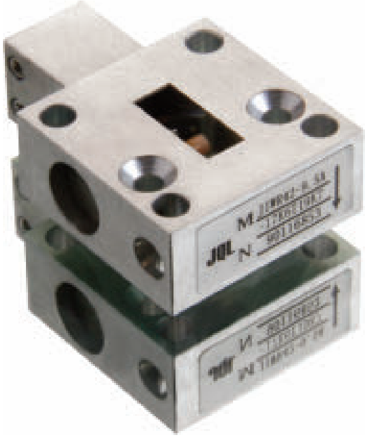

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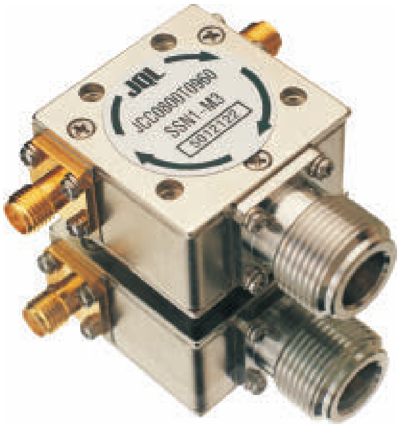

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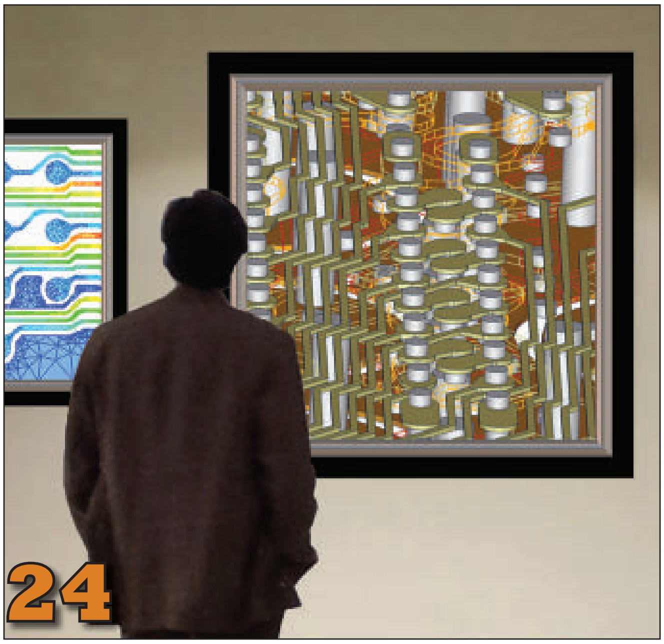

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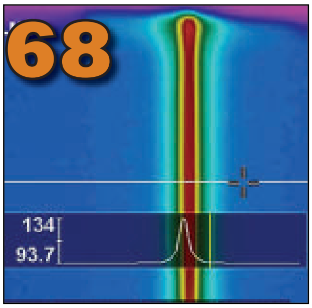

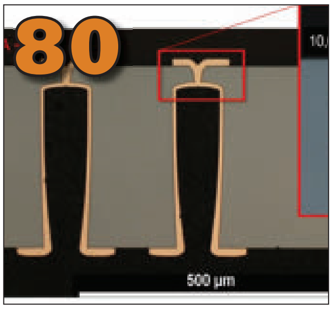

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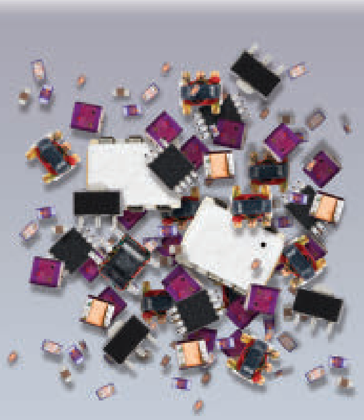

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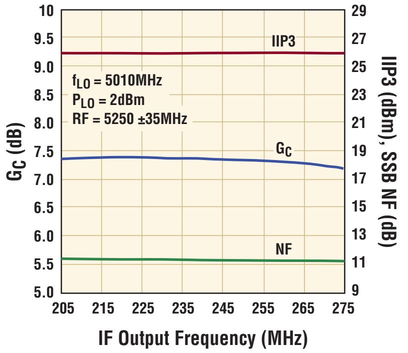

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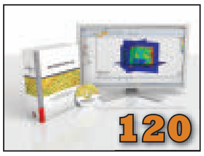

Product Features

Tech Brief

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Erratum: *In last month's Cover Feature "Next Generation Affordable Smart Antennas," an author's name was mispelled (January 2014, pg. 24). The correct spelling of the author's name is S. Ebadi.*

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Technical Education Training Improve Overall System Performance with New TriQuint GaN Products *Presented by: Richardson RFPD*	February 25th
Technical Education Training PCB Material Selection for High Speed Digital Design *Presented by: Isola*	February 26th

Executive Interviews

Liam Devlin, CEO of **Plextek RF Integration**, explains the evolution, operation and future initiatives of the independent UK-based design house that offers RF and microwave design services up to mm-wave frequencies.

Yonghui Shu, president and CEO of **SAGE Millimeter**, discusses the company's formation in 2011 and plans for growth and opportunities in the millimeter wave market.

White Papers

Noise Figure Measurements:
Making Successful, Confident NF Measurements on Amplifiers
Anritsu

Echo Reduction by Modal Filtering Technique in Advanced Near Field Antenna Measurement
Microwave Vision Group

Choosing the Proper Elastomer for Microwave Absorption
RFMW

Virtual Antenna^{TM} Technology: The Flexible and Off-the-Shelf Mobile Antenna Solution
Richardson RFPD
By: Fractus

Output Standing Wave Ratio (SWR) Test Using the TEGAM 1830A RF Power Meter
TEGAM

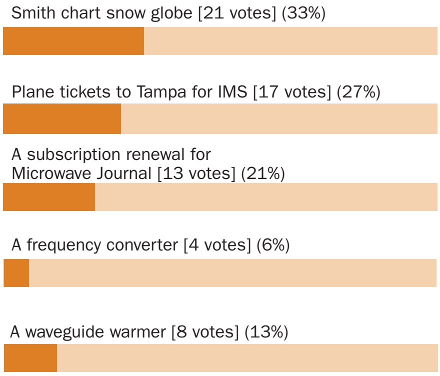
Web Survey

What technology would you most like to see introduced at Mobile World Congress?

Look for our multiple choice survey online at mwjournal.com

December Survey

What's the perfect Christmas gift for the microwave engineer?



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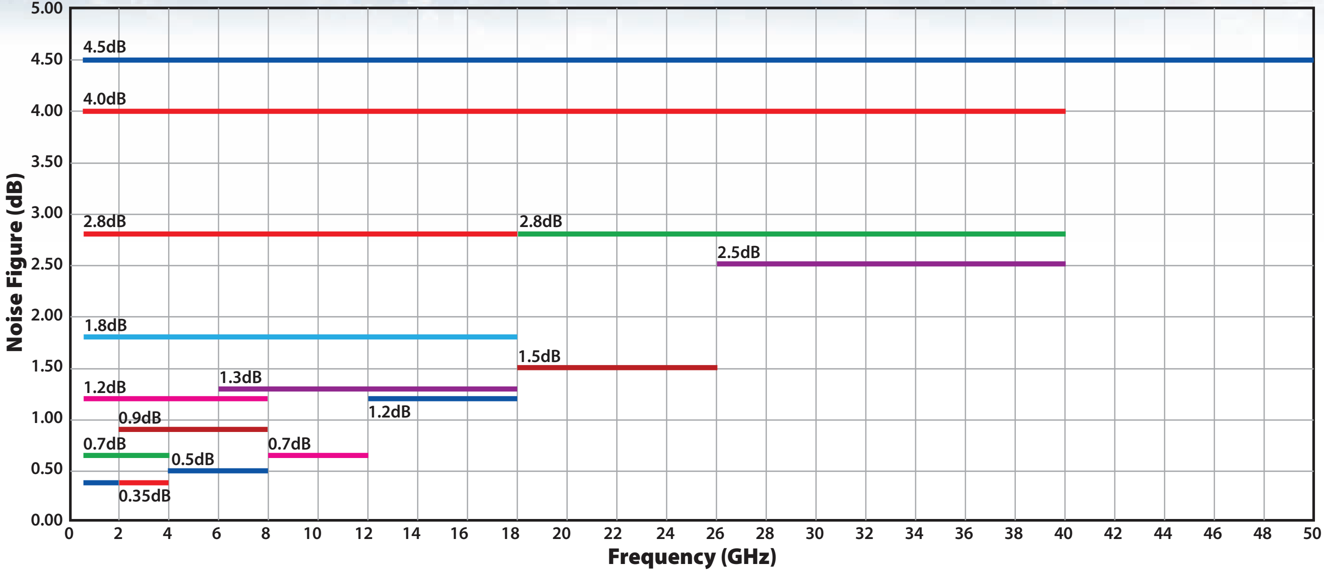

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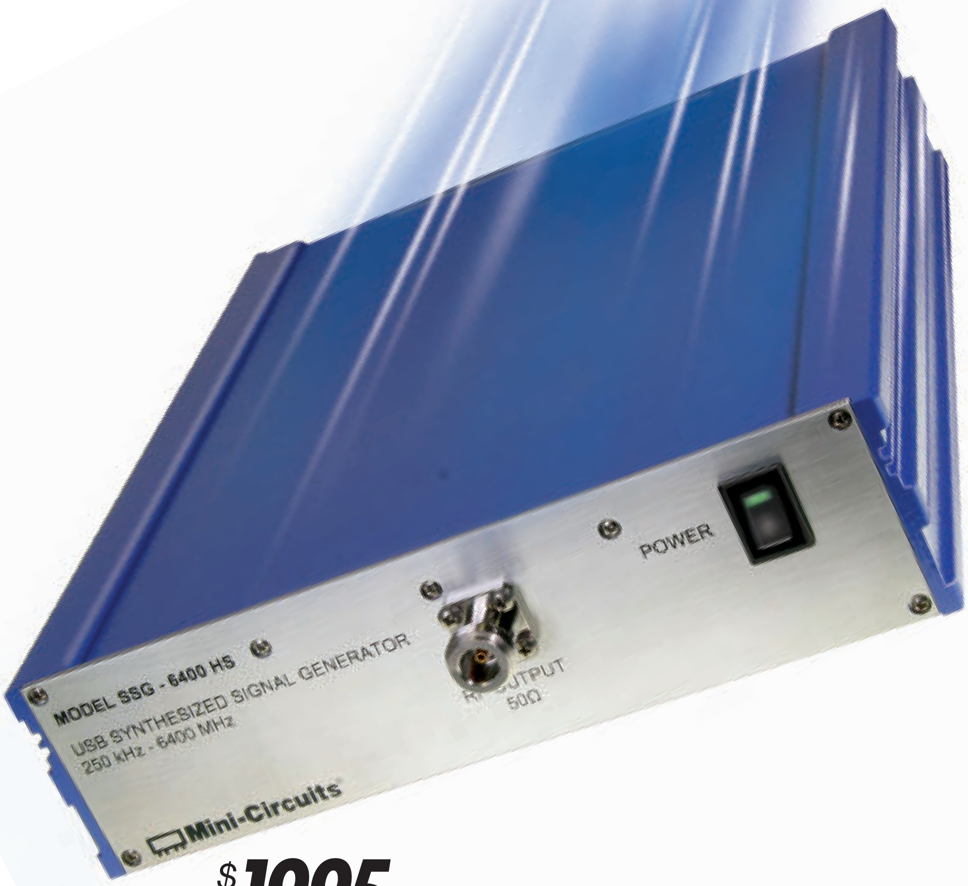

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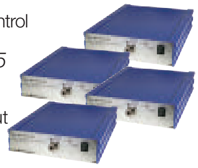

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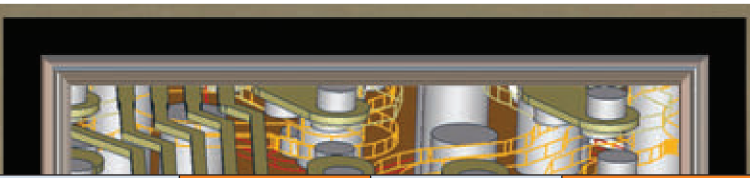

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
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9	10 SATELLITE 2014 iMAPS **DPC 2014** **10th Annual Device Packaging Conference** Fountain Hills, AZ	11 **Webinar:** **Non-Standard Connection Characterization with ATE Systems** Sponsored by Agilent Technologies	12	13	14 **Call for Papers Deadline** EuMW 2014 Defence, Security and Space Forum	15
16	17	18 **TAEECE 2014** **2nd International Conference on Technological Advances in Electrical, Electronics and Computer Engineering** Kuala Lumpur, Malaysia	19 Microwave & RF 19 & 20 March 2014	20	21	22
23 ACES The Applied Computational Electromagnetics Society Jacksonville, FL	24 IWCE Las Vegas, NV	25	26	27 **Webinar:** **E-Band Wireless Backhaul: System Design & Test Challenges** Sponsored by Agilent Technologies	28	29
30	31 GOMACTech Charleston, SC	1	2	3	4 **Next month:** EDI CON 2014 Electronic Design Innovation Conference 电子设计创新会议 April 8–10, 2014 • Beijing, China	5

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www.iaria.org

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

NATE UNITE 2014
Annual Conference for the National Association of Tower Erectors
February 24–27, 2014 • San Diego, CA
www.natehome.com/annual-conference

MARCH

ISQED 2014
International Symposium on Quality Electronic Design
March 3–5, 2014 • Santa Clara, CA
www.isqed.org

SATELLITE 2014
March 10–13, 2014 • Washington D.C.
www.satellite2014.com

DPC 2014
10th Annual Device Packaging Conference
March 10–13, 2014 • Fountain Hills, AZ
www.imaps.org/devicepackaging

TAEECE 2014
2nd International Conference on Technological Advances in Electrical, Electronics and Computer Engineering
March 18–20, 2014 • Kuala Lumpur, Malaysia
www.sdiwc.net/conferences/2014/taeece2014

Microwave & RF 2014
March 19–20, 2014 • Paris, France
www.microwave-rf.com

ACES 2014
30th International Review of Progress in Applied Computational Electromagnetics
March 23–27, 2014 • Jacksonville, FL
www.aces-society.org/conference/2014

IWCE 2014
International Wireless Communications Expo
March 24–28, 2014 • Las Vegas, NV
www.iwceexpo.com

GOMACTECH 2014
Government Microcircuit Applications & Critical Technology Conference
March 31–April 3, 2014 • Charleston, SC
www.gomactech.net

APRIL

Space Tech Expo 2014
April 1–3, 2014 • Long Beach, CA
www.spacetechexpo.com

INMMIC 2014
International Workshop on Integrated Nonlinear Microwave and Millimetre-wave Circuits
April 2–4, 2014 • Leuven, Belgium
www.inmmic.org

IDGA Military Radar Summit 2014
April 7–9, 2014 • Washington D.C.
www.militaryradarsummit.com

EDI CON 2014
Electronic Design Innovation Conference
April 8–10, 2014 • Beijing, China
www.ediconchina.com

MAY

EW Europe 2014
Electronic Warfare Europe
May 13–15, 2014 • Edinburgh, United Kingdom
www.eweurope.com

NEMO 2014
International Conference on Numerical Electromagnetic Modeling and Optimization for RF, Microwave and Terahertz Applications
May 14–16, 2014 • Pavia, Italy
www.nemo-ieee.org

CS ManTech 2014
International Conference on Compound Semiconductor Manufacturing Technology
May 19–22, 2014 • Denver, CO
www.csmantech.org

JUNE

RFIC 2014
IEEE Radio Frequency Circuits Symposium
June 1–3, 2014 • Tampa, FL
www.rfic-ieee.org

IMS 2014
IEEE International Microwave Symposium
June 1–6, 2014 • Tampa, FL
www.ims2014.org

83rd ARFTG Microwave Measurement Symposium
June 6, 2014 • Tampa, FL
www.arftg.org

WAMICON 2014
IEEE Wireless and Microwave Technology Conference
June 6, 2014 • Tampa, FL
www.wamicon.org

ISPSD 2014
International Symposium on Power Semiconductor Devices and ICs
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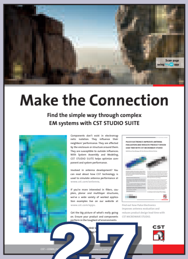
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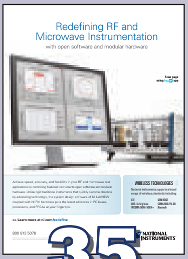
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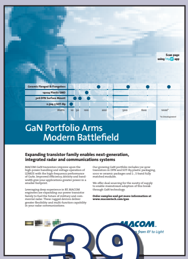
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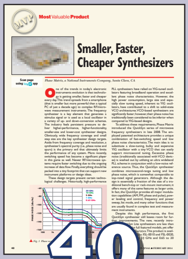
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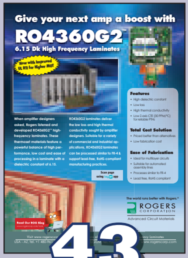
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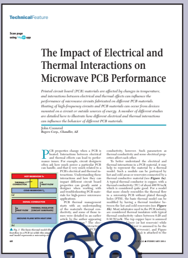
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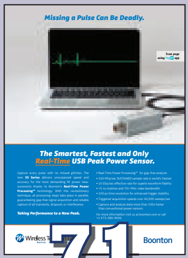
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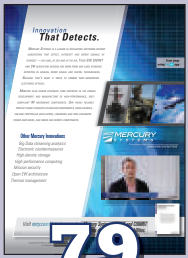
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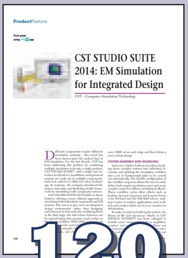
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EDI CON 2014 Electronic Design Innovation Conference 电子设计创新会议

Countdown to EDI CON 2014

David Vye, *Microwave Journal* Editor

For many in this industry, the calendar year is defined by a series of global trade shows. Product development and marketing schedules are often driven by the timing of a handful of events at which customers will gather to peruse the offerings of competing vendors in search of that solution that best fits their needs. There are events for component and test instrument manufacturers targeting specific end-markets (mobile and military communications, SATCOM, UAVs, etc.) and there are events designed to support the component and test instrument manufacturers themselves. January and February start off each year with examples of both, namely DesignCon and Mobile World Congress (MWC).

DesignCon takes place in Santa Clara in the heart of Silicon Valley and focuses on solutions for high-speed digital designers grappling with signal and power integrity challenges at the IC and PCB levels. Like the International Microwave Symposium (IMS) or European Microwave Week (EuMW), DesignCon is focused on the technology and techniques behind electronic component design, albeit high-speed digital rather than RF/microwave centric. The DesignCon technical program is also differentiated by its industry focus as opposed to the more research-driven society events. The result is a conference with an educational and professional development emphasis that is well-aligned with the goals of exhibiting component, test instrument and software vendors highlighting their latest solutions for the engineering challenges of today.

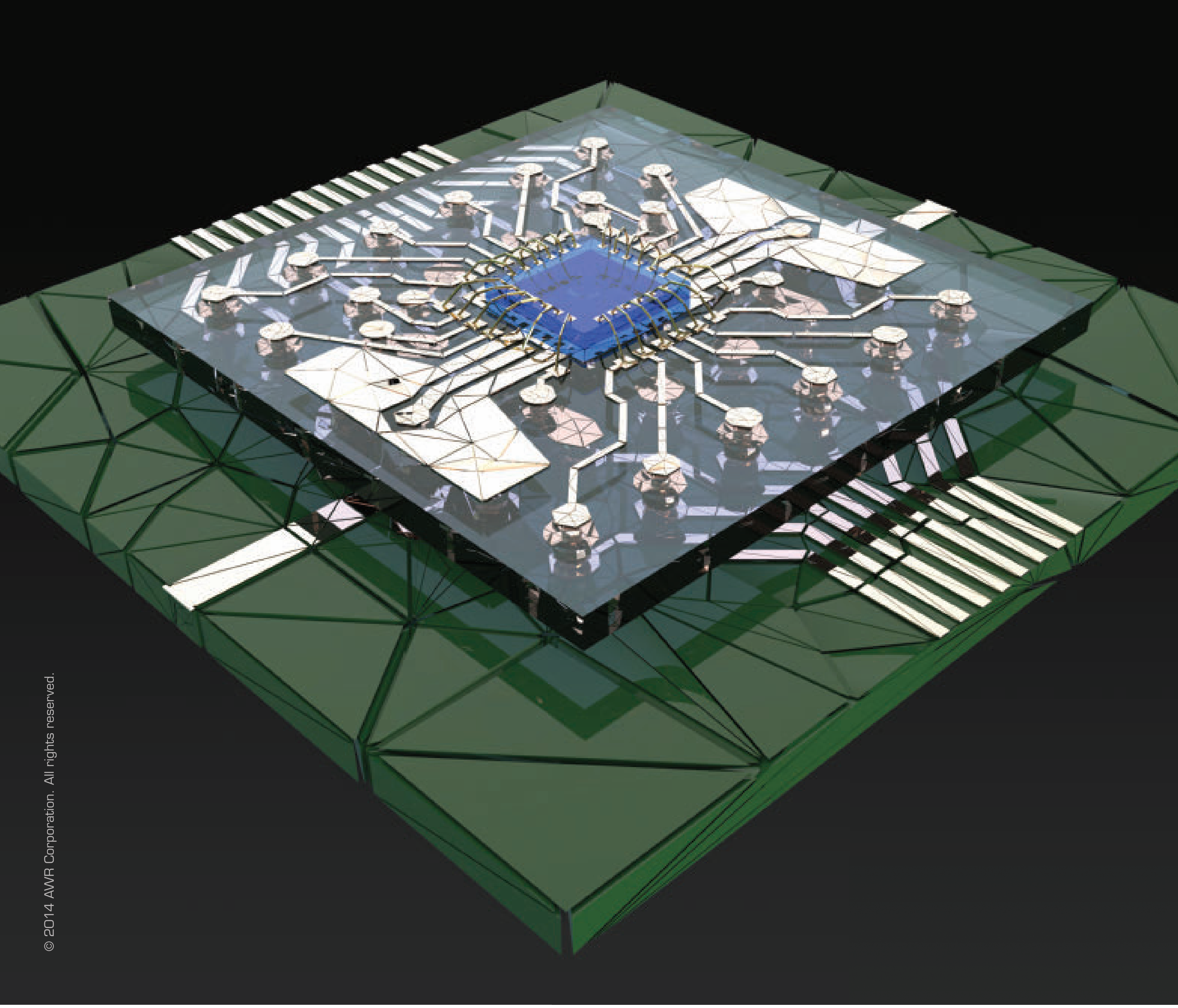
Hopping over to Barcelona, Spain later this month, MWC is the world's largest event to focus on the vast ecosystem supporting mobile communications including handheld devices, tablets, infrastructure and related communication ICs and test solutions. MWC is a massive event that draws global business leaders and technologists together in order to exchange the information that will ultimately guide multi-billion dollar decisions. RF integrated device and test instrument manufacturers will be among the RF/microwave companies presenting solutions to increase network capacity through the development and support of technologies such as voice over LTE (VoLTE), carrier aggregation, enhanced intercell interference coordination (eICIC), enhanced downlink MIMO, small cell and HetNet.

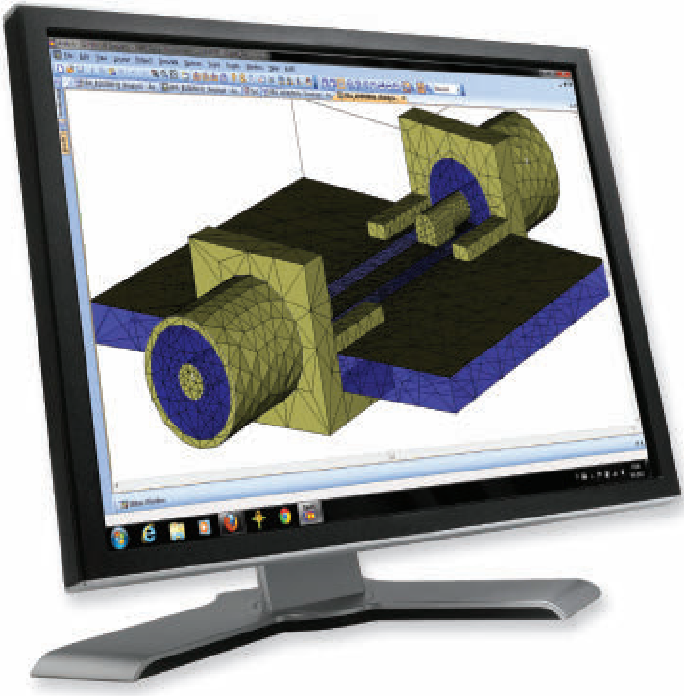
These two events are well timed to kick off the calendar year of trade shows as one sets the stage for discovering the latest in design tools and the other defines the next set of challenges for design engineers and system integrators.

The next stop in the global tour of technology is EDI CON 2014, which takes place April 8-10 in Beijing. The EDI CON technical program, which was announced at the end of January, features much of the technology that was unveiled in Santa Clara and Barcelona, this time debuting in China. For instance, the recent developments in evolutionary RF front end semiconductor technology, unveiled by integrated device manufacturers such as Peregrine Semiconductor at MWC will premier in front of a Chinese audience at EDI CON. Likewise, many advances in design tools (test equipment and software simulation) will be highlighted in the EDI CON technical program that was expanded to accommodate a strong showing of papers focused on RF/microwave, high speed digital, EMC/EMI and system-level design.

This year's crop of papers is a timely representation of the state of the industry in terms of systems being developed and the advances in technology that will support these systems. Radar, LTE-A, navigation satellite, 802.11 and MIMO were among the recurring system topics submitted mostly by industry, while GaN, CMOS, SOI and SIW were among the popular semiconductor technologies submitted for consideration. Overall, we added two specific modeling tracks (one for System-Level and the other for EMC/High-Speed Digital) and an additional twelve hours of presentations to the first day in order to accommodate the increase in paper submissions over 2013. In all, EDI CON will feature 86 technical papers, 30 workshops, 5 special panels, an Agilent education forum and a keynote session with speakers from industry, research institutes and local universities.

2014 marks our third year of publishing *Microwave Journal China* and the starting point in our effort to build a strong China-based microwave community with the collaboration of local and international companies, various technical societies and academics. As the excitement, uncertainty and energy of this new venture transforms into a steady and familiar business environment, we are pleased that *Microwave Journal China* and EDI CON have become instrumental in providing Chinese design engineers with access to information that advances their pursuit of microwave-based systems and helps market opportunities for those we collaborate with transition from speculative to real.





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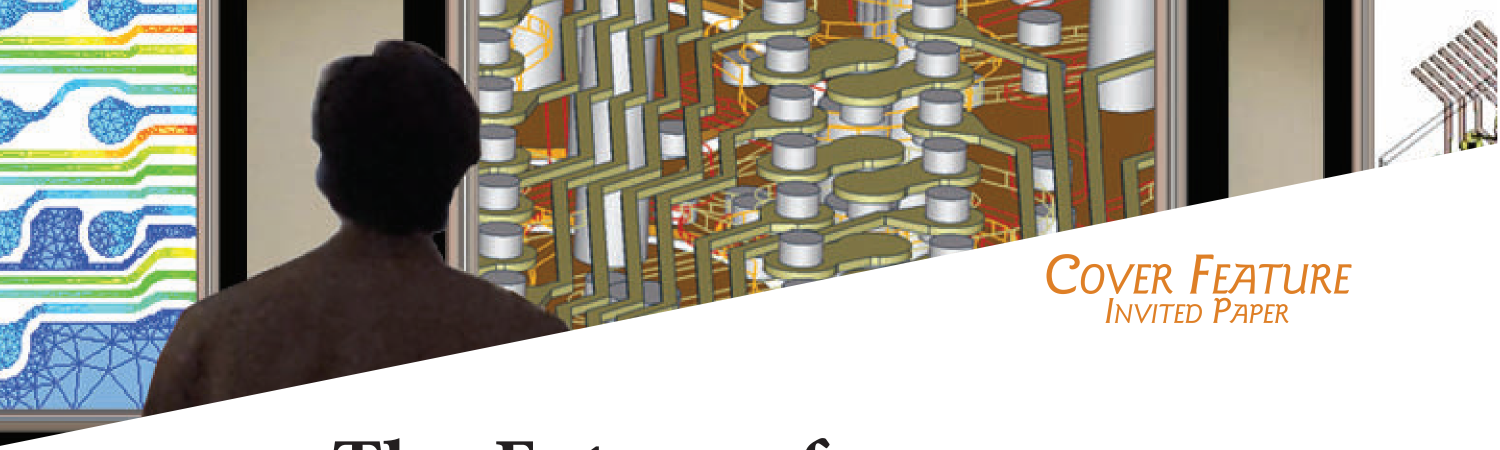

COVER FEATURE
INVITED PAPER

The Future of mm-wave Packaging

Liam Devlin
Plextek RF Integration, Great Chesterford, UK

Executive Interview

Liam Devlin, CEO of Plextek RF Integration

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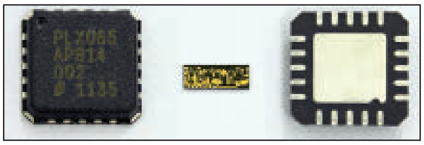
The mass market for consumer wireless products led to the development of low cost packaging technology suitable for use at RF frequencies. As the market developed, there was a drive for miniaturization that helped reduce package parasitics, which assisted in pushing up the maximum operating frequency. ICs are now readily available in surface mount technology (SMT) packages with maximum operating frequencies of around 40 to 45 GHz. Further development work is now on-going to push the upper operating frequency of SMT packaged MMICs still higher. Of particular interest is SMT packaging for use at V-Band (to address the ISM bands around 60 GHz), for automotive applications at 77 and 79 GHz and for E-Band applications at 71 to 76 and 81 to 86 GHz. This article discusses the challenges of meeting these requirements and looks at the potential approaches that could be used to address them.

The most popular package style for microwave frequency ICs is the quad flat no-leads (QFN). ***Figure 1*** shows a bare die microwave amplifier MMIC and two QFN packaged parts containing the same die type. The exposed paddle on the underside of the QFN package is normally the ground connection and is connected to the backside of the die. It is clear that the use of the bare die would still offer the ultimate in size reduction but the use of an SMT packaged component means that assembly and handling is comparatively straightforward. This facilitates reduced product cost for high volume applications and is why so much effort is being devoted to extending the frequency range of SMT packaging to still higher mm-wave frequencies.



▲ *Fig. 1 Microwave amplifier IC, QFN packaged and bare die.*

For frequencies up to around 20 GHz, traditional over-moulded plastic packaging is normally used. In this case, the plastic moulding compound is in direct contact with the surface of the die. As operating frequencies increase, air-filled plastic cavity packages also start to be used and at still higher frequencies, laminate or liquid crystal polymer[1] (LCP) based packages can be used to achieve optimum performance whilst still retaining the same QFN footprint.[2]

The two biggest challenges in SMT packaging of mm-wave ICs are tolerating the series inductance of the RF signal bonds and tolerating the overall grounding inductance (IC, package and PCB). With QFN packaged microwave ICs, the solid metal base provides a low grounding inductance for the package itself. The grounding inductance of the PCB, which often dominates, is minimised by:

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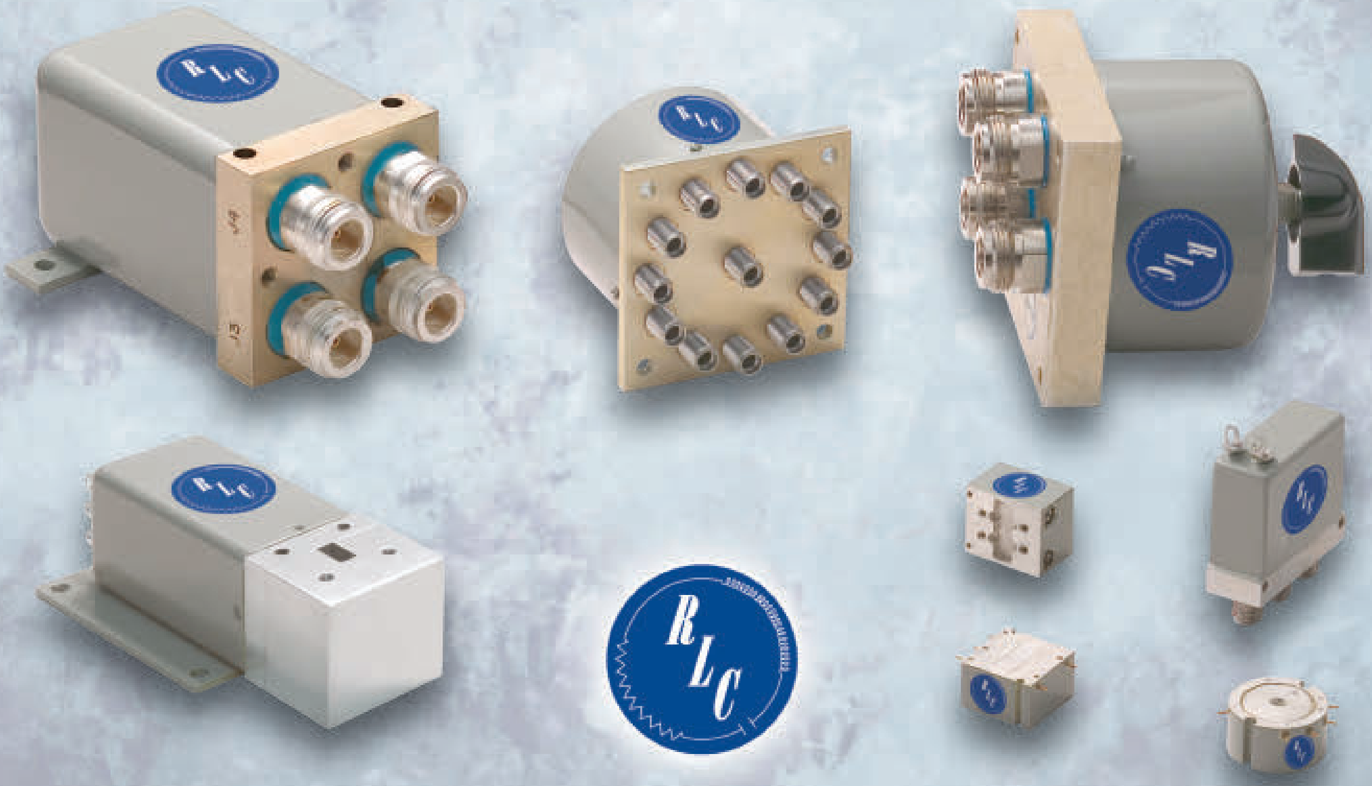

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- Using an array of ground vias providing a low inductance path from the package base to the PCB ground
- Specifying a suitably thin PCB material to reduce the inductance to the PCB ground
- Using grounded coplanar waveguide (GCPW) with close ground to signal line coupling.

The effects of package grounding are discussed in more detail in reference 3. The approach used to tolerate the series inductance of the RF bond from die to package pin is to absorb it into a lowpass filter structure.[3] Provided the inductance is adequately low then the package lead-frame and PCB land pattern can be adjusted together with the bondpad on the IC to provide effective shunt capacitances of suitable values for a well-matched low loss transition.

The absolute value of the series inductance that can be absorbed into such a lowpass filter dictates the maximum frequency to which this approach can be adopted. An inductance of 0.2 nH can be absorbed into a 50 Ω matched, third order lowpass filter with a cut-off frequency of around 45 GHz and this is essentially the upper frequency limit for SMT packaging of ICs using a conventional wire-bonded approach.

To allow operation beyond 45 GHz, new packaging approaches need to be developed, which either significantly reduce or avoid the effects of series RF bond inductance and grounding inductance. The following techniques provide a means of doing this and have all been successfully demonstrated as options for SMT packaging of ICs at high mm-wave frequencies:

- Packages with waveguide (WG) apertures
- Packages with integral antennas
- Micro-coax based packaging
- Packages using 'hot-vias'
- Flip-chip wafer level chip scale packaging (WLCSP).

Each of these approaches is described in more detail in the next section.

PACKAGES WITH WG APERTURES

Various techniques exist for transforming from waveguide to microstrip or GCPW.[4] The most compact approach is to use a probe transition. A probe normally extends through the broad wall of the waveguide and is positioned one quarter of a wavelength from a back-short (a waveguide short-circuit). The incoming RF signal is reflected from the back-short with a phase inversion. The reflected wave therefore adds coherently with the incident (incoming) wave at the location of the probe creating a voltage maximum. This generates an RF signal in the probe, which is passed through the broadside wall of the waveguide. Such transitions are commonly used in transceiver modules[5] and, at high mm-wave frequencies, the required dimensions are such that they can be incorporated into an SMT package to provide a waveguide aperture for reception and/or transmission of the mm-wave signals.

Figure 2 is a cross-section of a novel SMT package to waveguide transition taken with permission from reference 6. The packaged component is a 77 GHz transmitter for automotive radar, which is mounted onto a PCB motherboard

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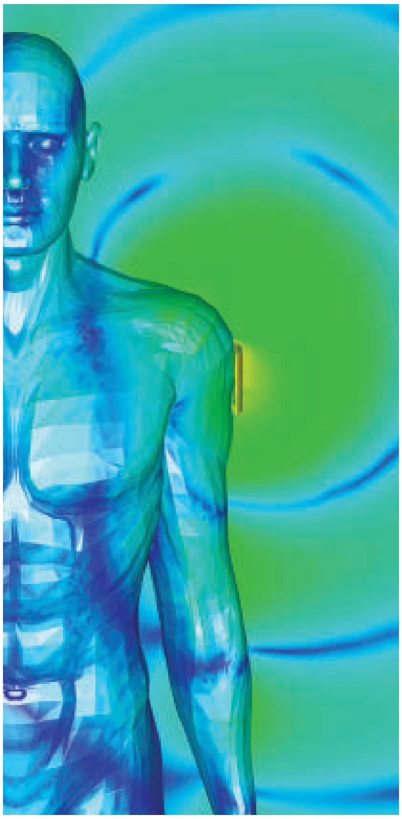

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Heikki Korva, Team Manager, RF, Pulse Electronics Wireless Division

Figure 1 LTE antenna audio-module, from simulation to mass production.

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The antenna is one of the first electromechanical components considered in a new product concept design. In the past, most of the R&D work was done in the laboratory, with the engineers constructing and testing different antenna designs for customers' products. While this is still a good approach for single antenna systems, the introduction of LTE diversity schemes and other radio systems such as Wi-Fi and GPS to current smartphones make reliable prototype evaluation very challenging.

Antenna prototypes typically include the device ground, PCBs, batteries, covers and any other large parts. Obviously, early prototypes seldom include any active transceivers, and so each antenna must be driven from an external coaxial cable. A typical LTE smartphone, with its main and diversity antennas, GPS and GLONASS systems and 2.4 GHz and 5 GHz WLAN capabilities, can need 7 or 8 cables to measure all the components at once. These cables would occupy too much of the volume of the prototypes, and severely distort the evaluation results. With electromagnetic simulation, the performance of a complex device can be calculated without worrying about these cable effects.

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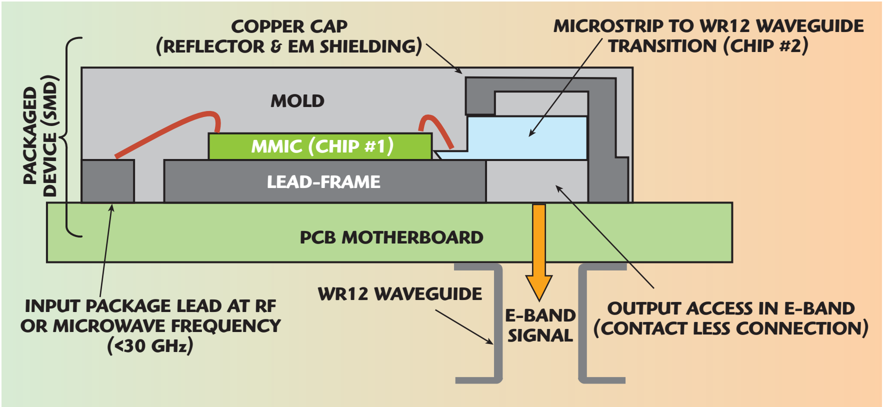
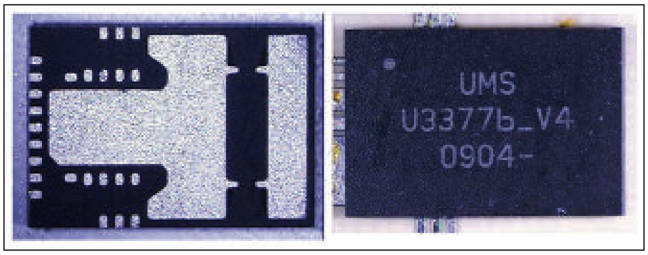


▲ *Fig. 2 Formation of 77 GHz SMT package with WG aperture (courtesy of UMS).*



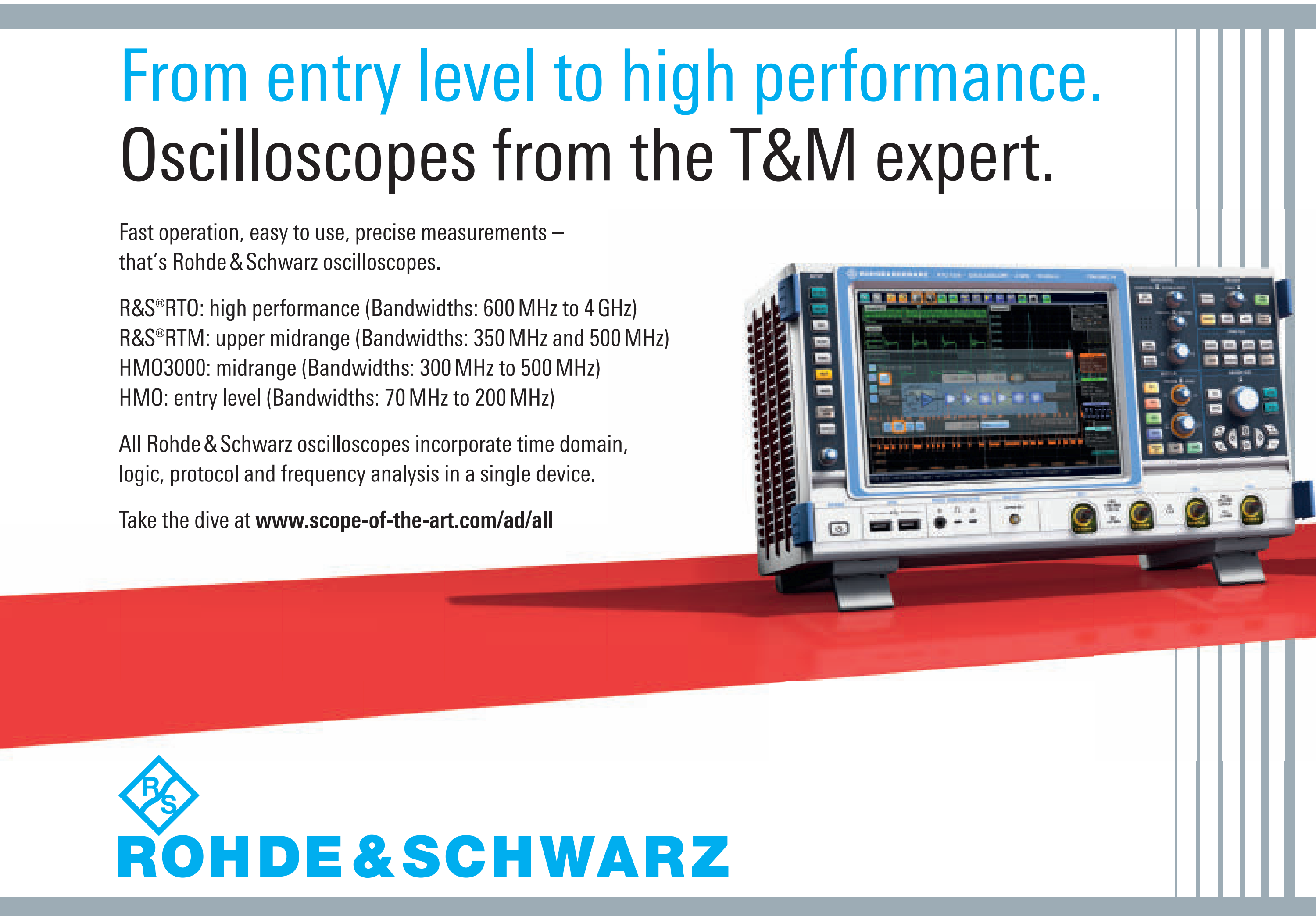
▲ *Fig. 3 A plastic SMT package with integral WG aperture (courtesy of UMS).*

with a WR12 waveguide output on the underside. Chip #1 is the automotive radar MMIC; chip #2 is the transition realized as a printed structure on an organic PCB material.

The transition described in reference 6 demonstrates an insertion loss of 1.2 dB for a single transition at 77 GHz, based on evaluation of a back-to-back test piece. For the MMIC assembled into the WG package, the measured transmit power drops by 3 dB compared to that measured on wafer. This is mainly attributed to the wire-bonded transition from the probe substrate (chip #2) to the MMIC (chip #1) which had not yet been optimised. Both faces of the 9 × 6 mm QFN package are shown in ***Figure 3***. Although the use of plastic packaging technology significantly reduces the cost of this style of package compared to previous ceramic versions, it is still significantly higher than conventional packaging in SMT plastic QFN packages.

PACKAGES WITH INTEGRAL ANTENNAS

Rather than attempting to develop a package with a mm-wave SMT interface, or a waveguide aperture as described previously, another alternative is to integrate the antenna into the package. Variants of this approach using both single antenna elements and multiple antenna elements (antenna arrays) have been demonstrated.[7] In both cases, all other interfaces to the IC are SMT with



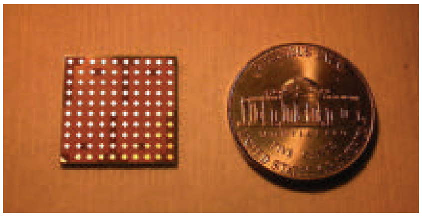


Fig. 4 A 94 GHz SMT transceiver with integral antenna array (courtesy of IBM).

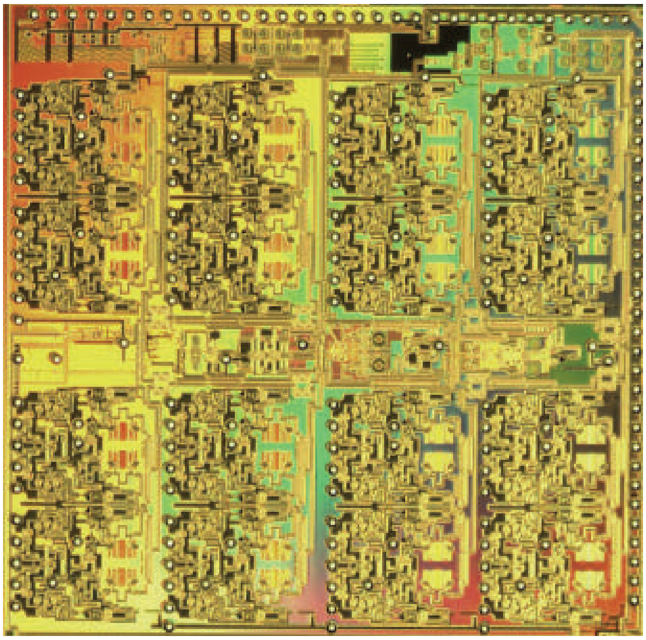


Fig. 5 A 94 GHz multi-element transceiver IC (courtesy of IBM).

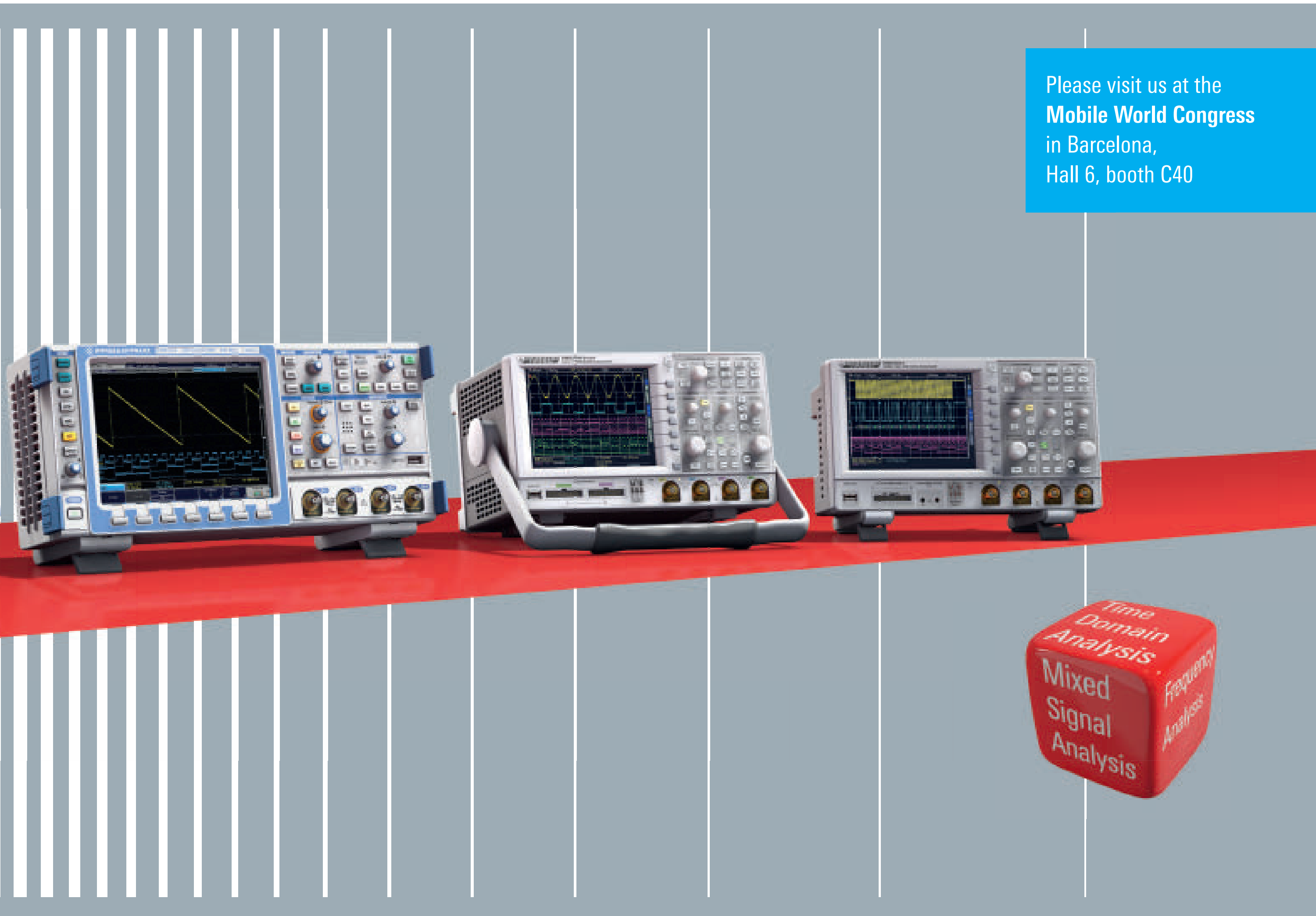
the integral antenna forming the mm-wave transition. This approach is only possible at high mm-wave frequencies where the required physical size of the antenna becomes sufficiently small.

One of the most impressive demonstrations of this approach to date is a W-Band phased array transceiver from IBM.[8] Four 16-element transceiver ICs were integrated into a single package containing 64 radiating elements. ***Figure 4*** illustrates the package showing the antenna array. The spacing between the elements is λ/2 at 94 GHz (around 1.6 mm). The spacing from the edge antennas to the side of the package is λ/4, which facilitates the tiling of multiple components to realize a larger array. The design targets radar and active imaging applications where small size and low weight are required.

A 16-element die is shown in ***Figure 5***. It contains 32 receive channels (to facilitate simultaneous reception in two polarizations) and 16 transmit channels (which can be switched to either polarization). In addition to dispensing with RF bondwire inductance, the use of the multi-element antenna array has two other advantages:

- The total output power is the sum of multiple parallel transmitters so the available transmit power is increased
- The phase of the different transmit/receive elements can be adjusted to provide beam steering.

The control of the amplitude of each transmit/receive elements also provides the possibility to shape the antenna pattern and even introduce nulls to avoid interferers.



One potential downside to this approach is that additional channel filtering cannot be included. However, the small size of the antenna means that it should provide significant rejection at low frequencies.

MICRO-COAX BASED PACKAGING

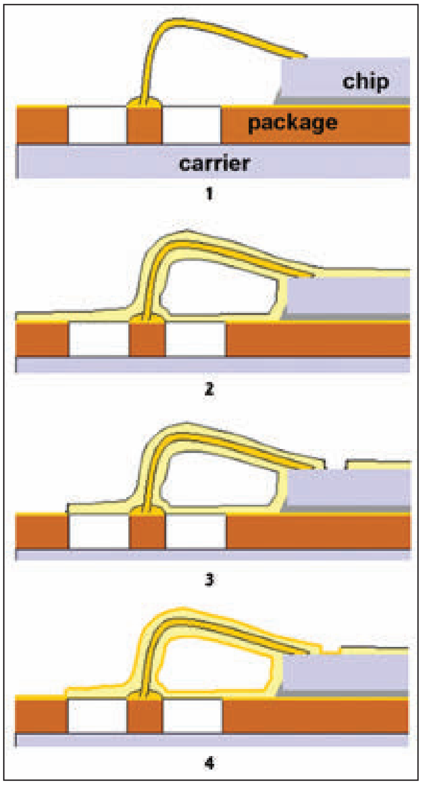
Micro-coax packaging is an innovative and elegant approach to addressing the problem of RF bond inductance. The bondwire is transformed into a coaxial transmission line of controlled impedance (normally 50 Ω) by the addition of a dielectric coating and then a grounded conductive outer. Accurate control of the dielectric constant and the thickness of the dielectric are required to set the characteristic impedance of the micro-coax transmission line.

The formation of the micro-coax transition, from reference 9, is depicted in ***Figure 6***. The package assembly steps include:

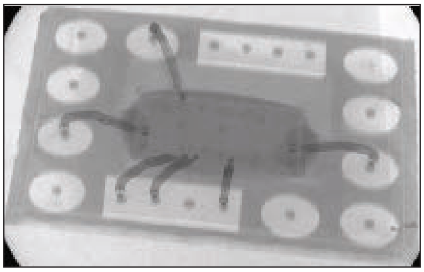
1. Die attach and wire bond
2. Conformal dielectric coating
3. Laser cutting of vias to allow metallic contact
4. Selective metallization of ground shield.

Obviously, some form of capping step would normally follow the process.

The measured performance of micro-coax test pieces has shown an insertion loss of less than 0.7 dB at frequencies up to 115 GHz for a 2.2 mm long test piece. The return loss of this test piece was better than 20 dB across most of this band with a worst case value of around 17 dB. ***Figure 7*** is an X-ray of an 18 to 31 GHz LNA (CHA2069 from UMS) packaged using micro-coax technology. The coaxial structure of the interconnects



▲ *Fig. 6 Formation of micro-coax interconnects (courtesy of Bridgewave).*



▲ *Fig. 7 X-ray photograph of a micro-coax packaged LNA (courtesy of Bridgewave).*

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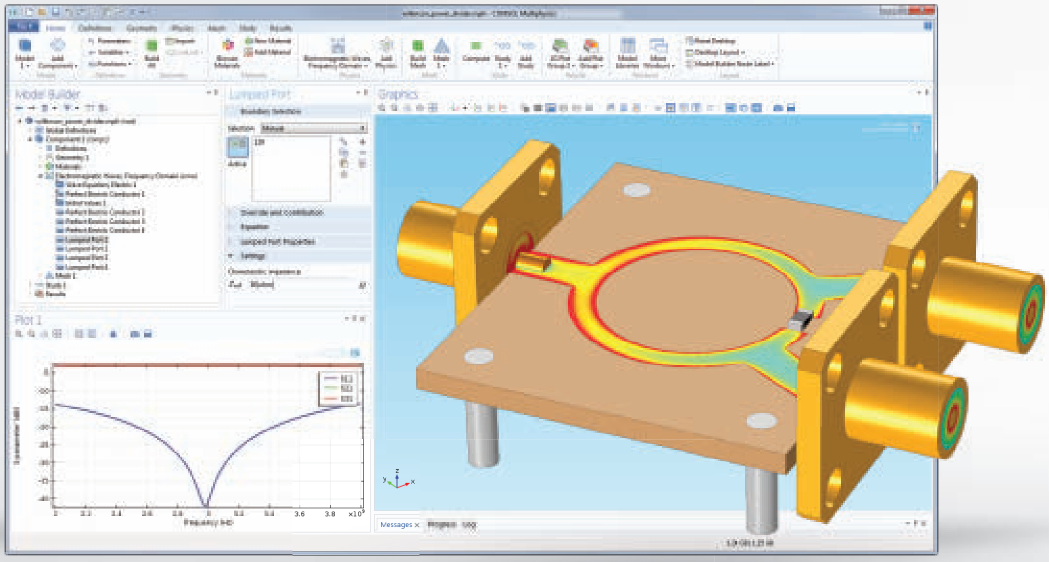

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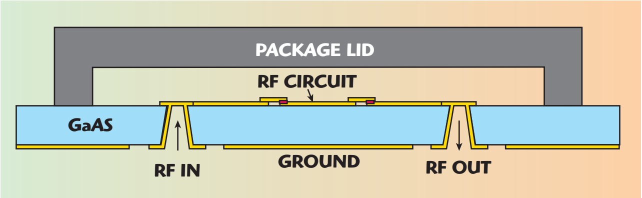

▲ *Fig. 8 Use of 'hot-vias' in SMT packaging.*

is clearly visible, as are ground vias within the MMIC die. The measured performance of this part can be found in reference 9 and is very close to that of the bare die.

The micro-coax approach depicted in Figure 6 and Figure 7 uses a coaxial feed-through. It has the benefit that it can be used to realise a hermetically sealed package but the downside is that it is not cost-effective for most consumer applications. In order to address this, a micro-coax/leadframe approach is described in reference 9, which allows for lower production costs. A QFN style package is used as a demonstration vehicle and good performance is demonstrated to 50 GHz.

The micro-coax approach is a viable route to avoiding the effects of series RF bond inductance and as a transmission medium it has been demonstrated to show good performance to beyond 100 GHz. However, there is still some uncertainty about its potential to provide a low cost packaging solution for use in the 50 to 100 GHz range.

PACKAGES USING HOT-VIAS

Most GaAs and GaN processes include a through substrate via capability. This provides low inductance interconnects from the front side of the die to the back. The effective inductance is dependent on the substrate height and via size but is typically around 20 pH. In conventional MMIC designs, the vias are used to provide low inductance ground points with the back side of the die being ground. If patterning of the back side metal is possible, then some of these ground contacts can be isolated and can be used as low-inductance RF interconnects.

This allows the die to form the base of a true chip-scale SMT package as depicted in ***Figure 8***. The inductance of the RF interconnect has been reduced to around 20 pH, which should, in theory, allow operation to beyond 100 GHz.

The hot-via packaging approach has previously been demonstrated[10] with measured through line test pieces indicating losses of 0.5 dB at 45 GHz for a single hot-via transition. The measured performance of a 15 to 30 GHz amplifier IC, modified to allow hot-via packaging, is also presented in reference 10 and shows performance similar to that of the bare die.

Avago has introduced commercially available parts in wafer scale packages (WSP) that make use of hot-vias. Published data from Avago[11] suggests that the hot-via transition should work well up to 45 GHz. However, at the time of writing, the product range offered in this package style does not appear to extend beyond 12 GHz.

It is clear that hot-via transitions offer a practical way to significantly reduce

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Dynamic Range (BW=10Hz,dB,typ)	120	120	120	120	120	120	115	100	100	60
Dynamic Range (BW=10Hz,dB,min)	100	100	100	100	100	100	100	80	80	40
Magnitude Stability (±dB)	0.15	0.15	0.15	0.15	0.25	0.25	0.3	0.5	0.8	1
Phase Stability (±deg)	2	2	2	2	4	4	6	8	10	15
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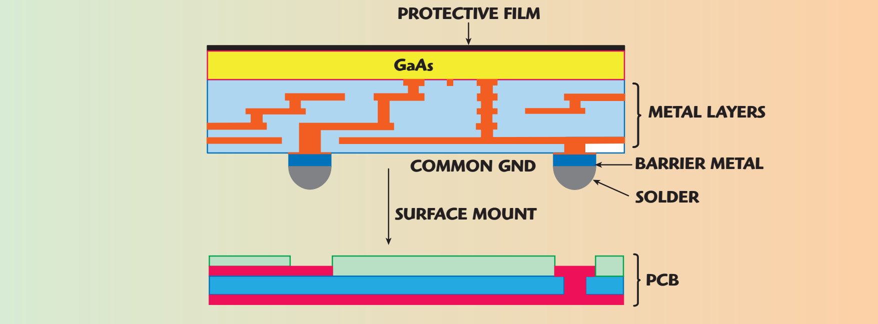

▲ *Fig. 9 Cross-section of WLCSP approach (courtesy of Sumitomo).*

the series inductance of an IC to PCB transition. However, the technology has yet to prove itself practical for commercial use at mm-wave frequencies.

FLIP-CHIP WLCSP

In wafer level chip scale packaging (WLCSP) the die is normally packaged in a ball grid array with the surface of the die facing down towards the PCB on which it is mounted. The resulting package is truly chip scale, being not much larger than the die itself. This approach provides miniaturization and results in very low interconnect parasitics. WLCSP is often undertaken as an augmentation to the wafer fabrication process.

A number of manufacturers have WLCSP processes. Infineon's embedded Wafer Level Ball Grid Array (eWLB) technology[12] has been successfully used in its V-Band and E-Band transceiver products,[13] which are about to be released as commercially available products.

Sumitomo has demonstrated a set of E-Band ICs in WLCSP.[14] These include a frequency tripler, an LNA, a balanced mixer and a power amplifier (PA). The packaging technology is depicted in ***Figure 9***. The actual IC is GaAs PHEMT technology with additional processing steps to form the WLCSP. This includes the ability to add routing to connect to a uniform array of solder balls for SMT attach. The surface of the IC package is covered with a common ground metal, which has multiple links to the die ground. Openings are made in the package ground plane for signal, control and bias connections to the die.

Figure 10 shows an example of one particular WLCSP part, an LNA. The packaged part was mounted on a PCB with a GCPW interface. The performance of the packaged part on the PCB was measured with G-S-G probes, as would be used for RFOW evaluation. The comparison of the measured to modeled performance gives an honest indication of the degradation due to packaging. Each RF transition incurs an insertion loss of around 1.5 dB.

For ICs having net gain, with input and output at the same frequency (such as the LNA above), the effects of grounding inductance are much more significant than for transceivers. Great care must be taken to minimise

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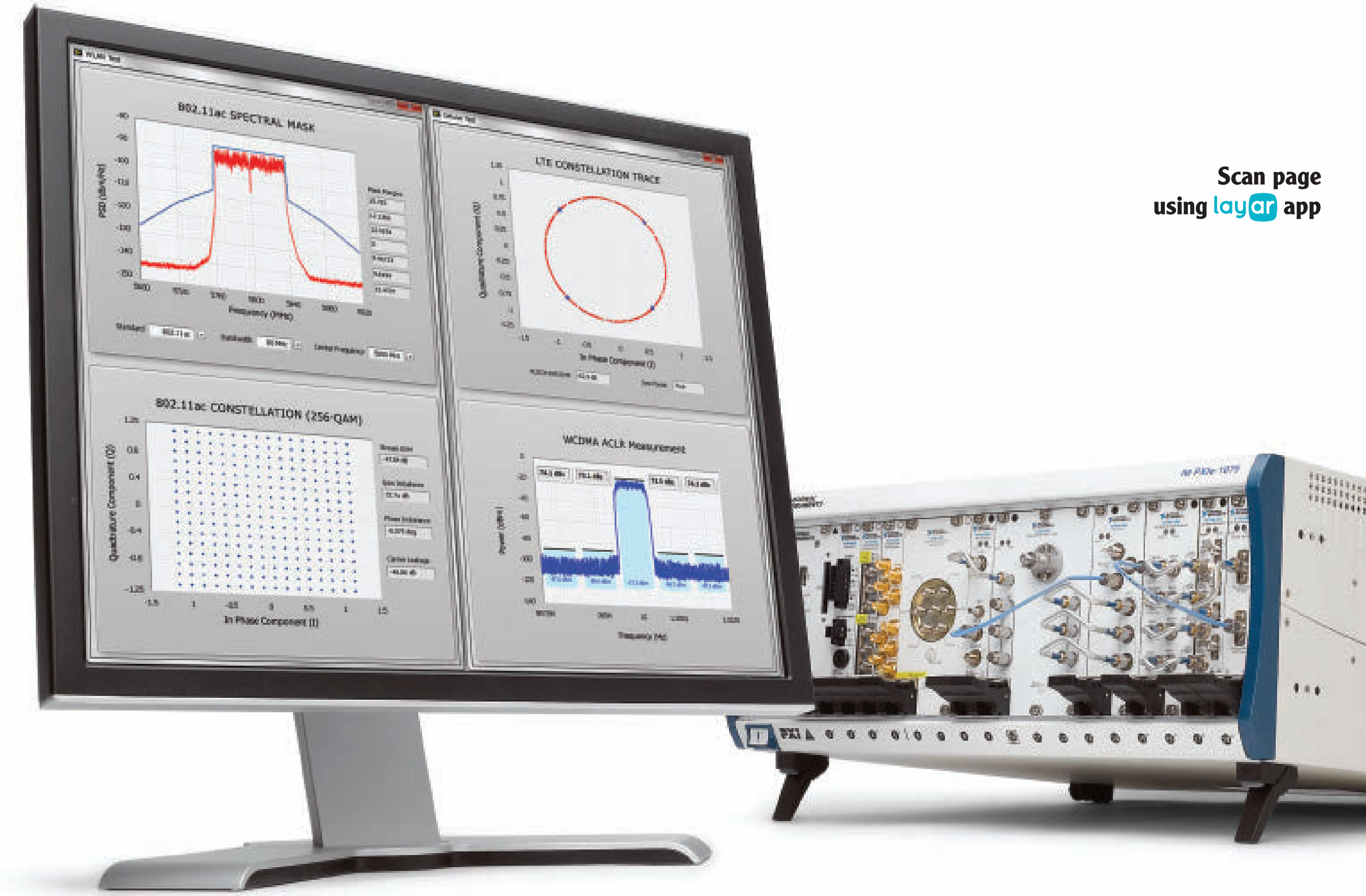

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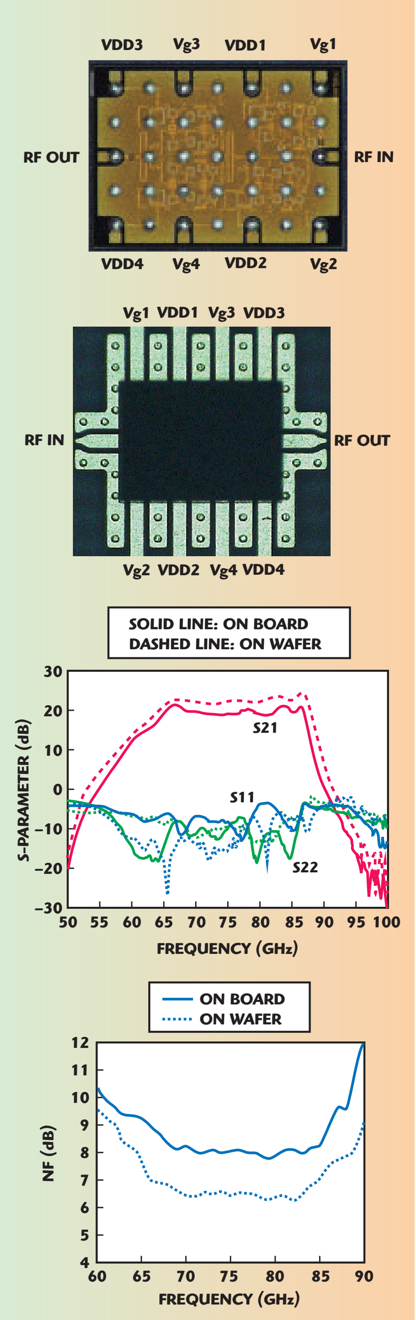
the effective grounding inductance or severe performance degradation, or even instability, can result.

CONCLUSION

All of the packaging approaches described above have demonstrated their potential for use at frequencies to around 100 GHz. However, in the author's opinion, there are two of these that are likely to see significant deployment in commercial products. These are the ICs with integrated array antennas and the flip-chip mounted ICs in WLCSP.

The integrated antennas avoid the problems associated with making a mm-wave SMT contact to a PCB. They also mean that the tolerable grounding inductance can be much higher. The use of an antenna array allows increased transmit power by in-air combination of multiple lower level signals and allows steering of the antenna beam. This approach is unlikely to be practical for longer range point to point links where higher transmit powers and antenna directivity would be required but it is very attractive for shorter range links and indoor communications.

WLCSP uses miniaturization to keep package parasitics to a minimum. The flip-chip mounting of the die means the path from the die to the PCB is minimised. The parasitics of the PCB can still have a significant effect on the ultimate performance and co-design of



▲ *Fig. 10 Example of E-Band LNA in an SMT WLCSP (courtesy of Sumitomo).*

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IC, package and PCB is necessary to achieve optimum results. With complete receiver or transmitter ICs having only a single mm-wave port, the effects of PCB grounding inductance are significantly reduced but functional blocks such as amplifiers must also tackle this issue as an integral part of their design and implementation. ■

ACKNOWLEDGMENTS

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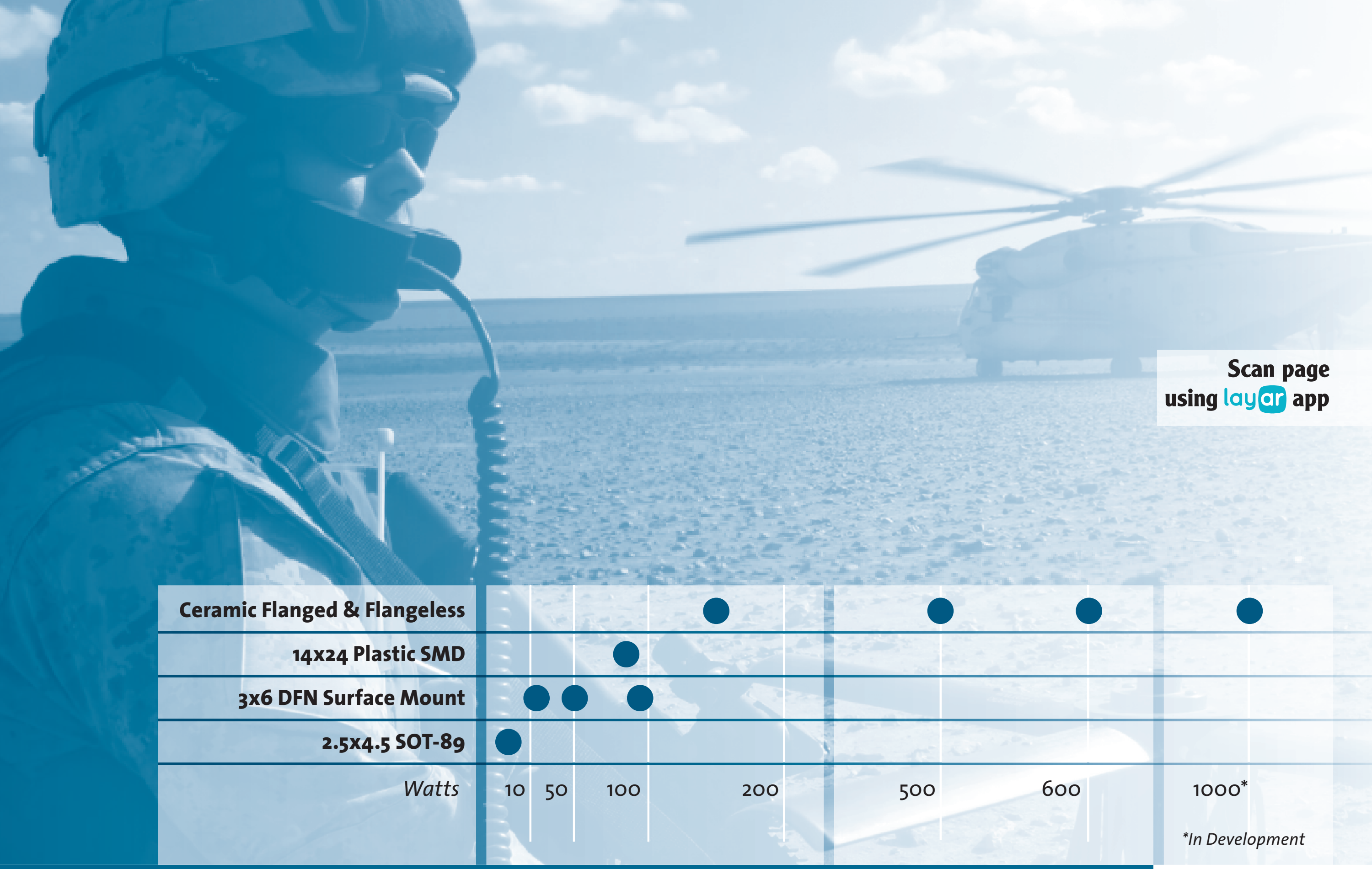
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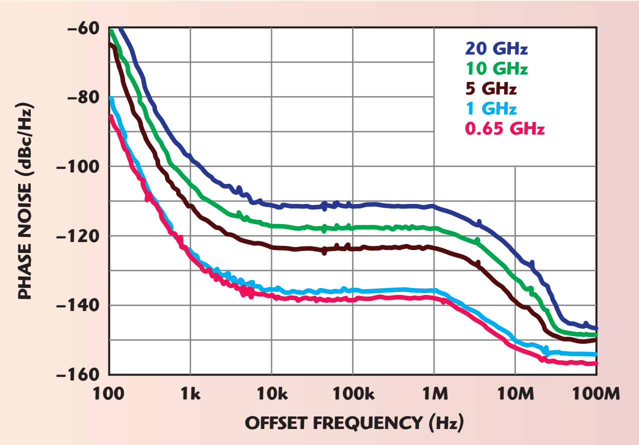
Smaller, Faster, Cheaper Synthesizers

Phase Matrix, a National Instruments Company, Santa Clara, CA

One of the trends in today's electronic instruments evolution is that technology is getting smaller, faster and cheaper every day. This trend spreads from a smartphone (that is smaller but more powerful than a typical PC of just a decade ago) to complex RF/microwave measurement instruments. The frequency synthesizer is a key element that generates a stimulus signal or is used as a local oscillator in a variety of up- and down-conversion schemes. The industry feels persistent pressure to deliver higher-performance, higher-functionality, smaller-size and lower-cost synthesizer designs. Obviously, wide frequency coverage and small step size are the key synthesizer design targets. Aside from frequency coverage and resolution, a synthesizer's spectral purity (i.e., phase noise and spurs) is the primary evil that ultimately limits the performance of any system. More recently, switching speed has become a significant player in this game as well. Newer RF/microwave systems require faster switching due to the ongoing increase of data flow. Finally, everything should be packed into a tiny footprint that can support new instrument platforms or design ideas.

These design targets present certain technological challenges. Historically, high-performance PLL synthesizers have relied on YIG-tuned oscillators featuring broadband operation and excellent phase noise characteristics. However, the high power consumption, large size and especially slow tuning speed, inherent to YIG oscillators, have contributed to a shift to solid-state VCO architectures. VCO-based synthesizers are significantly faster; however, their phase noise has traditionally been considered to be inferior when compared to YIG-based designs.



▲ *Fig. 1 Phase noise performance.*

To address these requirements, Phase Matrix introduced the QuickSyn series of microwave frequency synthesizers in late 2008. The employed patented architecture provides a unique combination of fast-switching speed and low phase noise characteristics. The main idea is to substitute a slow-tuning, bulky and expensive YIG oscillator with a tiny VCO that can easily support microsecond tuning. Excessive phase noise (traditionally associated with VCO devices) is washed out by utilizing an ultra wideband PLL scheme in conjunction with a low-noise reference source. Thus, the QuickSyn synthesizer combines microsecond-range tuning and low phase noise, which is somewhat comparable to top-rated signal generators. Although the design is essentially a fraction of the size of a traditional bench-top or rack-mount instrument, it offers many of the same features as larger units. In fact, the QuickSyn provides all major modulation capabilities (AM, FM, phase and pulse), power leveling and control, frequency and power sweep, list mode, and many other functions that are usually found in complex test and measurement instruments.

Despite this high performance, the first QuickSyn synthesizer still leaves room for further improvements. The new, recently introduced QuickSyn Lite synthesizers are less than half the size of the full featured models, yet offer remarkable characteristics. This product is available in two models, the FSL-0010 and FSL-0020, covering the 0.65 to 10 GHz and 0.65 to 20 GHz win SEMICONDUCTORS

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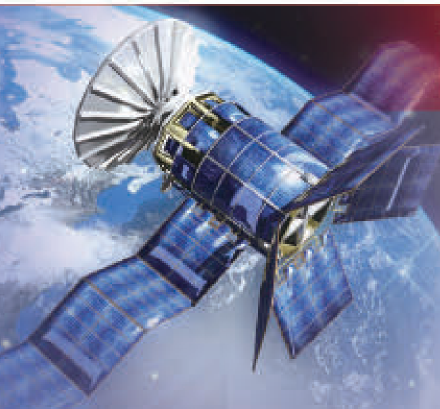

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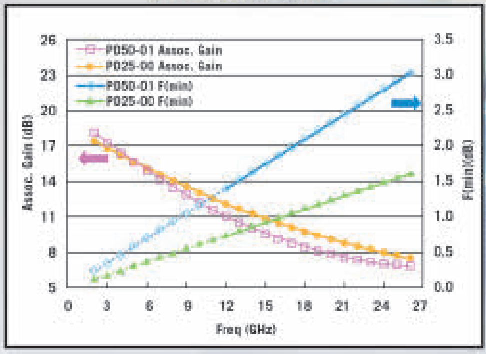
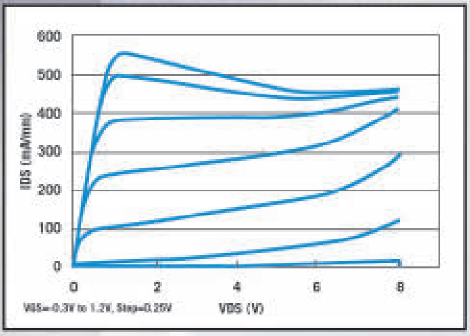
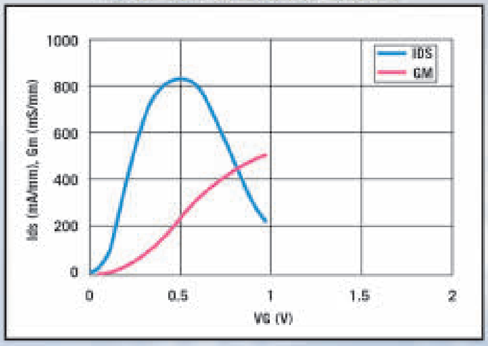


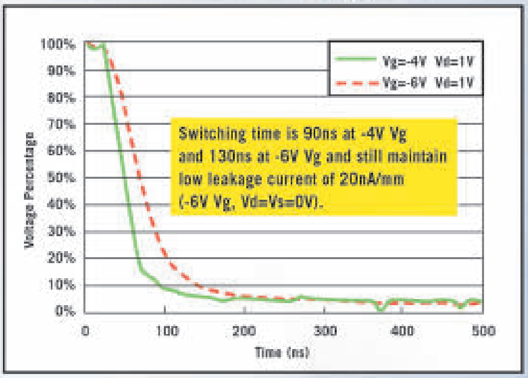
E-mode I-V Characteristics



E-mode Transfer Curve



D-mode Switching Speed



Switching time is 90ns at -4V Vg and 130ns at -6V Vg and still maintain low leakage current of 20nA/mm (-6V Vg, Vd=Vs=0V).

D-mode Device Performance

	PD50-01		PD25-00	
	Single	Triple	Single	Triple
Ron (ohm.mm)	1.9	3.7	1.3	2.2
Coff (fF/mm)	168	83	163	92
RonxCoff(ohm.fF)	316	310	209	198

DUT: NOF x UGW= 5 x 12µm

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ranges, respectively. Both models utilize broadband solid-state VCOs that offer fundamental output to 10 and 20 GHz, respectively. In contrast to widely used frequency multiplication schemes, this approach eliminates possible spectrum contamination by subharmonic products. The VCO coverage is extended down by utilizing a frequency divider that improves phase noise and spurious characteristics at lower frequencies as shown in ***Figure 1***. The use of the advanced DDS approach (in conjunction with dedicated spur-reduction circuitry) enables a very fine frequency resolution of 0.001 Hz without a common penalty of slower tuning speed or elevated spurs. The utilized PLL hardware itself needs just a few tens of microseconds to bring the output frequency to a desired value while the output is completely locked and refined within less than a hundred microseconds. Digital signal processing adds extra delays required to receive a tuning command, perform all necessary calculations in accordance with the employed frequency plan, and program individual devices. Hence, the total switching time is specified at 200 μsec in the regular operation mode when new frequency commands are sent one by one. Most of these delays, however, can be reduced or completely eliminated in the list mode. The switching speed in the list mode is specified at 100 μsec regardless of the current and destination frequency (i.e., the specification is valid from “any to any” frequency step within the entire operating range).

The synthesizer includes an internal dual-oscillator reference that is composed by combining TCXO and VCXO devices. This results in excellent thermal stability and low phase noise without a common penalty of large size and high power consumption of OCXO devices. The internal reference is factory calibrated to a GPS standard to ensure adequate accuracy of the synthesized signal. The synthesizer supplies a 10 MHz reference signal to the outside world. The internal oscillator can be automatically locked to an external reference too. The synthesizer also provides the ability to adjust the internal oscillator frequency (via software) for temperature and aging compensation as desired.

Both models include SPI and USB control interfaces and are immediately deployable by connecting them to a personal computer and power source. A soft front panel allows the user to access all synthesizer functions. The synthesizer is shielded in a small metal box measuring 4" × 4" × 0.8". It is biased from a single +12 V DC supply. The built-in self test monitors the synthesizer’s internal temperature and voltages as required. Overall, the exceptional performance and extended functionality make the QuickSyn Lite synthesizer an ideal building block for a variety of instruments and subsystems. Designers restricted by reduced footprint goals, power consumption constraints and the need for low phase noise will appreciate the QuickSyn Lite synthesizer as the single solution to a multitude of design challenges.

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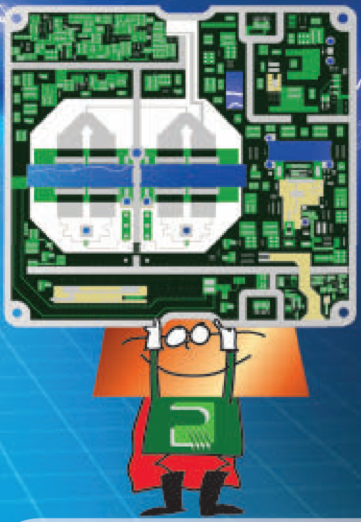


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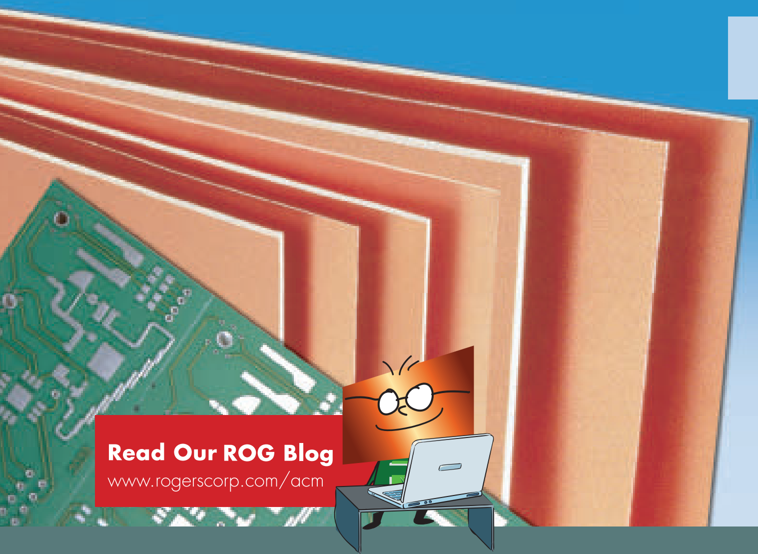

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For Better SWaP, Choose GaN

David Silvius, Director of Strategic Marketing, Richardson RFPD

Today's GaN-based products are rising to the challenge of rapidly evolving demands for size, reliability, linearity, power density and energy efficiency, by providing RF system engineers with the flexibility to achieve significantly higher power and efficiency, with lower part count, board space and resultant cost. GaN technology is suited to meet today's size, weight and power (SWaP) demands better than traditional technologies like GaAs because GaN offers:

- Higher power densities leading to reduced combining losses for a given power target
- Increased efficiency over frequency
- Ability to maintain high performance over wide bandwidths
- Higher thermal conductivity/lower thermal resistance (GaN on SiC)

GaN has better thermal properties than competing GaAs technologies. Thermal conductivity for SiC is roughly 4× that of GaAs. An added benefit is that GaN can support the million hour MTTF reliability benchmark at a junction temperature of 200°C or higher versus 150°C for GaAs. These thermal advantages do not solve the thermal problem at the system level; however, they bring the thermal management concern down to a reasonable design trade-off for the system engineer.

To date, the defense industry has benefitted most from advances in GaN technology, primarily due to the pulse and continuous wave GaN power devices from suppliers like Macom, Microsemi, Nitronex, TriQuint and UMS.

Macom recently announced its portfolio of GaN in plastic high power transistors. Packaged in a convenient 3×6 mm plastic package and well suited for pulsed radar, TDMA amplifiers, ultra wideband power amplifiers, and high power SatCom applications, the wideband transistors should compete well against traditional GaAs devices, thanks to GaN's higher power density.

Microsemi is focused on high pulsed power products for avionics and radar. Its 1011GN-700ELM GaN power transistor is specifically designed for extended length message Mode-S transponders and is capable of delivering 700 W of pulsed peak power and over 21 dB power gain with greater than 70 percent efficiency at 1030 MHz. For S-Band radar applications, there is the Microsemi 2729GN-500, offering 12 dB gain, 500 W of pulsed RF output power at 100 µs pulse width, and 10 percent duty factor across the 2700 to 2900 MHz band. And Microsemi has recently released 50 V products, including the 0912GN-650V — a GaN on SiC HEMT transistor capable of providing over 17 dB gain, 650 W of pulsed RF output power at 128 µs pulse width, 10 percent duty factor across the 960 to 1215 MHz band.

In addition to significant funding from DARPA, GaN development is now occurring globally. Europe-based supplier UMS has introduced a family of high-performance GaN HEMTs with up to 50 W Psat CW and up to 6 GHz frequency coverage from its wafer foundry in France. UMS has also recently released a 0.25 µm GaN HEMT foundry process to support industry development of new GaN components.

Besides pulse power, GaN is finding use within CW appli-

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cations, such as commercial and military communications. The inherent broadband and high gain features of GaN lend themselves well for fixed mobile markets. The ability of GaN to maintain gain and stability at lower DC voltages is especially suited for mobile and portable communications, such as military manpack and land mobile radio handsets.

Nitronex has been a leader in GaN manufacturing with its unique GaN on Si process that allows for higher volume manufacturing using a lower cost substrate. The company's 28 V, 5 W NPTB00004 and NPTB00025 RF power transistors are increasingly popular for military communication applications. In addition, Nitronex has recently introduced a new family of 48 V GaN-on-Si RF power transistors that operate up to 4000 MHz, are designed for CW, pulsed and linear operation, and include plastic and ceramic package options. The NPT2010, for example, is optimized for DC to 2200 MHz operation and offers 17 dB gain, 50.5 dBm Psat, 64 percent power added efficiency and 61 percent drain efficiency.

And GaN is branching out to encompass more than power amplification. For example, in addition to its industry-leading array of GaN-based semiconductor products (including discrete transistors, power amplifiers and low noise amplifiers), TriQuint Semiconductor now offers a range of GaN-based switches that are capable of achieving up to five times the power handling of GaAs.

TriQuint's GaN switches achieve high levels of power handling in a small form factor, particularly versus insertion loss. For example, a 3 W GaAs switch at 6 GHz may have about 2 dB insertion loss, whereas a 40 W GaN switch at 6 GHz may have less than 1 dB insertion loss for the same amount of isolation. Additionally, GaN switches require very low current — measured in microamps (μA) as opposed to milliamps or even amps for PIN switches. And because GaN essentially brings more power per mm^2 to the table, small but higher power-handling components are needed to switch that level of power. TriQuint's TGS2351-SM, for example, can switch 40 W, as compared to GaAs FET-based switches that can typically switch between 3 and 10 W in a similar board space.

Applications include radar, EW and communications — all of which require the output power versus size advantage that is only available through GaN. There is also plenty of GaN development in the works for commercial markets like weather and marine radar, CATV and cellular infrastructure. For these applications, cost is a bigger driver than it is for defense applications; but as the cost of GaN is coming down, it is certainly more of an option today than it was just two years ago. Even today, GaN offers cost benefits over other technologies when viewed in terms of dollars per watt, as opposed to the standard dollars per square millimeter comparison. As the frequency increases from S- and X-Band to Ku-Band, GaN's dollars per watt cost offers a markedly better value than GaAs and other existing technologies, both now and in the years ahead. ■

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CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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DefenseNews

Cliff Drubin, Associate Technical Editor

NV Selected as UAV Development Center

The Federal Aviation Administration (FAA) announced that Nevada has been selected as one of six locations to be a center for unmanned aerial vehicle (UAV) development in the United States. As a UAV development site, the most likely economic forecast shows that there could be thousands of jobs for UAS direct employees with an average wage of approximately $62,000; an estimated $2.5 billion in economic impact in present dollars; and an estimated $125 million in annual state and local tax revenue.

"Being selected as one of six sites for UAV development in the country is a historic moment for Nevada," Governor Brian Sandoval said. "With the climate and air space of Nevada, we are uniquely equipped to help expand the development of UAVs. We have also partnered with private industry and academia to establish the curriculum necessary to create the UAS civilian workforce of the future in Nevada. Our state has been preparing for this selection and we are ready to enter this new era of aviation history. I thank Senator Reid for his tireless work on this issue and the opportunity to work together on this momentous day for our state."

The selection follows Nevada's application, submitted to the FAA in May of 2013. Nevada's application included the state as the direct applicant, and a 28 member team including the Nevada System of Higher Education, the Nevada National Guard, Bowhead Systems, Navigator Development and Drone America. Team members, who represented a cross-section of public and private partners, industry and academic leaders, within the northern and southern regions of the state, identified three test ranges and four test sites in the state's application.

Courtesy of U.S. Air Force

Increasing Range of Military Applications for GPS/GNSS Devices Will Drive Market

Global spending on GPS/GNSS systems and devices is expected to remain robust over the coming decade, according to Strategic Defence Intelligence new report – The Global Military GPS/GNSS Devices Market 2013-2023 – which forecasts market growth at a CAGR of 4.6 percent, primarily driven by their extensive use alongside associated software in modern or fourth-generation warfare.

The increasing breadth of uses for GPS technology, which now sees systems evident in virtually every operational aspect of a country's armed forces, will further drive the market, with auto-landing for aircraft, GPS embedded uniforms, and the development of GPS guided parachutes just some of the wide range of military applications for GPS technology that will help precipitate growth through to 2023.

The austerity measures adopted by a number of western countries – such as the U.S., Germany, France, Italy and the UK – are however expected to adversely affect the growth rates in the sector. Whilst the continued fallout of the global economic crisis are set to remain a detrimental factor to the market's growth, this impact is predicted to taper off toward the end of the coming decade.

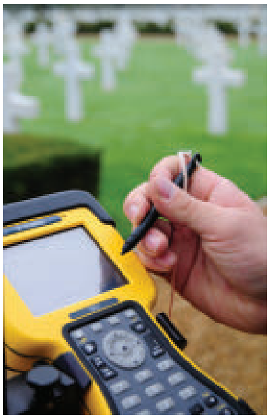
To capitalize on the opportunities presented by market growth, organizations with a vested interest in the global GPS/GNSS devices market must remain sensitive to the key drivers of the market, thereby facilitating informed business decisions that maximize profits with minimized risk.

Advancement in Anti-Jamming

The recent increase in jamming and spoofing activities has resulted in the creation of a relatively new market in the sector, that of the anti-jamming devices and related systems. The illegal sale of jamming devices on the Internet, and their subsequent proliferation, particularly by rogue nations and terrorist outfits, has made their purchase almost mandatory by countries across the world. Products are now being launched to counter these threats, either by overcoming jamming signals or locating their source. This is expected to act as a significant driver on the global military GPS/GNSS market to 2023.

Increased Expenditure on Satellite Navigation Programs

A satellite navigation system provides GPS positioning from a global perspective, and is thus of utmost importance for modern day military operations which rely on accurate real time data relating to hostile forces in order to carry out precision attacks. It is here that GPS/GNSS devices assume an important role, as they are imperative in the transfer of signals from satellites back to stations on earth.



Courtesy of U.S. Air Force

As a result, several major defense spenders across the globe – including India, China, Russia, and the UK – have now launched or initiated the development of satellite navigation systems. This is driven by the desire of militaries to cover more areas and derive as much accurate information by a range of GNSS receivers/sensors in the shortest

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possible time. It is also worth noting that the commercial use of this technology for non-combat purposes is increasing and is expected to encourage expenditure by helping to lower the overall costs of GNSS/GPS receivers.

USAF Awards LM Contract to Complete Two More GPS III Satellites

The U.S. Air Force has awarded Lockheed Martin more than $200 million in contract options to complete production of its fifth and sixth next-generation global positioning system satellites, known as GPS III.

Last February, the Air Force awarded Lockheed Martin a fixed price $120 million contract to procure long lead parts for a second set of four GPS III space vehicles (SV 05-08). This new award provides funding to complete the first two satellites (SV 05-06) in this order. Full production funding for the next two space vehicles (SV 07-08) is expected in 2014.

Lockheed Martin is already under contract to produce four GPS III space vehicles (SV 01-04). The first two GPS III satellites are currently on the production floor at Lockheed Martin's GPS III Processing Facility (GPF) in Denver, CO.

"Lockheed Martin's GPS III program has a rigorous testing plan and mission success focus aligned with the Air Force's back-to-basics approach, and is specifically designed to enable predictable and affordable recurring production through disciplined development and early risk reduction," said Mark Stewart, vice president of Lockheed Martin's Navigation Systems mission area.

GPS III is a critically important program for the Air Force, affordably replacing aging GPS satellites in orbit, while improving capability to meet the evolving demands of military, commercial and civilian users. GPS III satellites will deliver three times better accuracy, provide up to eight times improved anti-jamming capabilities, and include enhancements that extend spacecraft life 25 percent further than the prior GPS block. It will be the first GPS satellite with a new L1C civil signal designed to make it interoperable with other international global navigation satellite systems.

The GPS III team is led by the Global Positioning Systems Directorate at the U.S. Air Force Space and Missile Systems Center. Lockheed Martin is the GPS III prime contractor with teammates Exelis, General Dynamics, Infinity Systems Engineering, Honeywell, ATK and other subcontractors. Air Force Space Command's 2nd Space Operations Squadron (2SOPS), based at Schriever Air Force Base, CO, manages and operates the GPS constellation for both civil and military users.

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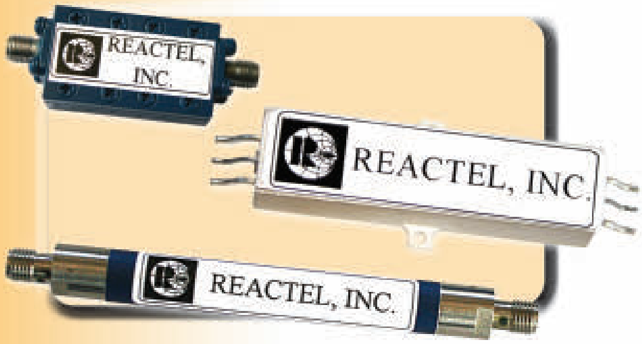

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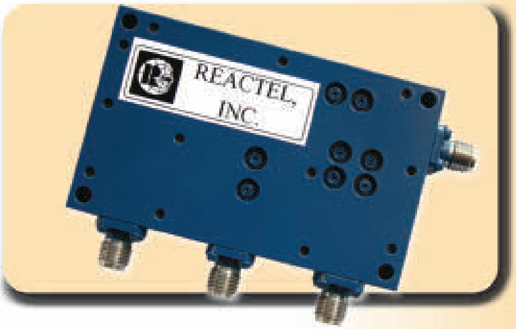

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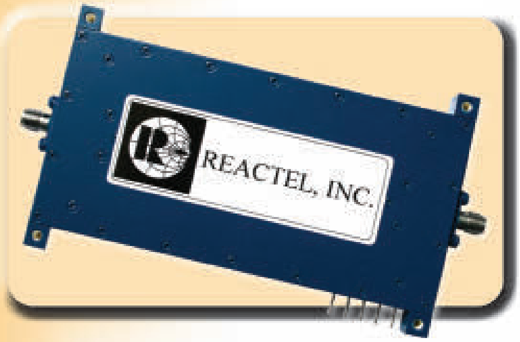

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EU and South Africa to Step Up Cooperation

The EU and South Africa will step up collaboration in the fields of earth observation, research infrastructures and global health research, senior officials agreed at the 12th Joint Science and Technology Cooperation Committee meeting. The meeting took place to review and plan new priorities of collaboration under the new Horizon 2020 EU research and innovation programme and similar South African research programmes.

In December 2013, the European Commission launched the first calls under Horizon 2020, with several focus areas for cooperation with Africa in general and South Africa more specifically.

In the context of the post-2015 strategy for the Group on Earth Observations (GEO) both parties will explore a possible joint action to support the AfriGEOSS initiative and Africa-EU GEO-related cooperation. In the domain of research infrastructures, the EU and South Africa will discuss synergies between the European Strategy Forum for Research Infrastructures (ESFRI) and the South African national research infrastructure roadmap. Cooperation in the area of radio astronomy will specifically be encouraged, including support for the Africa-European Radio-Astronomy Platform (AERAP). In preparation for the second programme of the European and Developing Countries' Clinical Trials Partnership, the EU and South Africa will work together to mobilise broader African participation.

The meeting took note of South Africa's planned association to the EUREKA Network for industrial research. Another possible future area of cooperation discussed was marine research.

Astrium and Inmarsat Sign Agreement on Global Xpress

Astrium and Inmarsat have reached a strategic distribution partnership agreement which will see Global Xpress® high-speed broadband services made available to Astrium Services' large partner and customer base through its worldwide distribution channels. The strategic agreement will cover key vertical markets, including the maritime as well as the government and defence sector, initially in Europe. In due course, the Astrium Services Global Xpress offering will encompass all service types – packaged services, bandwidth capacity, as well as commercial and military Ka-Band.

Inmarsat's Global Xpress Ka-Band satellite network will provide a seamless worldwide broadband service. The first Global Xpress satellite was successfully launched on 8 December 2013 and is on schedule to achieve global coverage by the end of 2014. Astrium Services customers will benefit not only from the world's first globally available mobile broadband network, but also from a comprehensive range of global connectivity services designed for commercial and government markets.

"This agreement is the natural continuity of a long-standing partnership between Astrium Services and Inmarsat," Evert Dudok, CEO of Astrium Services said. "Astrium Services has been Inmarsat's number one distribution partner since we acquired Vizada in December 2011. We are eager to continue this strong relationship by bringing the benefits of Global Xpress to our customers using our satcom expertise."

Rupert Pearce, CEO of Inmarsat said: "We are delighted that Astrium has committed to continue its long and valued partnership with Inmarsat into the Global Xpress era. Global Xpress is going to change the game in mobile satellite connectivity and we are delighted that Astrium Services is joining us in bringing the benefits of the world's first high speed global broadband service to its impressive portfolio of customers. Astrium serves an unparalleled range of market segments and, together with their powerful network of service providers, will help make Global Xpress the preferred choice for end-users in those segments, extending and deepening our global business partnership."

> "Global Xpress is going to change the game in mobile satellite connectivity..."

EU Boosted by Eight New Research Partnerships

The European Commission has launched eight contractual Public Private Partnerships (cPPP) of strategic importance for European industry. The partnerships will leverage more than €6 billion of investments to be allocated through calls for proposals under Horizon 2020. Each euro of public funding is expected to trigger additional investments of between €3 and €10 to develop new technologies, products and services which will give European industry a leading position on world markets.

European Commissioner for Research, Innovation and Science Máire Geoghegan-Quinn said: "Europe needs industry to innovate to create income and jobs." She continued, "We want these contractual PPPs to have a substantial impact on the competitiveness of the EU industry, on sustainable economic growth and the creation of new high-skilled jobs in Europe."

A number of the eight cPPPs are relevant for the RF and microwave industry, with the most significant being Advanced 5G networks for the Future Internet (5G), aimed at stimulating the development of network internet infrastructure to ensure advanced ICT services for all sectors and users.

Vice President Neelie Kroes, commissioner responsible for the digital agenda, said: "This is a great opportunity for Europe. These PPPs will maintain our global lead in robotics, photonics, high performance computing, telecoms and give us a head start in smart cities, intelligent transport,

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“Europe needs industry to innovate...”

education, entertainment, media and other promising markets. Combined with a comprehensive industrial strategy, the PPPs will ensure vigorous European leadership and a better future for all.”

The cPPP areas represent a large part of the European economy. The telecommunications sector, for instance, employs at least 1.2 million in the EU and Europe has a 27 percent share of a €17,000 billion global market, while the photonics industry employs 300,000 people directly, with a share of 18 percent of the €350 billion global photonics market. Also, European manufacturing industry generated an added value of €1,400 billion in 2010 and accounted for more than one in five European jobs, while the process industry sector accounts for 6.8 million jobs in more than 450,000 enterprises.

European Standardisation Expert Seconded to China

Major economic, political and social changes in Asia, Europe and other regions of the world are shaping new markets and creating new opportunities for trade and investment relations between these regions and Europe. Recognizing the importance of these developments, CEN, CENELEC and ETSI in partnership with the EC and EFTA, are intensifying the cooperation on standardization issues with these regions.

Major economic, political and social changes... are shaping new markets and creating new opportunities for trade and investment relations...

This endeavour is aligned with the EU policy to promote European Standardization in strategically important regions/countries. After two successful phases of the SESEC project (2006-2008 and 2009-2011), the stakeholders (EC, EFTA and the ESOs) are recruiting a third Seconded European Standardization Expert in China (SESEC III).

CEN is managing the project and reports to the SESEC III project Steering Committee, involving the three ESOs, the European Commission and EFTA. The contract foresees the appointment of an expert who will be trained by partners, prior to operating in China for a period of 36 months.


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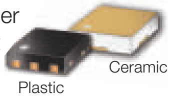
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Cliff Drubin, Associate Technical Editor

Intel Acquires Mindspeed's Wireless Business

Mindspeed has announced that Intel is acquiring its wireless business for an undisclosed sum. Mindspeed announced its acquisition by MACOM last month and at the same time its intention to look for a buyer for its wireless assets. The Intel deal is expected to close this month.

ABI Research reported on Mindspeed's potential shift in strategy in the May 2013 ABI Insight, "A Change of Mindspeed," which was when Mindspeed announced that it was seeking strategic alternatives and retained Morgan Stanley to assist in the process. With last month's MACOM acquisition, it appears as though the final piece of the puzzle is falling into place.

Mindspeed, a spin-off from Conexant Systems, acquired the U.K.-based small cell SoC designer Picochip in January 2012 for US$75 million. Mindspeed stands out because of its strong share positions in small cells. Mindspeed also claims the top spot for overall share of the small cell baseband SoC market and almost half of the 3G small cell business in 2012, which includes its Transcede SoC portfolio.

Mindspeed brings market leading small cell baseband SoCs to Intel and a strong roadmap and portfolio for LTE. It can count among its design-ins: ip.access, Cisco/Ubiquisys, Alcatel-Lucent, Sagem, Argela, GWT, Alpha Networks, Contela, ZyXEL, Askey, C&S Micro and SK Telesys. Earlier in 2013, Mindspeed claimed 60 design engagements, 34 of which were for LTE. Mindspeed stands out among semiconductor vendors' shipping solutions for all four access technologies: HSPA, TD-SCDMA, TD-LTE and FD-LTE.

> Mindspeed brings market leading small cell baseband SoCs to Intel and a strong roadmap and portfolio for LTE.

In addition to the Mindspeed/Picochip acquisition in the rapidly consolidating small cell SoCs market, ABI Research has already seen Broadcom acquire Percello and Provigent in 2011 and NetLogic in 2012; Cavium acquire Wavesat in 2011; and Qualcomm acquire DesignArt. Now there is a new entrant alongside the remaining and more established players, which includes Qualcomm, Freescale, Broadcom and Cavium.

Intel says that its platforms already handle application processing, control processing and packet processing. With the Mindspeed acquisition, it can now also offer the "Fourth Workload:" signal processing. According to the company, its goal is to consolidate all four workloads on IA. It claims to have made progress on this in its collaboration agreements with SKT and China Mobile on C-RAN architectures.

C-RAN stands for both centralized RAN and cloud RAN, and is based around the idea of enabling lower cost, centralized control of radio resources in a baseband hotel or pool — much like a data center. If Intel can merge all four workloads on its platforms, then it will be well positioned to acquire a major portion of the C-RAN silicon market.

IMS Deployments Edging Up as Leading LTE Operators Ramp for VoLTE, Reaching US$4B by 2017

ABI Research finds IMS Core Network deployments are edging up as operators put the necessary infrastructure and capacity in place for planned 2014 VoLTE launches. Spending for the core network products (HSS, CSC, Media Controllers and Gateways, MSF, IBCF, SBC and P-CSCF) integral to a functioning IMS network will reach US$4 billion by 2017. "We see increasing IMS Core Network revenues through 2017," comments Joe Hoffman, research director, "after which IMS revenues will flatten and reflect capacity expansion."

IMS spending for mobile 4G markets follows the LTE deployments, as operators seek to get their network coverage in place, stabilized and compatible mobiles for VoLTE become available. The leading LTE market, North America, will peak 2015 to 2016, while the largest market, Asia-Pacific shows continued growth into the foreseeable future. Virtualization will be widespread since much of the IMS solution is delivered on ×86 architecture and works on bare metal or virtualized platforms.

While the IMS driver is clearly VoLTE, operators will also find competitive advantage with a standardized, network-integrated solution that can also deliver superior user experience for WebRTC and OTT services under network congestion. "Many operators will take a wait-and-see attitude as they already have 3G and CSFB for voice," continues Hoffman, "but they will quickly comprehend the monetization advantage with 4G and Voice, and adjust their strategies." Simply put, the whole world is moving to all-IP, and 4G/IMS/VoLTE is the standard migration path for Telecom.

> Simply put, the whole world is moving to all-IP, and 4G/IMS/VoLTE is the standard migration path for Telecom.

4G LTE Connections to Reach 2B in 2018

Global 4G LTE connections will grow from 238 million in 2013 to 2 billion in 2018 according to a new forecast from Strategy Analytics' Wireless Operator Strategies service. The report, "Worldwide Cellular User

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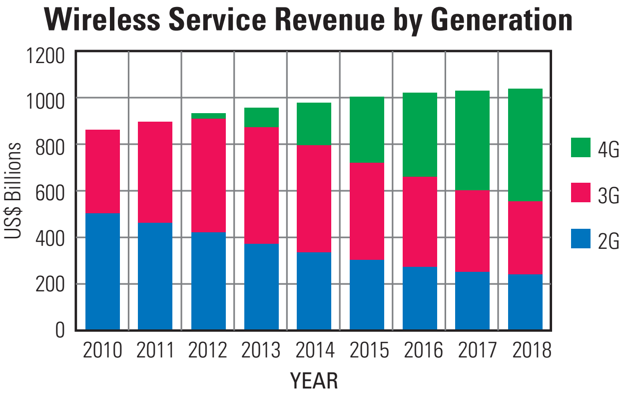
Forecasts, 2013-2018," predicts that LTE networks will account for almost half of mobile service revenue globally by 2018, up from under 10 percent in 2013.

The U.S., Japan and South Korea are finally starting to see their grip on the global LTE market weaken in the second half of 2013. Their share of global connections will fall from 90 percent at the start of 2013 to 76 percent by year end, with Western Europe in particular generating more meaningful 4G volume as LTE increasingly penetrates operators' smartphone portfolios.

> "...China should be the catalyst driving lower-cost 4G devices into the global market..."

"Even in 2014, the U.S., Japan and South Korea will remain the dominant LTE markets, but all eyes will be on China," comments Phil Kendall, director of Strategy Analytics' Wireless Operator Strategies service and author of the report. "With TD-LTE licenses now awarded and China Mobile particularly keen to expand and launch its already large precommercial network, China should be the catalyst driving lower-cost 4G devices into the global market over the next two years."

Susan Welsh de Grimaldo, director, wireless operators & networks, added, "Mobile operators are increasingly looking to LTE for value creation in the market, with the technology currently generating average revenue per user (ARPU) almost four times the global average. That premium is more a result of the regional mix of LTE connections at present and we forecast just 1.5 percent annual growth in wireless service revenue over the next five years. In this scenario, LTE is more about securing higher-value customers than accelerating market growth."



Source: Strategy Analytics, 2013

RF PARTS.
AND RF SMARTS.

Around the **Circuit**

Laura Glazer, Staff Editor

MERGERS & ACQUISITIONS

AMETEK Inc. has acquired the **Teseq Group**, a manufacturer of test and measurement instrumentation for electromagnetic compatibility (EMC) testing, for $92 million. Headquartered in Luterbach, Switzerland, the privately held company has annual sales of approximately $53 million. Teseq manufactures a broad line of conducted and radiated EMC compliance testing systems and RF amplifiers for a wide range of industries, including aerospace, automotive, consumer electronics, medical equipment, telecommunications and transportation. Teseq joins AMETEK as part of its Electronic Instruments Group (EIG).

Koch Industries Inc. has completed its $7.2 billion acquisition of **Molex Inc.** The acquisition was finalized through the merger of Koch Industries' wholly owned subsidiary, Koch Connectors Inc., with and into Molex. As a result of the merger, Molex is now an indirect wholly-owned subsidiary of Koch Industries Inc., retaining its name and headquarters in Lisle, IL. The company will continue to be operated by its current management team. Under the merger agreement, all of the outstanding shares of Molex were converted into a right to receive $38.50 per share in cash, plus an adjustment of $0.18 per share representing a pro rata portion of the regular quarterly cash dividend.

TRM Microwave Inc. announced that it has completed the acquisition of the high-power product line of **Putnam RF Components** of Manchester, NH.

COLLABORATIONS

Anritsu Co. announces a working cooperation with **Wild River Technology** to provide test solutions that meet the rigorous test requirements associated with high-speed serial data interconnects, SERDES testing, cables and backplanes used in Next Generation Networks (NGN). As part of the cooperation, Anritsu has introduced the Wild River Technology CMP-28 and CMP-32 channel modeling platforms as complements to the Anritsu VectorStar™ MS4640B VNA series. Together, the CMP platforms and VectorStar provide a means of accurately verifying measurement-simulation correlation for signal integrity engineers and designers working on high-speed systems ranging from 6 to 32 Gbps data rates.

Micron Technology Inc., a provider of advanced semiconductor solutions, announced its collaboration with **Broadcom Corp.** to develop the industry's first solution designed for customers challenged by an intrinsic DDR3 timing parameter called tFAW, or four activate window. The Micron solution validated by Broadcom reduces the tFAW value from 35 ns to 30 ns for a 2 KB page size, DDR3-2133, improving operations per second by 18 percent. The four activate window solution enables Broadcom's BCM88030 200 Gb/s NPU to achieve extremely scalable L2, IPv4 and IPv6 lookup capacities at wire speed performance using Micron's DDR3 memory.

CEA-Leti announced an agreement with **Qualcomm Technologies Inc.**, a subsidiary of Qualcomm Inc., to assess the feasibility and the value of Leti's sequential 3D technology, in which Leti has shown a number of significant technical advances. The arrangement between Leti and Qualcomm Technologies will allow the critical assessment of this technology in the context of practical applications, further evaluating the potential impact of this sequential 3D technology for future industrialization.

Ericsson successfully supported **Telstra**, an Australian telecommunication operator, in further enhancing its LTE Advanced (LTE-A) commercial service network. Telstra and Ericsson successfully demonstrated 300 Mbps downlink speeds for a data transfer across Telstra's live network. The demonstration used Ericsson's commercially released LTE-A software which aggregated 20 MHz bandwidth within the 1800 MHz band and 20 MHz bandwidth within the 2600 MHz band. The demonstration included downloading video content while measuring download throughput.

NEW STARTS

Agilent Technologies Inc. revealed the name of the electronic measurement company it expects to spin off in early November 2014 as **Keysight Technologies**. The name Keysight conveys the ability to see what others cannot, offering the critical or key insights to understand and unlock the changing technology landscape. Keysight will concentrate solely on the electronic measurement industry, focusing on its test and measurement customers. The new company will include the entire portfolio of Agilent electronic measurement products and the largest sales and support team in the test and measurement industry. Keysight will be headquartered in Santa Rosa, CA and have approximately 9500 employees in 30 countries.

NXP Semiconductors and **Datang Telecom Technology Co. Ltd.** have established a joint venture that is claimed to be the first true automotive semiconductor company in China. The joint venture will focus on developing and marketing semiconductor solutions for the domestic hybrid and electric car market, a top priority in the latest five-year plan of the Chinese government. The new company – **Datang NXP Semiconductors Co. Ltd.** – will be headquartered in Nantong, China, close to Shanghai. It will be a fabless company that primarily serves the domestic Chinese market, focusing on the research, development and sale of advanced application specific automotive ICs in high performance mixed signal technology.

ACHIEVEMENTS

The **Z-Wave Alliance**, an open consortium of leading global companies deploying Z-Wave, the world's largest ecosystem for wireless control products and services, announced the approval of radio frequency allocations

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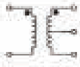
Model Number	Frequency (MHz)	Impedance Ratio	Schematic
TM4-0	0.2 - 350	4:1	
TM1-0	0.3 - 1000	1:1	
TM1-1	0.4 - 500	1:1	
TM1.5-2	0.5 - 550	1.5:1	
TM2-1	1 - 600	2:1	
TM1-6	5 - 3000	1:1	
TM2-GT	5 - 1500	2:1	
TM4-GT	5 - 1000	4:1	
TM8-GT	5 - 1000	8:1	
TM4-1	10 - 1000	1:4	
TM4-4	10 - 2500	1:4	
TM1-2	20 - 1200	1:1	
TM1-9	100 - 5000	1:1	
TM1-8	800 - 4000	1:1	

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that will bring Z-Wave control and automation to the South Korean market. The Korean Communications Commission (KCC), in tandem with the nation's regulatory National Radio Research Agency (RRA), has approved three frequency bands suitable for Z-Wave's sub-gigahertz transmission protocol. The approval of these frequencies for control and automation applications brings the benefits of the world-standard Z-Wave wireless protocol to the world's most advanced nation for information and communications technology (ICT), according to the International Telecommunications Union (ITU).

Isola Group S.a.r.l. announced that its plant in Suzhou, China has received ISO/TS 16949 certification. This is the company's third such certification, which represents the highest international quality standard for the automotive industry. Isola's plants located in Duren, Germany and Huizhou, China are similarly certified. The certification of the Suzhou facility is a significant achievement in the company's strategic roadmap to further its presence in the automotive market.

San-tron Inc. announced that it has achieved its AS9100 certification, a quality standard for companies that design, develop or produce aerospace products. This certification along with its ISO 9001:2008 certification means that San-tron has met all of the requirements specific to aerospace product safety and reliability.

EADS North America Test and Services announced that its software, hardware and systems development unit has been appraised at Level 3 of the CMMI Institute's Capability Maturity Model Integration (CMMI) for Development. The appraisal was performed by Delivery Excellence Inc. CMMI is a process improvement model that provides organizations with the essential elements of effective processes that ultimately improve their performance. An appraisal at maturity level 3 indicates the organization is performing at a "defined" level. At this level, processes are well characterized and understood, and are described in standards, procedures, tools and methods.

CONTRACTS

The **U.S. Navy** has awarded **BAE Systems** a three-year, $171 million contract to continue providing engineering and integration support to its Fleet Ballistic Missile Program. Specifically, the work will focus on the Navy's Trident II D-5 submarine-launched ballistic missiles. The company has supported the Navy's Trident D-5 program for more than 50 years, including during the evolution of the program through the Polaris, Poseidon and Trident lifecycles. The current design and development of the U.S./U.K. Common Missile Compartment is part of the Ohio Class Submarine replacement program.

Rockwell Collins has been selected by the Defense Advanced Research Projects Agency (**DARPA**) to develop a direct conversion digital receiver based on photonic technology. The three-year contract for the DISARMER program is valued up to $8.5 million. Rockwell Collins seeks to


Mini-Circuits
MCL

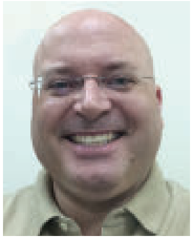
apply the photonic analog to digital converter (ADC) technology developed under the recently completed DARPA RADER program to create a digital receiver that can accommodate X-Band frequencies.

Comtech Telecommunications Corp. announced that its Santa Clara, CA-based subsidiary, **Comtech Xicom Technology Inc.**, received an order for approximately $7 million from a U.S.-based system integrator for traveling wave tube amplifiers (TWTA) for a major U.S. Army satellite communications program.

Exelis is supporting Japan's forecasting capabilities with the delivery of its first advanced weather satellite payload to **Mitsubishi Electric Corp.**, based in Japan. Mitsubishi Electric will integrate the AHI into the Himawari-8 satellite for the Japan Meteorological Agency. The Himawari-8 and -9 geostationary satellites will replace the Multifunctional Transport Satellite (MTSAT) series. Himawari-8 is scheduled to launch next year. Unlike the MTSAT series, which performs both meteorological and aeronautical functions, to include air-traffic control communications and position information, Himawari-8 and -9 will have a dedicated meteorological mission.

PEOPLE

Jackie Lau joins **OML** as its new product marketing manager. Graduating with a bachelor of science degree in marketing from San Jose State, Lau brings with her 12 years of sales, marketing and management experience from the retail industry. She is looking forward to bringing her passion to the millimeter wave industry.



▲ *James Riter*

James (Jim) Riter has joined the **Richardson RFPD** sales team. He is focused on the RF, wireless, energy and power markets as a field sales engineer, supporting customers in NJ and eastern PA. Prior to joining Richardson RFPD, Riter worked as director, business development & marketing for MECA Electronics, where he was responsible for global sales and marketing projects. Prior to that, he was director of sales & marketing for SGMC Microwave. He received a bachelor of business administration degree from County College of Morris, in Randolph, New Jersey.

D.L.S. announced that **Tim Lusha** is joining its team of seminar instructors. Lusha has been with D.L.S. for the past 17 years. He has four iNARTE certifications: EMC Engineer, EMC Laboratory Engineer, EMC and ESD Technician. He is a current member of RTCA/DO-160, IEEE and ESDA. Lusha has worked at D.L.S.'s Wisconsin facility involved in FCC, EC and VCCI commercial requirements as well as measurement uncertainty, transmitters and calibrations. He is presently at the Wheeling location immersed in MIL STD 461 and DO-160 topics, custom test setups, software programs and networks for lightning and related testing.

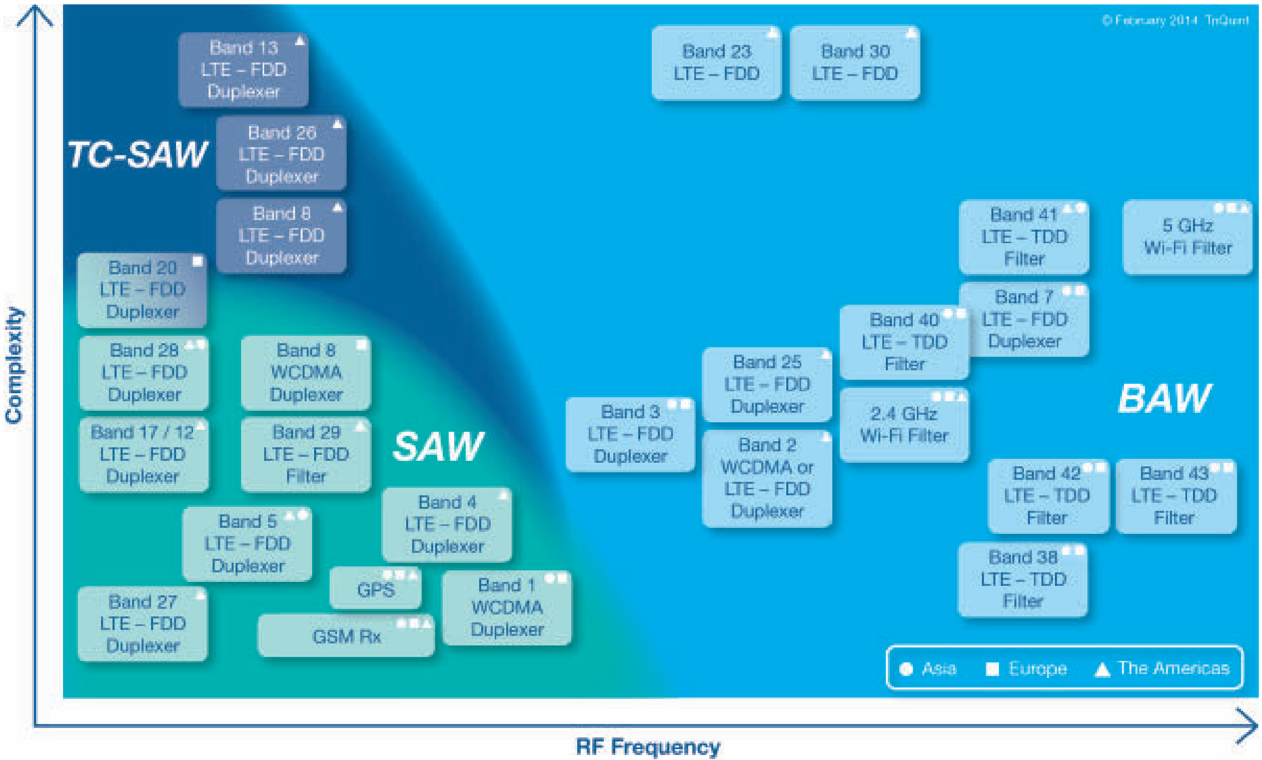
Enabling LTE Advances with Premium Filters

Solving complex LTE interference challenges is a key design consideration for next-gen smartphones, as the information provided below makes clear. With every model you create, you need to develop multiple platforms tailored for different regions, and then factor in global roaming, too. As band counts rise and higher filter performance is required, TriQuint is leveraging its advanced filter technologies, such as BAW and TC-SAW, to help you tackle the industry's toughest interference problems.

Key Frequency Bands

Band	Mobile Phone Tx Band (MHz)			Mobile Phone Rx Band (MHz)			Duplexer / Filter Mode	LTE Bandwidths	Recommended Filter / Duplexer Technology	Region(s) of Usage
1	1920	-	1980	2110	-	2170	FDD	5, 10, 15, 20	SAW	Asia, EMEA, Japan
2	1850	-	1910	1930	-	1990	FDD	1.4, 3, 5, 10, 15, 20	BAW	LatAm, N. Amer.
3	1710	-	1785	1805	-	1880	FDD	1.4, 3, 5, 10, 15, 20	BAW	Asia, EMEA
4	1710	-	1755	2110	-	2155	FDD	1.4, 3, 5, 10, 15, 20	SAW	LatAm, N. Amer.
5	824	-	849	869	-	894	FDD	1.4, 3, 5, 10	SAW	LatAm, N. Amer.
7	2500	-	2570	2620	-	2690	FDD	5, 10, 15, 20	BAW	Asia, EMEA
8	880	-	915	925	-	960	FDD	1.4, 3, 5, 10	SAW / TC-SAW	EMEA, LatAm
12	699	-	716	729	-	746	FDD	1.4, 3, 5, 10	SAW	N. Amer.
13	777	-	787	746	-	756	FDD	5, 10	TC-SAW	N. Amer.
17	704	-	716	734	-	746	FDD	5, 10	SAW	N. Amer.
20	832	-	862	791	-	821	FDD	5, 10, 15, 20	SAW / TC-SAW	EMEA
23	2000	-	2020	2180	-	2200	FDD	1.4, 3, 5, 10, 15, 20	BAW	N. Amer.
25	1850	-	1915	1930	-	1995	FDD	1.4, 3, 5, 10, 15, 20	BAW	N. Amer.
26	814	-	849	859	-	894	FDD	1.4, 3, 5, 10, 15	TC-SAW	Japan, N. Amer.
27	807	-	824	852	-	869	FDD	1.4, 3, 5, 10	SAW	LatAm
28	703	-	748	758	-	803	FDD	3, 5, 10, 15, 20	SAW	Asia, LatAm
29	N/A	-	N/A	717	-	728	FDD	3, 5, 10	SAW	N. Amer.
30	2305	-	2315	2350	-	2360	FDD	5, 10	BAW	N. Amer.
34	2010	-	2025	2010	-	2025	TDD	5, 10, 15	SAW	China
38	2570	-	2620	2570	-	2620	TDD	5, 10, 15, 20	SAW	Asia, EMEA
39	1880	-	1920	1880	-	1920	TDD	5, 10, 15, 20	SAW	China
40	2300	-	2400	2300	-	2400	TDD	5, 10, 15, 20	BAW	China, India
41	2496	-	2690	2496	-	2690	TDD	5, 10, 15, 20	BAW	China, N. Amer.
42	3400	-	3600	3400	-	3600	TDD	5, 10, 15, 20	BAW	EMEA
43	3600	-	3800	3600	-	3800	TDD	5, 10, 15, 20	BAW	EMEA
44	703	-	803	703	-	803	TDD	3, 5, 10, 15, 20	SAW	Asia
XGP	2545	-	2575	2545	-	2575	TDD	5, 10, 15, 20	BAW	Japan

Leveraging Advanced Filter Technology for Regional Demands



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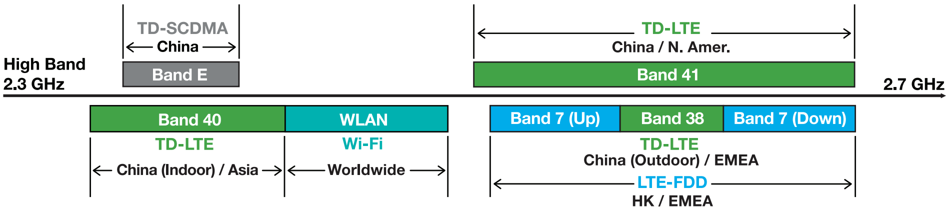
Solving the Toughest RF Challenges

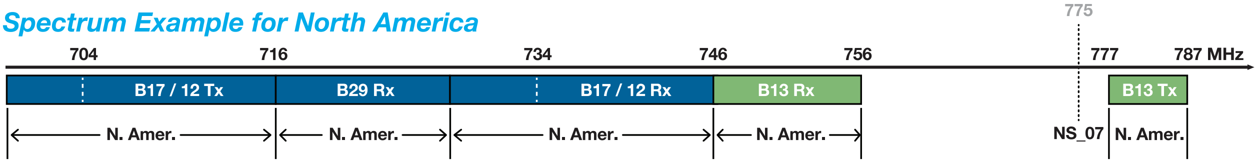
As LTE rolls out, the spectrum crunch is forcing new frequency bands to be squeezed next to existing ones, often with minimal band guards. You can count on TriQuint's specialty filters to meet the most stringent performance requirements for global and regional applications, including those vexing LTE / Wi-Fi coexistence issues. Whether you're designing smartphones or the network infrastructure that connects them, TriQuint simplifies RF design and boosts performance by integrating our premium filters with other components like broadband amplifiers into tiny space-saving modules with more functionality.

Crowded Spectrum Drives Filter Complexity / Performance

Spectrum Example for Asia / EMEA



Spectrum Example for North America



TriQuint Advanced Filtering Solutions

Bands	Part #	Description	Filter Technology	Size (mm)	Features
Band 38 and 40	885043	LTE B38 / 40 Tx Filter	BAW	1.7x1.3x0.5	2-in-1 Filter for Full Band 40 Coverage with Low Loss
Band 7	TQM976027	LTE SE / SE Duplexer	BAW	2.0x1.6x0.9	Excellent Insertion Loss
Band 41	TQQ0041	LTE B41 Rx Filter	BAW	2.0x2.0x0.8	Low IL and High Wi-Fi Attenuation
Band 13	TQQ1013	LTE SE / SE Duplexer	TC-SAW & SAW	2.5x2.0x0.9	Solution for Public Safety NS_07 Requirements
Band 25 and 4	TQQ2504	LTE SE / SE Duplexer	SAW & BAW	3.6x2.0x0.9	B25 / 4 Quadplexer
Band 25 (BC14)	TQM963014	LTE SE / SE Duplexer	BAW	2.6x2.1x0.9	Excellent Triple Beat Performance
Band 2 (PCS) (BC1)	TQM966002	PCS SE / SE Duplexer	BAW	2.5x2.0x0.9	Excellent Triple Beat Performance
Band 25	TQM966025	LTE Diversity Receive Filter	BAW	2.5x2.0x0.8	2.6dB Insertion Loss and 40dB Tx Attenuation
Band 25 / 26	TQQ2526	LTE Duplexer Bank – BAW / TC-SAW	BAW & TC-SAW	2.8x4.7x1.0	Diplexed Duplexer for B25 / 26 Applications
Band 38	885026	LTE B38 Tx / Rx Filter	BAW	1.4x1.2x0.5	Tx or Rx B38 Filter
Band 40	885049	LTE B40 Tx / Rx Filter	BAW	1.4x1.2x0.5	Tx or Rx B40 Filter
WLAN	885033	LTE / Wi-Fi Coexist Filter	BAW	1.4x1.2x0.5	WLAN BPF Filter B38 / 40 Reject
WLAN	885032	LTE / Wi-Fi Coexist Filter	BAW	1.4x1.2x0.5	WLAN BPF Filter B7 / 41 Reject
BC0 / B13	857031	BC0 Notch Filter for SVLTE Applications	TC-SAW	2.5x2.0x0.6	Low Loss, High Attenuation and High Linearity
BC0 / B13	857061	B13 Notch Filter for SVLTE Applications	TC-SAW	2.5x2.0x0.6	Low Loss, High Attenuation and High Linearity
Band 13	856879	LTE SE / BAL Duplexer	BAW	2.5x2.0x0.6	1.5dB (Tx) / 1.6dB (Rx) Insertion Loss
WLAN	885062	LTE / Wi-Fi Coexist Filter	BAW	1.4x1.2x0.5	+28dBm MCS7, Hi Rej B38 / B40, Hermetic MSL0, Temp -40 to 95°C
WLAN	885071	LTE / Wi-Fi Coexist Filter	BAW	1.4x1.2x0.5	+29dBm MCS7, Hi Rej B7 / B41, Hermetic MSL0, Temp -40 to 95°C
WLAN	885070	LTE Coexist / Wi-Fi Bandedge Filter	BAW	1.7x1.3x0.5	+30dBm MCS7, Bandedge Rej 2390 & 2483.5MHz, Hermetic MSL0, Temp -40 to 95°C

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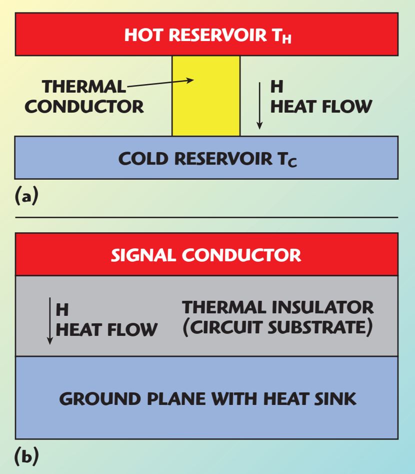
The Impact of Electrical and Thermal Interactions on Microwave PCB Performance

John Coonrod
Rogers Corp., Chandler, AZ

Printed circuit board (PCB) materials are affected by changes in temperature, and interactions between electrical and thermal effects can influence the performance of microwave circuits fabricated on different PCB materials. Heating of high-frequency circuits and PCB materials can occur from devices mounted on a circuit or outside sources of energy. A number of different studies are detailed here to illustrate how different electrical and thermal interactions can influence the behavior of different PCB materials.

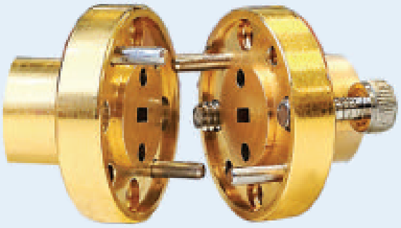
PCB properties change when a PCB is heated. Interactions between electrical and thermal effects can lead to performance issues. For example, circuit designers often ask how much power a particular PCB can handle, and that is very much related to a PCB's electrical and thermal interactions. Understanding these interactions and how they can impact different circuit board properties can greatly assist a designer when working with and troubleshooting PCB materials for high-power microwave applications.



▲ *Fig. 1 The basic thermal model illustrates heat flow in a PCB (a) while this simple thermal model represents a microstrip circuit (b).*

PCB thermal management starts with an understanding of the material's thermal conductivity, and some of those issues were detailed in an earlier article by the author appearing in this publication.[1] The electrical and thermal interactions that can occur within a PCB can be quite different than thermal conductivity, however. Such parameters as thermal conductivity and some electrical properties affect each other.

To better understand the electrical and thermal interactions in a PCB material, it may help to represent the material by a thermal model. Such a module can be portrayed by hot and cold areas or reservoirs connected by a thermal conductive material *(see **Figure 1a**)*. A typical thermal conductor is copper, with a thermal conductivity (TC) of about 400 W/m/K which is considered quite good. For a model that more closely resembles the thermal flow in a microstrip PCB without plated through holes (PTH), the basic thermal model can be modified by having a thermal insulator between the hot and cold reservoirs *(see **Figure 1b**)*. Most substrates used in the PCB industry are considered thermal insulators with typical thermal conductivity values between 0.20 and 0.30 W/m/K. The top copper layer is assumed to be the signal layer (or hot reservoir) while the bottom copper layer is assumed to be the ground plane (or cold reservoir), and Figure 1b assumes that a heat sink is attached to the ground plane.



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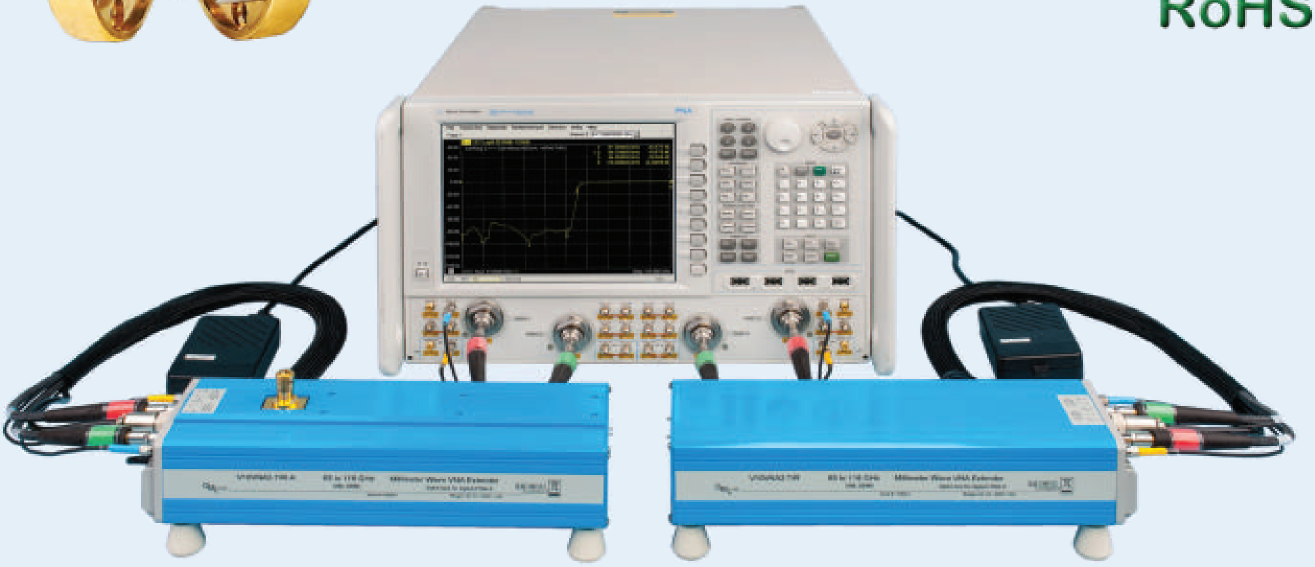


In regard to the basic thermal model in Figure 1a, the relationship for the transfer of heat between the hot and cold reservoirs is:

$$H = -kA\frac{\Delta T}{L} \quad (1)$$

$$H = -kA\frac{(T_H - T_C)}{L} \quad (2)$$

where H is heat flow, k is the thermal conductivity, A is the area at the reservoir-thermal conductor interface, ΔT is the heat difference, and L is the length of the thermal conductor joining the reservoirs. In this model, it is assumed the temperature of the thermal conductor has reached equilibrium. The simple model and the equations indicate that less heat transfer will occur between reservoirs for a thermal conductor with low thermal conductivity. This is the case when considering the microstrip circuit in Figure 1b, where the substrate acts as a thermal conductor with low thermal conductivity. The distance between the reservoirs will also impact the amount of heat transferred, while a thinner thermal conductor will increase heat flow. Increased heat flow will allow heat to transfer more efficiently to the ground plane (heat sink), with the circuit staying cooler.

A rudimentary microstrip circuit thermal model assumes that the heat is generated on the signal plane, although this may not be entirely correct. In general, heat can be produced within a PCB as an artifact of RF heating or from an active device mounted on the circuit and generating heat. When heat is generated by conduction from a mounted device, the simple model that assumes heat flow originates on the signal plane is relatively accurate. In the case of RF heating, the heat is related to insertion loss and is often caused by a mix of losses, including the losses of the conductor on the signal plane and the dielectric losses of the substrate material. In this scenario, the heat source is not entirely within the signal conductor; however, for circuits that are relatively thin and where conductor losses dominate, much of the heat will be generated at the signal plane. More specifically, heat will be generated in areas where the current density is highest, which is at the copper-substrate interface of the signal conductor. For applications where the heat is the result of RF heating, the heat patterns will be similar to the high current density patterns. With this in mind, different heat patterns can be projected when comparing a transmission line to an edge-coupled or stub feature in a PCB.

TABLE I

COMMON MATERIALS USED IN PCB FABRICATION AND TYPICAL VALUES OF PROPERTIES IMPORTANT TO THERMAL ISSUES

	Dk	**Df**	**Thermal Conductivity**	**TCDk**
Nearly Pure PTFE	2.2 to 2.4	0.001	0.2	-150
Ceramic Filled PTFE	3.5	0.002	0.5	-30
High Dk Ceramic Filled PTFE	>6	0.0025	0.7	-250
Ceramic Filled Hydrocarbon	3.5	0.0035	0.6	50

MATERIAL PROPERTIES

Thermal conductivity is an important PCB property and most circuit materials have low thermal conductivity values. Nearly pure PTFE substrates have very good electrical performance at microwave frequencies, but typically exhibit low thermal conductivity values in the range of about 0.2 W/m/K. Some ceramic-filled PTFE substrates offer improved thermal conductivity values, in the range of 0.4 to 0.7 W/m/K. In general, a PCB material with thermal conductivity above 0.5 W/m/K is considered good and values above 1.0 W/m/K are considered extremely good.

Other material properties that affect PCB thermal behavior are coefficient of thermal expansion (CTE), glass transition temperature (Tg), dissipation factor (Df), dielectric constant (Dk or ε_r), rated thermal index (RTI), copper surface roughness, thermal coefficient of dielectric constant (TCDk), and thermal coefficient of dissipation factor (TCDf). The CTE and Tg properties are typically used for reliability considerations. RTI is a rating given to UL-rated circuit materials for the maximum temperature the raw material can be exposed to indefinitely without degradation in material properties. When the raw material is made into a circuit, there is another rating which is most applicable to the power-handling capability of a circuit and that is the maximum operating temperature (MOT). MOT refers to the maximum temperature to which a circuit can be exposed without degradation of critical properties. The MOT is always less than a circuit material's RTI. When reviewing the maximum RF power-handling capability of a PCB, MOT is used as the maximum temperature a circuit can be exposed to over long periods of time.

For example, a circuit with heat rise of +70°C above an ambient of +25°C must endure a temperature of +95°C indefinitely. The RF power that creates this heat rise is acceptable if the circuit has an MOT rating of +105°C. But if the circuit's heat rise is greater than +80°C above ambient, the applied RF power level that created the heat rise would not be acceptable.

Material parameters Df and copper surface roughness affect the heat produced by a PCB by impacting the insertion loss of a circuit, since a circuit with high insertion loss will generate more heat when RF power is applied than a circuit with low insertion loss. A circuit with low Df and smooth copper surface results in less insertion loss and less heat produced when RF power is applied. The Dk can also affect loss since lower-Dk materials enable circuits with wider conductors for a given impedance, resulting in lower conductor losses and lower overall insertion losses and less heat generated from applied power. In general, an ideal circuit material for high-power applications should have low Dk, low Df, smooth copper surface, thin substrate material, high thermal conductivity, and be capable of a high MOT. ***Table 1*** provides a summary of properties for materials used in PCBs that can impact microwave thermal performance.

Other circuit material properties important to understanding electrical-thermal interactions are TCDk and TCDf. TCDk is a property of all circuit materials and a measure of how much the Dk will change for a given change in temperature. Similarly, TCDf is a mea-

sure of the change in Df with change in temperature. These parameters are generally considered important for circuits in environments with changing temperatures. A PCB with high TCDk, for example, could undergo changes in impedance, affecting the performance of matching networks as Dk changes with temperature. TCDf can be a factor for circuits with tight loss budgets, where an increase in temperature can cause a rise in Df and increased loss. TCDk and TCDf are properties to consider for their impact on electrical-thermal interactions.

A PCB with copper conductors can have its performance affected by a parameter known as temperature coefficient of resistance for copper, which is a measure of how much the copper resistance changes as the copper is heated. This is a relatively simple calculation for DC applications, but it becomes more difficult to determine at microwave frequencies. This is because at higher frequencies, conductor loss, which is a component of total insertion loss, has a frequency dependency on resistivity due to skin depth.

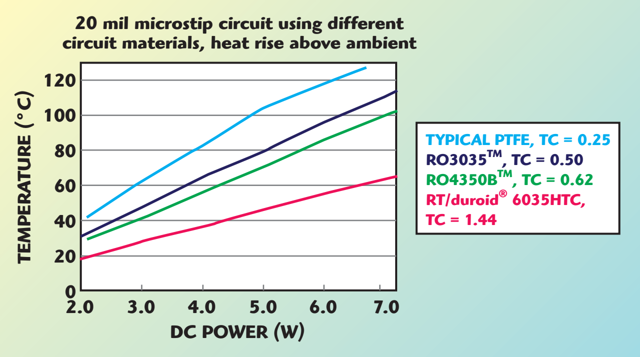
MICROWAVE ELECTRICAL-THERMAL INTERACTIONS

A number of studies were performed on microwave PCBs to better understand these electrical-thermal interactions on circuits. The first study explores differences in thermal conductivity only, when DC power heats the circuit, ignoring RF power and loss issues. The second study examines external heating of microstrip filters and monitors changes in filter performance as a result. The third study uses RF power to heat transmission line circuits of different con-

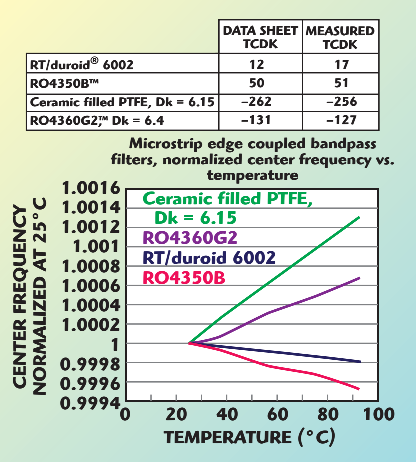
TABLE II

THERMAL PERFORMANCE COMPARISONS FOR DIFFERENT TRANSMISSION-LINE CIRCUITS BASED ON SUBSTRATES WITH VARIOUS PROPERTIES AND HEAT APPLIED RF POWER AT DIFFERENT FREQUENCIES AND POWER LEVELS

Circuit Material	Transmission Line Type	Dk	Df	Thermal Conductivity (W/m/K)	Copper Surface Roughness (RMS)	Insertion Loss Without Black Paint @ 3.4 GHz (dB/.in)	Insertion Loss With Black Paint @ 3.4 GHz (dB/.in)	Heat Rise (°C) 30 W @ 2 GHz	Heat Rise (°C) 85 W @ 3.4 GHz
10 mil RT/duroid® 5880 High Profile ED cu	Microstrip	2.20	0.0009	0.20	2.8	0.12	0.18	13	34
10 mil RO4350B™ High Profile ED cu	Microsrip	3.66	0.0037	0.64	2.8	0.17	0.27	8	22
10 mil RO4350B High Profile ED cu	GCPW, w18s6	3.66	0.0037	0.64	2.8	0.20	0.43	9	27
20 mil RO4350B High Profile ED cu	Microstrip	3.66	0.0037	0.64	2.8	0.12	0.19	7	29
20.7 mil RO4350B LoPro™ Low Profile ED cu	Microstrip	3.55	0.0037	0.64	0.6	0.10	0.14	3	22
20 mil High Perf FR-4 Std. ED cu	Microstrip	4.25	0.0200	0.25	1.4	0.36	0.37	10	74
20 mil RT/duroid® 6035HTC Std. ED cu	Microstrip	3.60	0.0013	1.44	1.8	0.08	0.11	2	14



▲ *Fig. 2 Results from a study showing the different temperature rise when using materials of significantly different thermal conductivity (TC).*



	DATA SHEET TCDK	MEASURED TCDK
RT/duroid® 6002	12	17
RO4350B™	50	51
Ceramic filled PTFE, Dk = 6.15	−262	−256
RO4360G2™ Dk = 6.4	−131	−127

▲ *Fig. 3 Normalized Dk vs. temperature chart for common high-frequency PCB materials.*

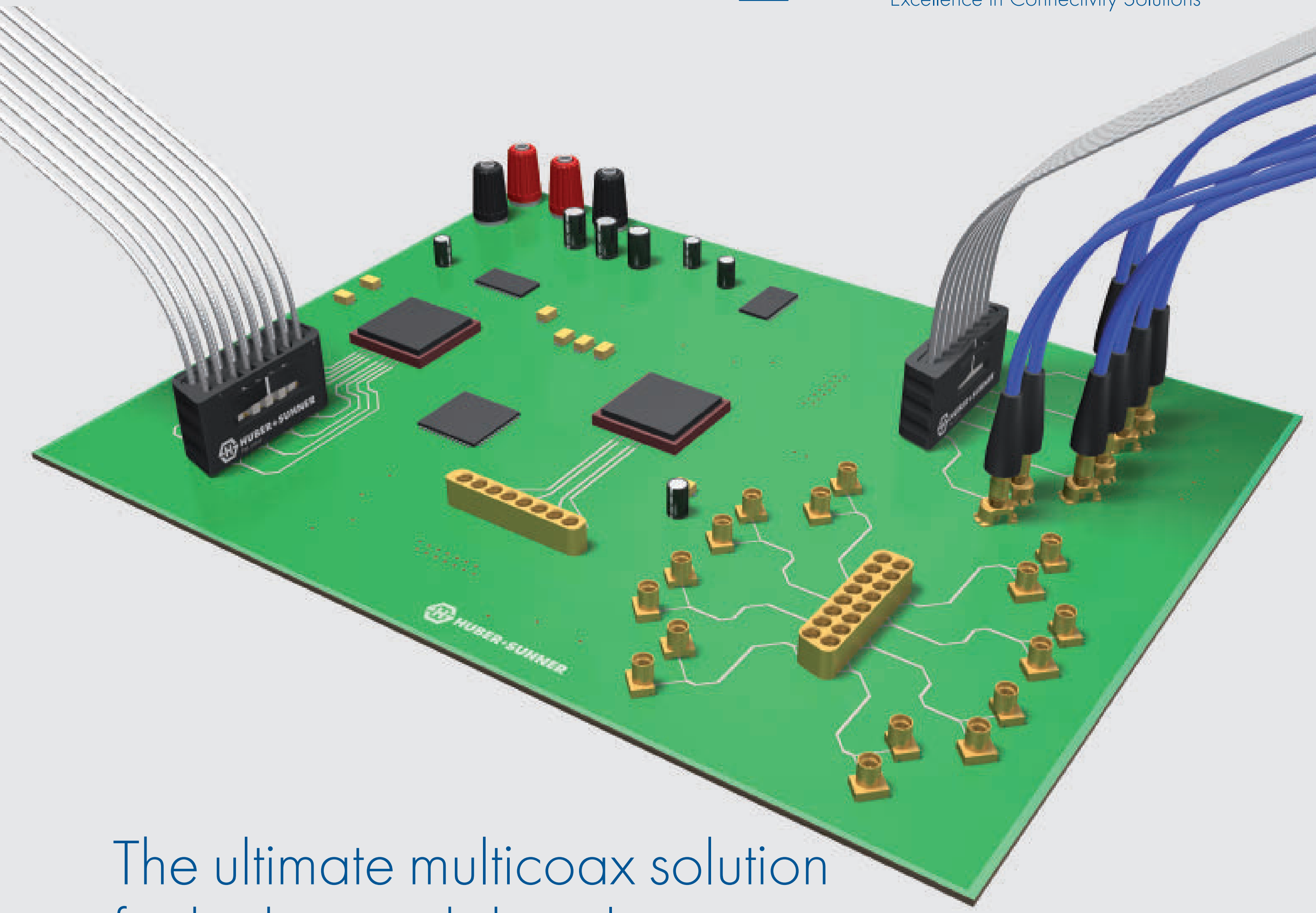
figurations, using dissimilar materials, at different frequencies and power levels. Finally, a brief study will show thermal images of a microstrip bandpass filter heated due to applied RF power and discussion of the different heat patterns.

Figure 2 shows the results of a study using materials of the same thickness, but with significantly different TC. The circuits were based on simple double-copper-layer PCBs with a surface-mount termination resistor soldered to the middle of the circuit. DC power was applied and equilibrium temperatures measured at different power levels. The circuits were mounted on a water-cooled heat sink which served as a consistent cold reservoir. It is clear to see that the circuits using materials with higher thermal conductivity had less heat rise above ambient (see *Microwave Journal*, November 2011 for more information on this study).

The next study used circuits made on several different materials and all circuits with the same nominal design. The circuit design was a microstrip edge coupled filter, a 0.1 dB ripple Chebyshev design with center frequency of 2.5 GHz, bandwidth of 235 MHz, and return loss better than 15 dB in the passband. Due to differences in circuit fabrication and material properties, the different filters had slight differences in center frequency and bandwidth; however, the results of the variations in center frequency were normalized. This study intended to show how the PCB property of TCDk manifests itself in terms of a shift in center frequency when the filter is heated. ***Figure 3*** provides comparisons of the materials' reported TCDk values and calculated TCDk values for the circuits exposed to different temperatures.

As Figure 3 shows, there are differences in measured TCDk for actual circuits compared to values reported on data sheets. There are several reasons for these differences. Data sheets are often the results of materials studied in a clamped stripline resonator test where raw substrate is typically evaluated. This test uses a loosely coupled stripline resonator and is much less sensitive to measurement system calibration, cables and connectors. This test suffers fewer variables than measurements on microstrip edge-coupled filters, where the center frequency can be altered by calibration, cables and connectors. This was intended as a simple study of one circuit for each data set; due to limited data, statistical validity cannot be assumed. In contrast, the clamped stripline resonator test on raw substrate was conducted across a large number of samples and the data are statistically sound.

The third study was performed using transmission line circuits with varying material properties. Additionally, the circuits were heated from RF power at different frequencies as well as power levels. ***Table 2*** provides a summary of the circuit performance and critical material properties for the circuits evaluated in the third study. The insertion loss numbers shown in



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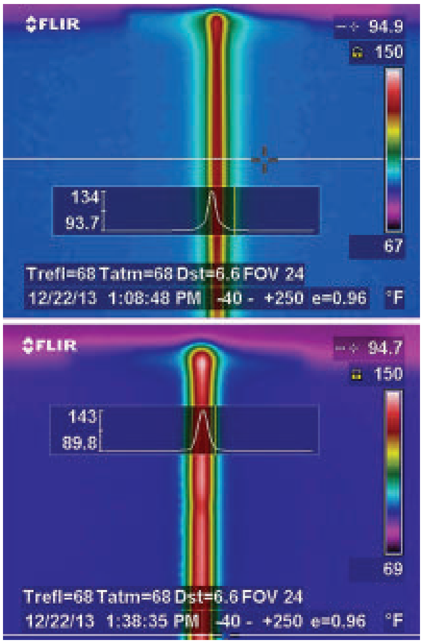

▲ *Fig. 4 Thermal imaging pictures showing the performance of circuits in rows 2 and 4 (from Table 2), when heated with 85 W at 3.4 GHz.*

Table 2 are from testing the circuits as a set, using a differential length method.[2] The circuits used bare copper with no finish or soldermask. For this study, the circuits were required to have a black paint applied, with a known emissivity, for accurate measurement using a thermal imaging camera. The black paint increased the insertion loss and depending on the circuit configuration, the increased loss will be more or less significant. The circuit in the first row shows a copper roughness of 2.8 and this is not typical for this material, but it was done for purposes of this study. All circuits were microstrip transmission line circuits with the exception of the circuit in the third row – this circuit is a grounded coplanar transmission line that is tightly coupled; the impact on insertion loss due to the paint is more significant on this circuit.

There is an abundance of information in Table 2 to consider and some generalities will be given. The circuits in the first two rows have the same thickness and copper roughness, however, much different Df and thermal conductivity. It can be seen that even though the insertion loss is lower for the material in the first row, the benefit of high thermal conductivity is shown with lower heat rise at different frequencies and power levels.

The circuits in rows four and five are the same thickness and with very similar material properties, however the copper surface roughness is significantly different. The benefit of smoother copper can be seen in lower temperature rise.

Lastly the circuits in rows six and seven are the extreme comparisons. The material in the last row has the best combination of properties for this study and the data shows the least amount of heat rise when comparing the different power levels at the different frequencies. An example of some thermal images taken is given in ***Figure 4***, showing differences for the circuit materials in rows two and four.

The photos shown in Figure 4 are a top view of the circuits with the signal launch area at the upper portion of the picture. The pictures show heat rise differences of two circuits using the same materials and the only significant difference is the substrate thickness. The benefit of a thinner circuit with a shorter heat flow path is demonstrated with the higher power testing.

The final study was performed to illustrate differences in heat patterns for other microwave circuit designs, which can differ greatly from transmission line patterns. A common edge coupled filter was used as example for this study.

The filter evaluated was based on 20 mil thick RO4003C™ circuit laminate. It was designed for a center frequency of 2 GHz, bandwidth of 175 MHz, and passband return loss of 15 dB. After the application of the black paint, several properties shifted and the center frequency was 2.010 GHz, bandwidth of 156 MHz and insertion loss of 6.5 dB in the passband. ***Figure 5*** gives details of the filter along with thermal images while RF power was applied.

Figure 5c shows the heat pattern of the microstrip bandpass filter at the center frequency with 30 W of applied RF power. If, for example, the applied power is shifted in frequency by 40 MHz, which is still within the passband, the heat pattern will change from what is shown. Also in this figure is a measurement white line aligned to the high temperature areas of the resonators for this filter on the left side of the circuit. There is a temperature mapping in regard to the white line and the highest temperature (140°F) can be seen at the end of the first coupled resonator.

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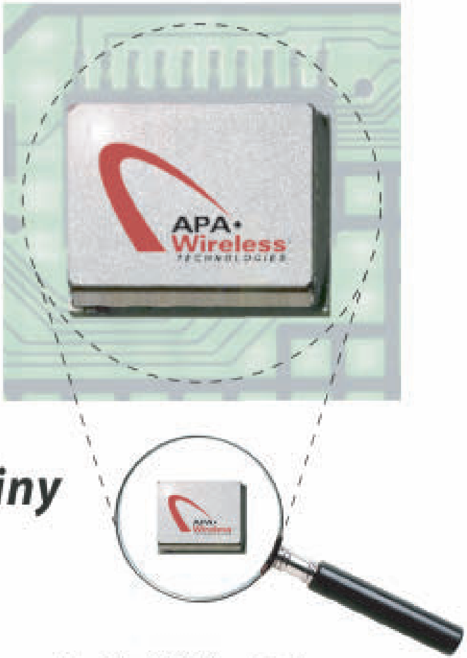

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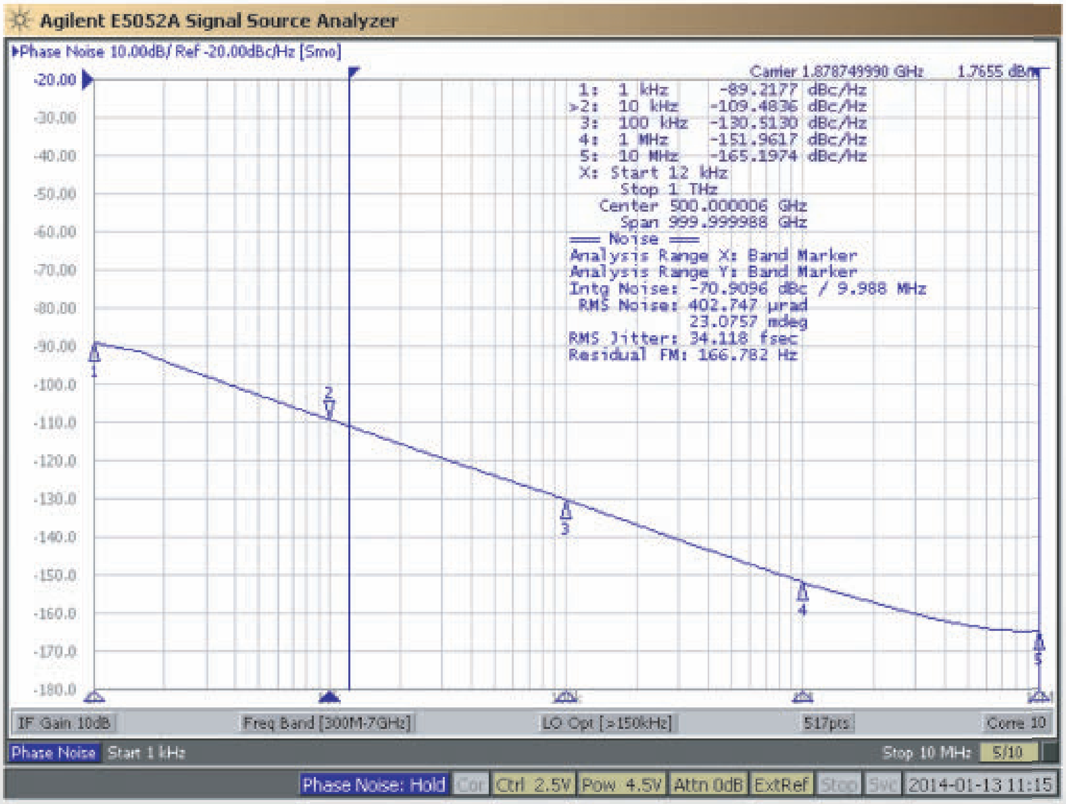

```
▸Phase Noise 10.00dB/ Ref -20.00dBc/Hz [Smo]
Carrier 1.878749990 GHz     1.7655 dBm
  1:  1 kHz       -89.2177 dBc/Hz
>2:  10 kHz     -109.4836 dBc/Hz
  3:  100 kHz   -130.5130 dBc/Hz
  4:  1 MHz     -151.9617 dBc/Hz
  5:  10 MHz    -165.1974 dBc/Hz
  X: Start 12 kHz
       Stop 1 THz
     Center 500.000006 GHz
       Span 999.999988 GHz
=== Noise ===
Analysis Range X: Band Marker
Analysis Range Y: Band Marker
Intg Noise: -70.9096 dBc / 9.988 MHz
 RMS Noise: 402.747 µrad
            23.0757 mdeg
RMS Jitter: 34.118 fsec
Residual FM: 166.782 Hz
```

```
IF Gain 10dB    Freq Band [300M-7GHz]    LO Opt [>150kHz]    517pts    Corre 10
Phase Noise  Start 1 kHz                                  Stop 10 MHz  5/10
Phase Noise: Hold  Cor  Ctrl 2.5V  Pow 4.5V  Attn 0dB  ExtRef  Stop  Svc  2014-01-13 11:15
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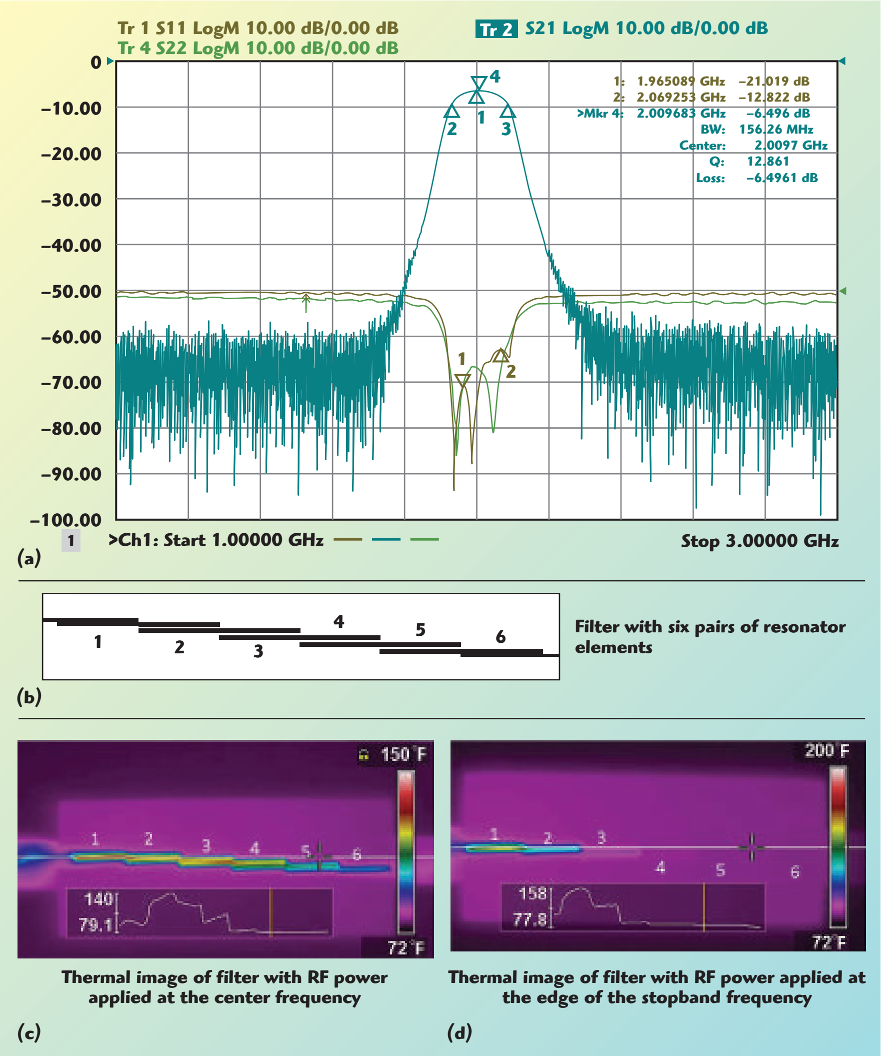

▲ *Fig. 5 The measured S-parameters for the filter under evaluation (a), the top view of the basic circuit pattern (b), thermal image of the fabricated filter at its center frequency (2.010 GHz) with 30 W applied (c) and the same applied power but at 1.900 GHz which is in the stopband of the filter (d).*

When the RF power is shifted in frequency by about 80 MHz down to 1.93 GHz, which is just below the edge of the stopband, a heat pattern occurs that is shown in Figure 5d. Again the white measurement line is the reference for the temperature mapping which shows where the highest temperature is at first resonator elements of the filter. The RF power is coming in from the left of the filter and a termination load is to the right of the filter.

Understanding the material property differences of high-frequency circuit materials is paramount in applications where thermal issues are a concern. The thermal issues are typically divided into two categories, where a circuit may be heated from a mounted device or the circuit is heated due to RF power being applied. Each scenario is affected by circuit material-related issues and, as has been shown, a material with optimum properties can ensure a robust design for applications where thermal management is a concern. ■

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John Coonrod *received his bachelor of science degree in Electrical Engineering (1989) from Arizona State University. He has been involved in the PCB industry for 26 years, is currently market development engineer for the Advanced Circuit Materials Division of Rogers Corp., Chandler, AZ.*


Ken Hermanny
RF & Microwave Solutions Group

Through-Silicon Vias and 3D Inductors for RF Applications

Thorbjörn Ebefors, *Silex Microsystems AB, Järfälla, Sweden*
Joachim Oberhammer, *KTH Royal Institute of Technology, Stockholm, Sweden*

To cope with an increasing number of frequency bands and advanced mobile phone standards supporting high data rates, current and future wireless communication systems must satisfy stringent performance expectations while simultaneously being more energy-efficient and having lower operating costs. One major limitation of today's mobile phones is poor impedance matching of the antenna to the RF front end section resulting in poor antenna efficiency. This is exacerbated by current trends toward higher miniaturization and integration, presenting ever increasing challenges in the design of complex RF systems and the management of RF interaction on signal lines. By introducing tunable RF elements, the overall system architecture can be simplified, leading to significant cost reductions and performance optimization.

This article introduces recent advances in RF MEMS vias that allow 3D signal routing using silicon interposers and make compact, high performance inductors commercially available using a combination of innovative MEMS techniques. This article also discusses why full wafer thickness processing makes the RF performance achievable and introduces advanced research in ferromagnetics, which can boost performance of the inductor component even further.

PERFORMANCE REQUIREMENTS FOR PRACTICAL RF IPDS

Current mobile phone designs still rely on discrete surface-mounted passive devices to provide RF signal conditioning throughout the handset. A typical mobile phone can have hundreds of surface-mounted passives yet only 20 to 40 ICs. In a typical mobile phone, the discrete passive components account for 90 percent of the component count, 80 percent of the size and 70 percent of the handset cost.[1]

To date, the industry has responded by reducing the size of the passive components down to a 0402 SMD package size, such as those recently launched by Murata Corp. in Japan.[2] The cost of mounting these ultra-miniature SMD devices, however, often negates the component cost savings. Further reductions in size and cost can only come from integrated passive devices (IPD) which can still deliver the performance required by the handset.

Focusing specifically on inductor components, high-Q inductors in the 1 to15 nH range with minimal footprints are needed to build matching networks that can both correct the real as well as the imaginary parts of RF sig-

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nals present in mobile communications systems. By using a novel 3D through-silicon via (TSV)-based approach, we have shown that both one- and two-port inductors with Q-factors above 30 for the 0.5 to 4 GHz frequency range, while covering an area of about 1 mm^2 for inductances of a few nH, are not only achievable, but are practical as the basis for a new class of IPDs. With next generation TSVs currently in development, even further die size reduction to much less than 1 mm^2 is possible for the same inductor values.

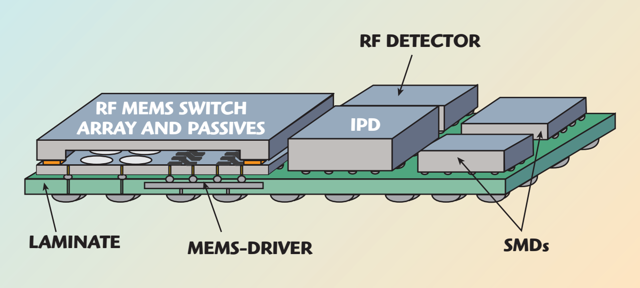

Fig. 1 Schematic of front end antenna module.

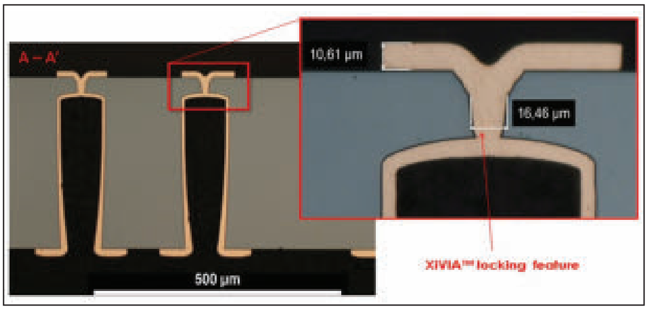

Fig. 2 Cross section of Met-Via TSV.

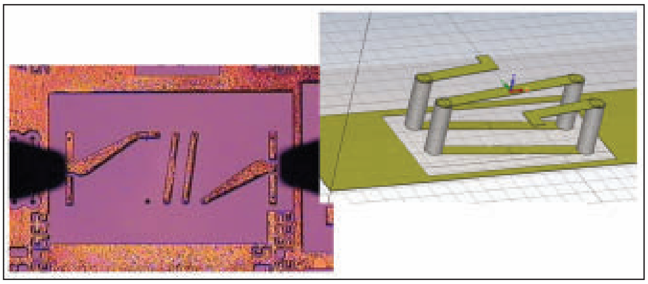

Fig. 3 Microphotograph of three-turn 3D inductor being probed, with CAD explosion.

BACKGROUND

Development of this new type of 3D inductor is pursued under the European Union ENIAC Joint Undertaking EPAMO project, a 15-member consortium to explore and implement a number of innovative process and testing technologies to realize an adaptive 4G radio front end system for mobile phones.[3] One of the main building blocks of the front end is the integrated adaptive antenna tuner, consisting of MEMS switches and passive RF 3D-IPDs with TSVs and 3D inductors on thin laminate substrates (schematically shown in ***Figure 1***). The complete module will finally be overmolded. With the availability of adaptive RF tuning in mobile handsets, mobile phone power levels can be reduced by up to 50 percent with no loss in signal strength or integrity. Base station power can also be conserved, with at least 10 percent power savings achievable.

High-Q inductors are needed to build the IPD matching networks. Miniaturized on-chip inductors, therefore, represent critical elements in the overall system. Due to the relatively low Q-factor values currently reported for on-chip semiconductor thin film components (typically in the range of 10 to 20 or lower), the need for new innovative solutions still exists. Addressing this need is one of the major goals of the EPAMO project.

Met-Via® TSV PROCESS

Despite much industry work on thin wafer TSV technologies utilizing wafers as thin as 20 µm (being driven by interposers for 3D IC packaging, among other trends), a high performance 3D RF inductor requires thicker substrates to maximize inductor length, without increasing its IPD footprint. Separating the inductor windings with a thick substrate reduces the capacitive as well as mutual inductance coupling. This allows the fabrication of compact IPD inductors without compromising inductor values or Q factors due to parasitic effects (such as is seen on 2D single-sided or CMOS 2-layer fabricated inductors). This approach is made possible by copper thru-wafer vias in 300 µm thick substrates that meet performance and reliability requirements for high volume commercial use.

The basis for this TSV is the Met-Via process developed at Silex Microsystems.[4] This process utilizes XiVia™ Technology from ÅAC Microtec which results in a highly reliable and ruggedized TSV capable of handling demanding temp cycling and operating life requirements. CTE mismatch between the copper and surrounding silicon is large enough that, with repeated temp cycling, a copper TSV can cause de-lamination or cracks in the silicon substrate leading to electrical opens, or breaks, and long term reliability concerns. Met-Via TSVs are all-copper electroplated TSVs with a unique locking structure for TSV reliability (the XiVia structure) as well as a copper-lined TSV topology (as opposed to completely filled TSV). This provides CTE mismatch relief during temperature cycling. The TSV is plated (front and back side) in one plating operation, which is a much more cost effective approach to TSV formation than typical blind via approaches, which require two separate plating operations. The one-step electroplating is what also enables the formation of the new 3D inductor. ***Figure 2*** shows the XiVia structure (the marrying of the small bore from the top with the large bore from below, to create a locking structure for the TSV in silicon).

3D INDUCTORS IN SILICON AND RF PERFORMANCE

Inductors using from 1 to 8 turns were fabricated for characterization. ***Figure 3*** is a top-side photomicrograph of a three-turn 3D inductor, with a CAD image of the inductor design (silicon removed for illustration). The 8" wafers with inductors on board were temporarily bonded to a glass substrate to isolate the readings from the effects of the underlying chuck. One- and two-port S-parameters are shown in ***Figures 4*** and ***5***. Q values, derived from measured Y-parameters, of over 30 at 1 GHz are achieved for all inductor designs. In Figure 5, the inductance value for each inductor design was determined from a fit of a parallel L-C model, with resistive loss in the L section, to the series branch of a pi-model of the measurement data. The


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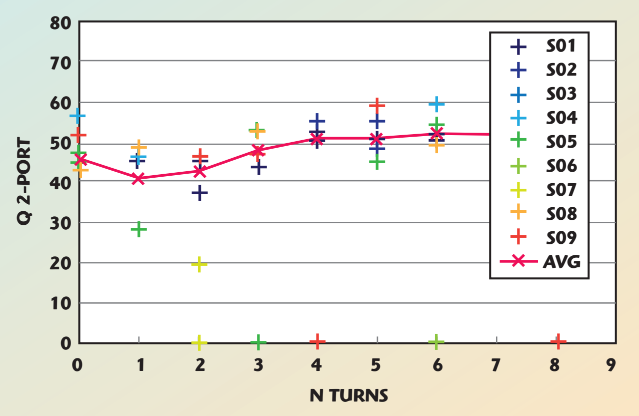
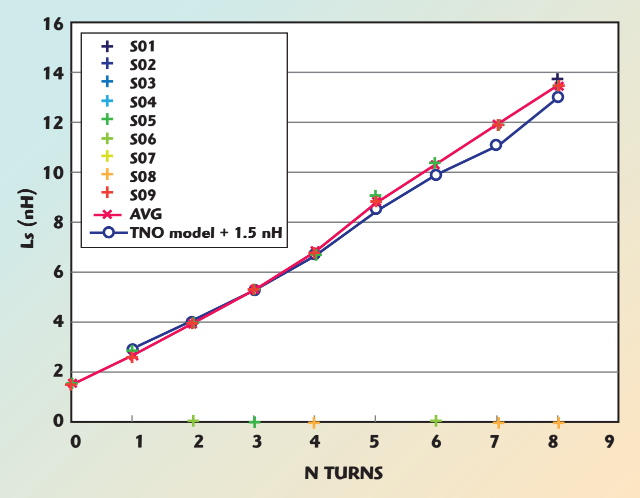
series and two parallel branches were determined, by direct calculation, from the Y-parameters. The inductors were characterized out to 10 GHz and practical RF inductors for frequencies up to 3.6 GHz were successfully demonstrated as well. Stable inductor performance was demonstrated up to 100°C. The self-resonance frequency (SRF) depends on the number of turns. For 1 to 6 nH inductors, an SRF of above 10 GHz is achieved. The authors are working on further improving this performance by integrating magnetic core material.



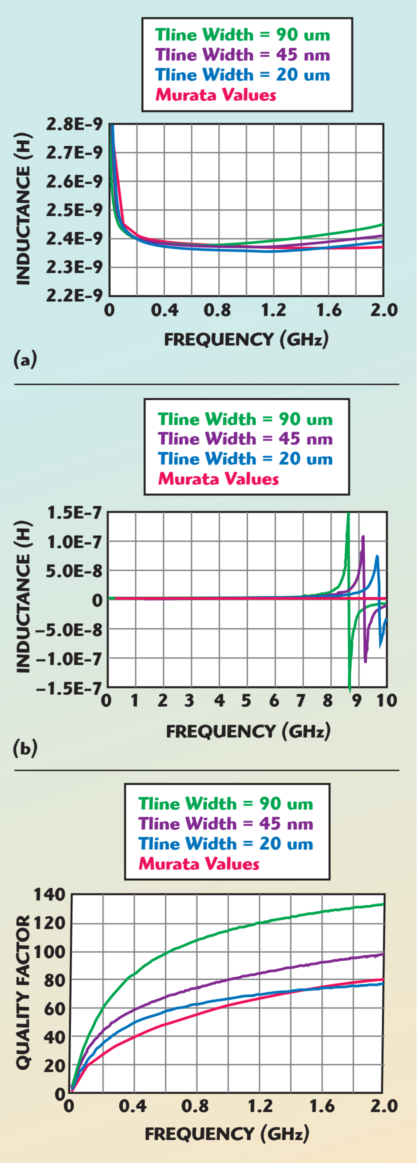
▲ *Fig. 4 Q-factors at 1 GHz vs. number of turns in the 3D inductor at nine different wafer positions (S01-S09) equally distributed over each tested 8" wafer.*



▲ *Fig. 5 Inductance values at 1 GHz vs. number of turns in the 3D inductor structure at nine different wafer positions (S01-S09) distributed over each tested 8" wafer compared with theoretical modeling.*

IPD VS SMD INDUCTORS

To benchmark the 3D-IPD inductors vs. commercially available SMD inductors for RF front end applications, the RF MEMS group at KTH has done modeling and designs of various 3D-IPD inductors using the Silex Met-Via RF 3D-IPD process and compared these designs to existing device models.[5] ***Figure 6*** illustrates three different TSV inductors designed to match a 2.7 nH inductor from Murata (LQW15AN2N7C00). Electromagnetic simulations of the inductors were performed using CST Microwave Studio and the frequency response of the Murata reference inductors was modeled in Agilent ADS. Very good inductance matching in the 0.4 to 2 GHz frequency regime is obtained with Silex 3D inductors having an SRF in the 9 GHz range and, depending on inductor design, Q-values in the 60 to 120 range are achieved over the frequency regime of interest.



▲ *Fig. 6 Inductance (a), self resonance (b) and Q-value (c) for three different 2.7 nH inductor designs using the Silex Met-Via 90 TSV process compared to commercial SMD inductors.*

FERROMAGNETICS: PUSHING THE PERFORMANCE BOUNDARY

With process support from Oerlikon Systems in Lichtenstein and Veeco Instruments in the U.S., the authors have developed a material platform for utilizing nickel-iron (NiFe) magnetic films for the first time at GHz frequencies.

On-chip integrated inductors, currently with a maximum inductance density of some few tens of nH/mm^2, would benefit from magnetic materials that significantly reduce the required area. At DC to approximately 10 MHz, the relative permeability of NiFe layers is reported to be as high as 3000 for thin films, and with an optimized electrodeposition process, a permeability of 8500 is achieved.[6] Homogeneous NiFe films, however, suffer from a number of limitations at RF frequencies above 100 MHz. Permeability decreases rapidly and crosses zero at the ferromagnetic resonance, which is around 650 MHz for unpatterned thin (100 nm) NiFe films.[7] For inductor cores, thicker layers are desired, but RF eddy current effects drastically reduce the effective permeability, the quality factor and even the ferromagnetic resonance frequency.

Isolating thin layers of the NiFe between sheets of isolating material bypasses this limitation and reaps the benefits of the ferromagnetic core in the inductor design. This effectively

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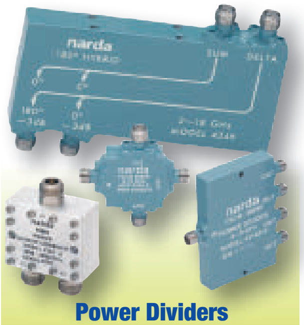

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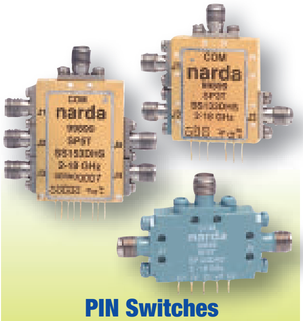

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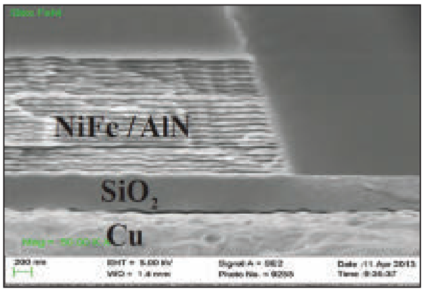
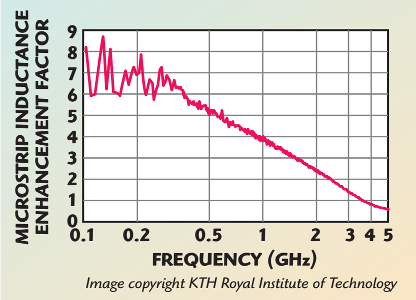
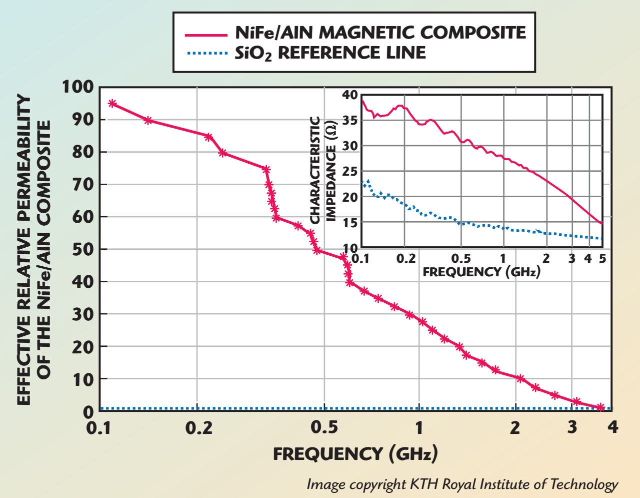
increases the thickness of the ferromagnetic material without increasing its losses. It is accomplished by using a multi-layer NiFe and AlN sandwich structure. This suppresses the induced currents very effectively and at the same time increases the ferromagnetic resonance frequency.[8,9]



▲ *Fig. 7 SEM of NiFe/AlN fabricated device.*



▲ *Fig. 8 Measured inductance enhancement factor vs. frequency, of microstrip test structures with ferromagnetic NiFe/AlN multilayer composite, relative to an SiO_2 reference line.*

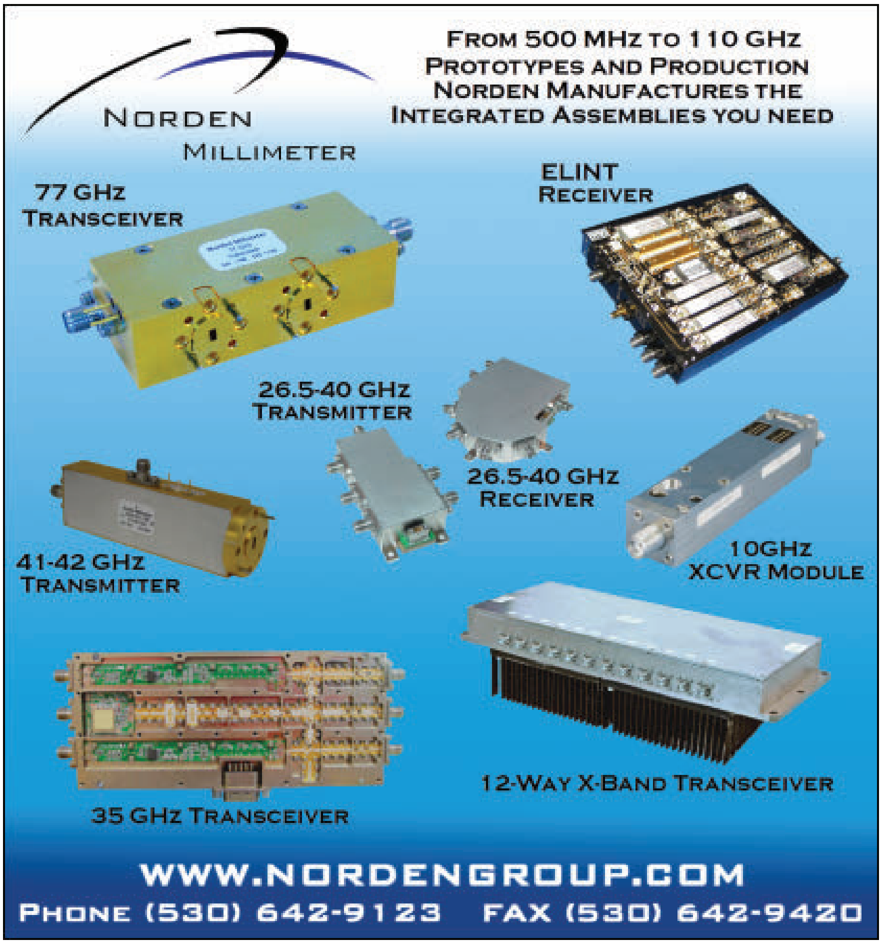


▲ *Fig. 9 Effective relative permeability of the ferromagnetic NiFe/AlN multilayer composite relative to an SiO_2 reference line.*

Test structures for evaluating the magnetic properties of the novel magnetic composite at RF frequencies were designed and fabricated with a cross-section of the microstrip transmission line test structures shown in ***Figure 7***. From the measured S-parameters, the frequency-dependent characteristic impedance and propagation constant are derived and used to calculate the inductance and capacitance per unit length. ***Figure 8*** shows the inductance enhancement factor for the NiFe/AlN multilayer composite line relative to an SiO_2 reference line, achieving an enhancement factor of 4.0 at 1 GHz. The frequency dependent effective relative permeability of the NiFe/AlN multilayer composite material (see ***Figure 9***) is extracted from the measurements by parameter matching of an Ansoft HFSS simulation model to the measured inductance per unit length for all individual frequency points, with the simulation model verified and matched by reference line measurements. An effective permeability of 28 is achieved at 1 GHz, and the ferromagnetic resonance exceeds 3.7 GHz. The permittivity of the composite material is also determined by special dielectric test structures to an effective permittivity of 25. The procedure was verified by measuring known SiO_2 reference structures.

The multilayer NiFe/AlN composite material enables an increase in ferromagnetic resonance by a factor of 7.1 as compared to previous work for a homogeneous NiFe film with the same total thickness,[7] and thus pushes the usability of commercially manufacturable NiFe films beyond 1 GHz (permeability cutoff at 3.7 GHz). To the authors' knowledge, an effective permeability of 28 at 1 GHz for on-chip NiFe layers is the highest yet reported.

To illustrate the effect of magnetic core integrated in inductor devices, modeling of a 7.5 nH inductor was done using a CST Microwave Studio simulation model with and without the magnetic core in the 3D inductor geometry. As seen in ***Figure 10***, the SFR is drastically improved using a magnetic core even when assuming a relative low effective μ_r of 10 for the thick magnetic core material. Simulations have



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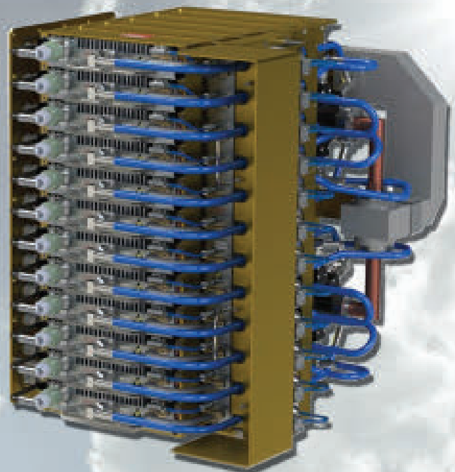

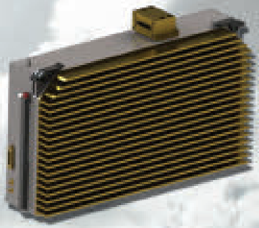

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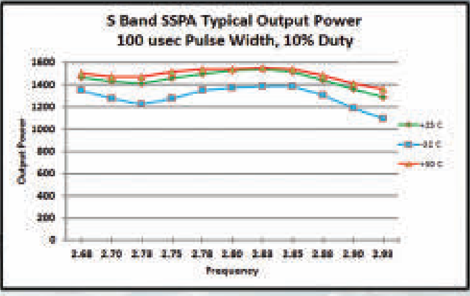

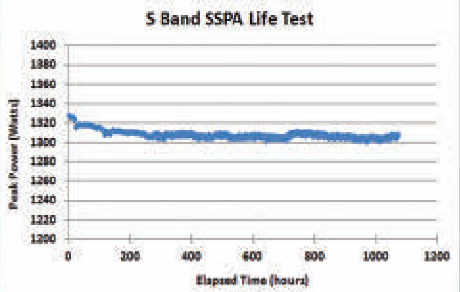

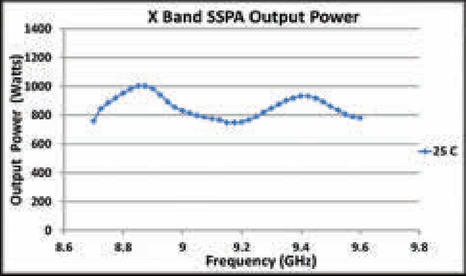

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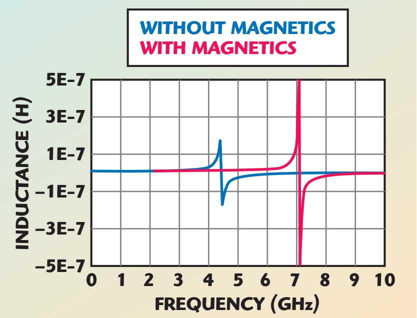

▲ *Fig. 10 Effect of magnetic materials in TSV based 3D inductors using Ansoft HFSS simulation model.*

shown that such magnetic materials in connection with 3D-TSV inductors result in an inductance enhancement of up to a factor of 5 at GHz frequencies for the same inductor area, or the same inductance can be achieved at 9 times smaller area and cost.

FUTURE RESEARCH AND COMMERCIALIZATION

The EPAMO project's focus extends beyond developing 3D RF inductor technology to encompass complete adaptive antenna front ends. Toward this goal, parallel work is ongoing at Silex for PZT-based MIM capacitors for IPD and energy harvesting applications, and thin film resistors for applications requiring fully integrated R, L and C functions in the IPD as well.

Silex and KTH are also collaborating on separate programs in the areas of advanced polymers for improved TSV and 3D RF-IPD inductor performance. KTH is modeling and designing various RF MEMS devices fabricated by Silex, as well as new research programs on THz microwave components and subsystems. ■

ACKNOWLEDGMENTS

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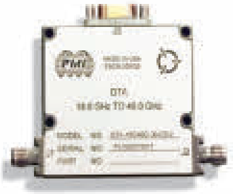

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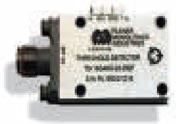

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CPW-Fed Folded Antenna with Forward-Directed Radiation Patterns for Handheld Dual-Band RFID Reader Applications

Ahmed Toaha Mobashsher[1,2] and Rabah W. Aldhaheri[1]
King Abdulaziz University[1], Jeddah, Saudi Arabia
The University of Queensland[2], Brisbane, Australia

A small (16.5 × 45 mm) forward-directional antenna covering the ISM bands of 2.45 and 5.8 GHz is designed for the next generation of multi-band compact handheld RFID readers. The antenna consists of a folded radiating copper strip fed by a CPW microstrip line and a ground plane. The copper strip produces surface waves at the operating frequencies that are reflected by the ground plane, producing radiation in the forward direction. Details of the antenna design and optimization are discussed by formulating closed-form equations for the resonances. Only 4 percent difference is found between the theory and simulation. The prototype exhibits 8.5 and 4 percent impedance bandwidths in the lower and upper operating bands, respectively. Measurements show forward-directed radiation patterns with good polarization purity, back radiation suppression and peak gain across the bands.

During the last decade, many techniques have been used to make handheld RFID devices more compact and multi-functional. It is common for a handheld RFID reader to employ a vertically radiating directional antenna at a right angle with the reader; thus the radiation literally becomes forward-directional to the reader.[1] In this way, forward directional antennas can provide higher levels of compactness. Quasi-Yagi[2] and folded dipole[3] antennas are reported to have unidirectional radiation patterns taking the advantages of surface waves, but their balun structures have complex mechanisms to match the reflection coefficients of the driver elements and resonate at only one operating frequency. Recently, a microstrip-fed directional antenna was reported.[4] Despite claims for long-range RFID coverage, it is printed double-sided (making it less compact and more difficult to integrate with solid-state active and passive components; and it, like the quasi-Yagi and folded dipole, resonates at only one operating frequency. The handheld multi-band antenna reported in reference 5 is also inappropriate for compact devices due to its large supporting ground plane. Although the Yagi antenna reported in reference 6 is uni-planar, it is difficult to incorporate circuitry due to its construction; and the feed transition of the multi-band quasi-Yagi-type antenna described in reference 7 requires a large area, which increases the an-

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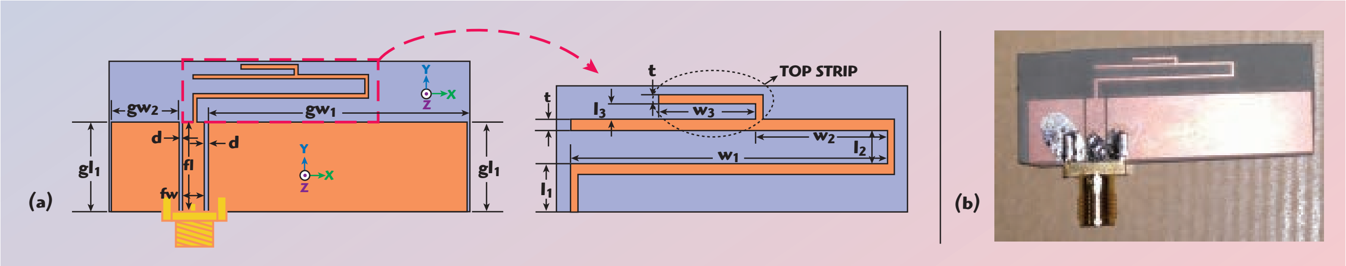
Frequency	20 MHz to 6 GHz	6 - 18 GHz
Nominal Pout	30 to 50 Watts	30 to 50 Watts
Applied Voltage	28 Vdc	26 Vdc
Maximum DC Current	8 Amps	16 Amps
Volume (inches)	2.5W x 7.7L x 1.4H	3.5W x 8.5L x 1.4H



▲ *Fig. 1 The geometry of the proposed antenna with an enlarged and elaborated view of the main radiating folded strip (a). Photograph of the fabricated prototype (b).*

tenna size significantly.

Inspired by the work reported in reference 4, this article describes a coplanar waveguide (CPW)-fed folded antenna with a small profile for handheld RFID reader applications. The antenna covers the ISM RFID bands of 2.45 GHz (2400 to 2483 MHz) and 5.8 GHz (5725 to 5875 MHz) with forward-directed radiation patterns in both bands. Details of the antenna design process and experimental results of the prototype are presented.

ANTENNA CONFIGURATION & OPERATION

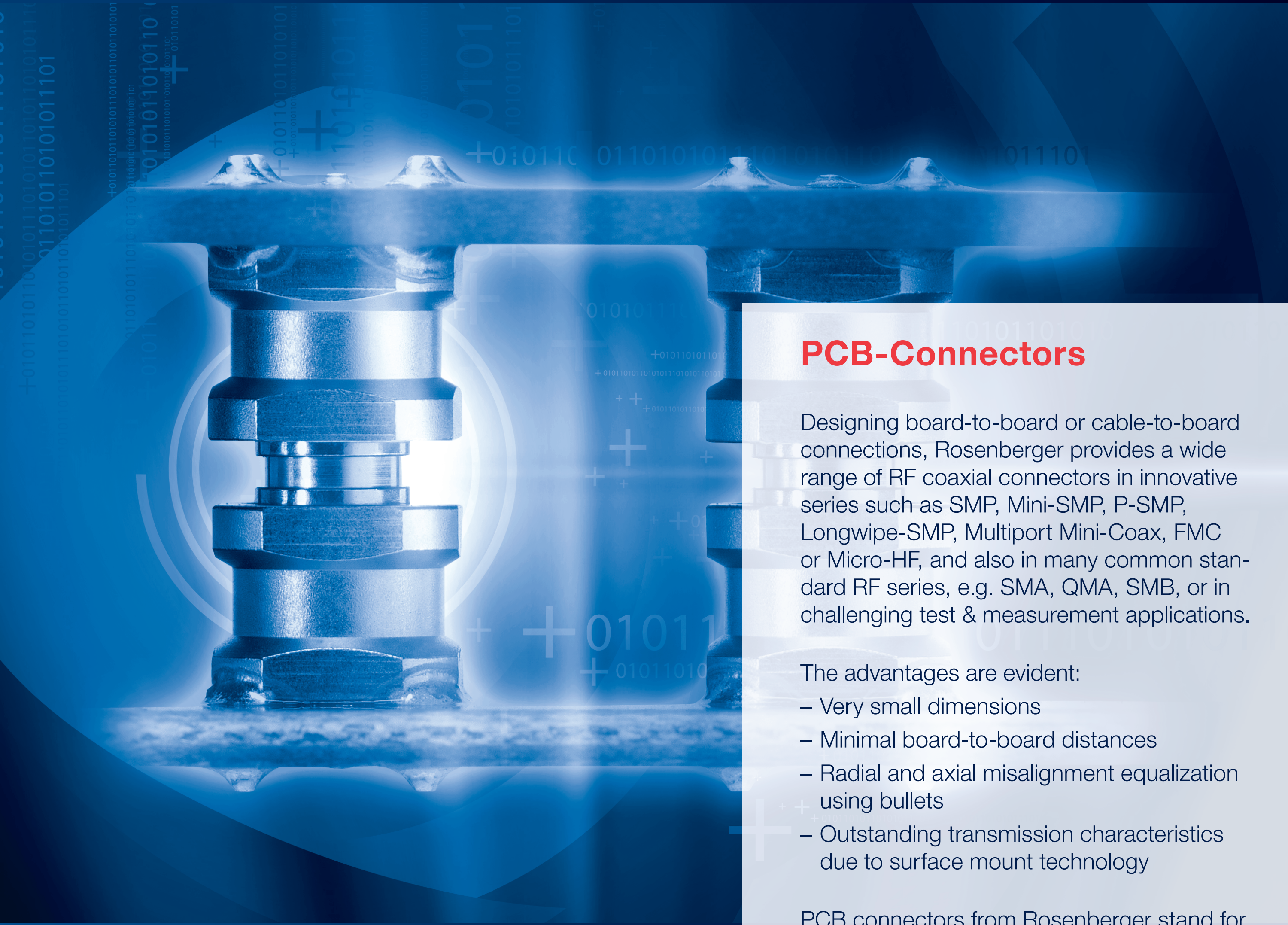
The geometry and configuration of the uni-planar folded RFID antenna is shown in ***Figure 1(a)*** and a photograph of the fabricated prototype is presented in ***Figure 1(b)***. The radiating element is a folded strip of copper foil printed on a low cost TMM4 substrate with 35 µm thick copper cladding, a dielectric constant of 4.5 and a substrate thickness of 1.52 mm. The antenna substrate must be thick enough to allow a significant number of surface waves to be launched into the bare-slab portion of the antenna.[1] A transmission line of width (fw) = 3 mm and length of (fl) = 10 mm is used to feed the folded strip. There is a gap of d = 0.3 mm between both sides of the transmission line and ground planes to form 50 Ω CPW line with the existing substrate. No metallization is applied on the reverse side of the substrate.

The longest path of the radiating folded strip defines the resonant frequency of the lower operating 2.45 GHz ISM band. Operation in the upper 5.8 GHz ISM band is achieved by the appropriate length and positioning of the top strip. Following this principle, the upper and lower resonances can be selected according to the following expressions:[8]

$$f_l \approx \frac{c}{1.5L_1\sqrt{\varepsilon_{eff}}} \qquad (1)$$

$$f_u \approx \frac{c}{0.7L_2\sqrt{\varepsilon_{eff}}} \qquad (2)$$

where the effective permittivity of the substrate is $\varepsilon_{eff} \approx (\varepsilon_r + 1)/2 \approx 2.75$ and c is the speed of light. $L_1 = l_1 + l_2 + 2w_1$ and $L_2 = l_1 + l_2 + l_3 + w_1 + w_2 + w_3 + t$ are the dominant lengths of the folded strip for resonant frequencies f_l and f_u, respectively. The widths of all portions of the radiating strip are optimized to be t = 0.5 mm. Parametric analysis illustrates that, due to the importance of current density on the performance of this antenna, t should be much smaller than the thickness of the substrate. In order to verify accuracy of the formulas for the resonating frequencies, the dominant lengths are varied while keeping the other parameters unchanged and the resonating frequencies are calculated using equations 1 and 2. The results are compared with those produced by the full-wave, method-of-moment based electromagnetic simulator Zeland IE3D. The comparison, shown in ***Figures 2(a)*** and ***(b)***, illustrates that the difference between the simulated and calculated values is only around 4 percent for both operating bands, confirming that the equations provide quite an accurate mathematical estimation for the required lengths of L_1 and L_2.



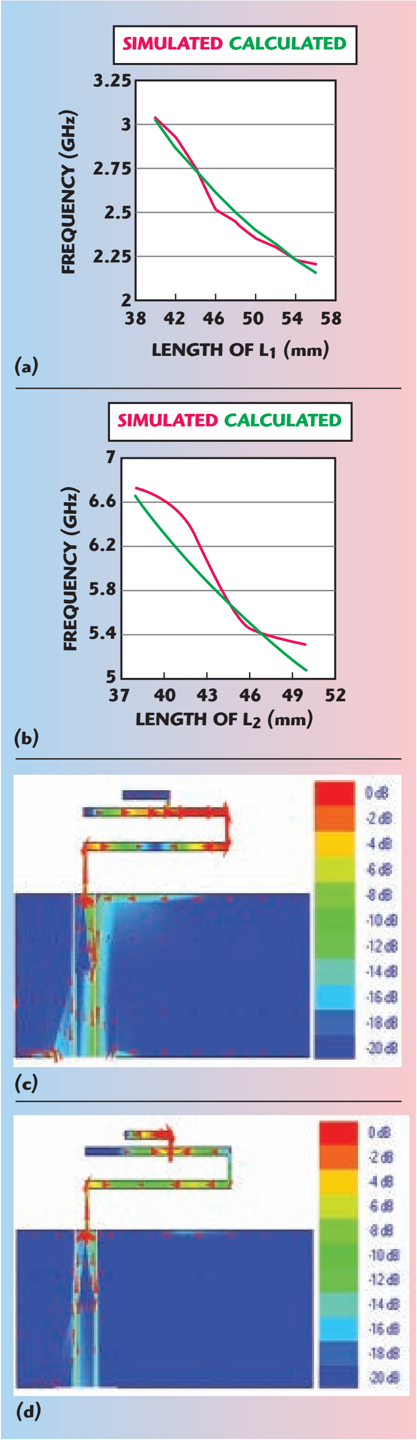
Another way to understand the operating principle of the antenna is by studying the excited surface current distribution, shown in Figures 2(c) and (d). From the strong current distribution observed in the folded strip, it is evident that the surface waves at both 2.45 and 5.8 GHz are generated from this region. Also at each resonant frequency, the current density is higher on the parts of the folded strip whose dimensions are assumed to govern that particular frequency. The lengths L_1 and L_2 might also be determined through this observation.

The ground plane does not carry significant current components. The currents flowing on the edges of ground plane are out of phase with the current on the feed strip in close proximity and thus their radiating effects are mostly nullified. This means that the ground plane does not actively participate in creating the resonances; it acts more likely as a reflector, forcing the electromagnetic energy developed by the surface waves, to be launched into the forward direction.[2] The ground plane dimensions, therefore, are critical for the directivity of the antenna, especially since there are two discrete operating bands. The dimensions of the ground planes are gw_1 = 32.7 mm, gl_1 = 10 mm and gw_2 = 8.7 mm.

The folding distances l_1, l_2 and l_3 have a prominent effect on the forward-directivity of the antenna. To obtain the best performance, these are optimized with the values l_1 = 3.15 mm, l_2 = 1.6 mm and l_3 = 0.6 mm. Note that the folding distances are comparable to the substrate thickness of the substrate or its multiplier. Other optimized values are: w_1 = 21.7 mm, w_2 = 9 mm and w_3 = 6.7 mm. The overall dimensions of the antenna are approximately $0.13\lambda_0 \times 0.36\lambda_0$ (16.5 × 45 mm), where λ_0 is the corresponding free space wavelength at lowest resonance 2.45 GHz.

SIMULATION & MEASUREMENT

An antenna prototype with the optimized parameters was fabricated and tested using the Agilent E8357A vector network analyzer. ***Figure 3*** shows good agreement between the simulated and measured return loss. Its impedance bandwidth (return loss greater than 10 dB) for the 2.45 GHz band is 210 MHz (2.36 to 2.57 GHz) and for the 5.8 GHz band is 230 MHz (5.69 to 5.92 GHz). These are equivalent to 8.5 and 4 percent fractional impedance bandwidths



▲ *Fig. 2 Comparison between the calculated and simulated resonating frequencies for different lengths of L_1 (a) and L_2 (b). Surface current distributions of the antenna at 2.45 GHz (c) and 5.8 GHz (d) showing frequency responses for different parts of antenna.*

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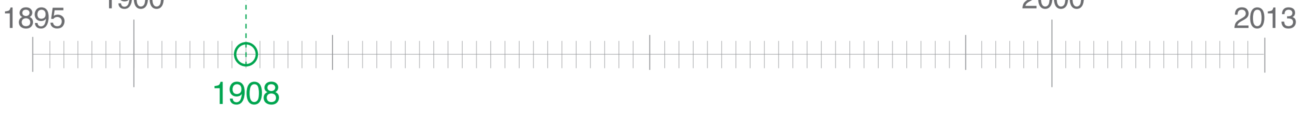

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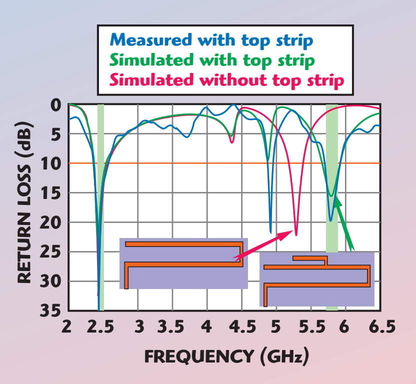
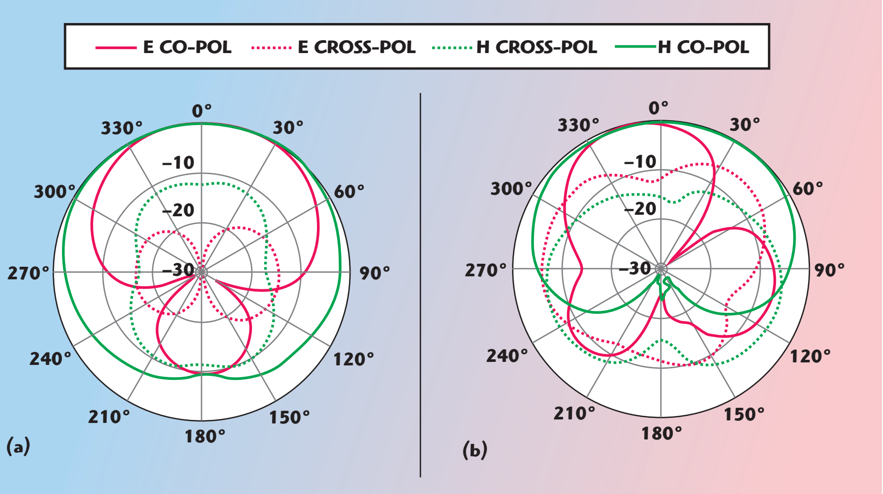


▲ *Fig. 3 Measured and simulated return loss of the dual-band antenna.*



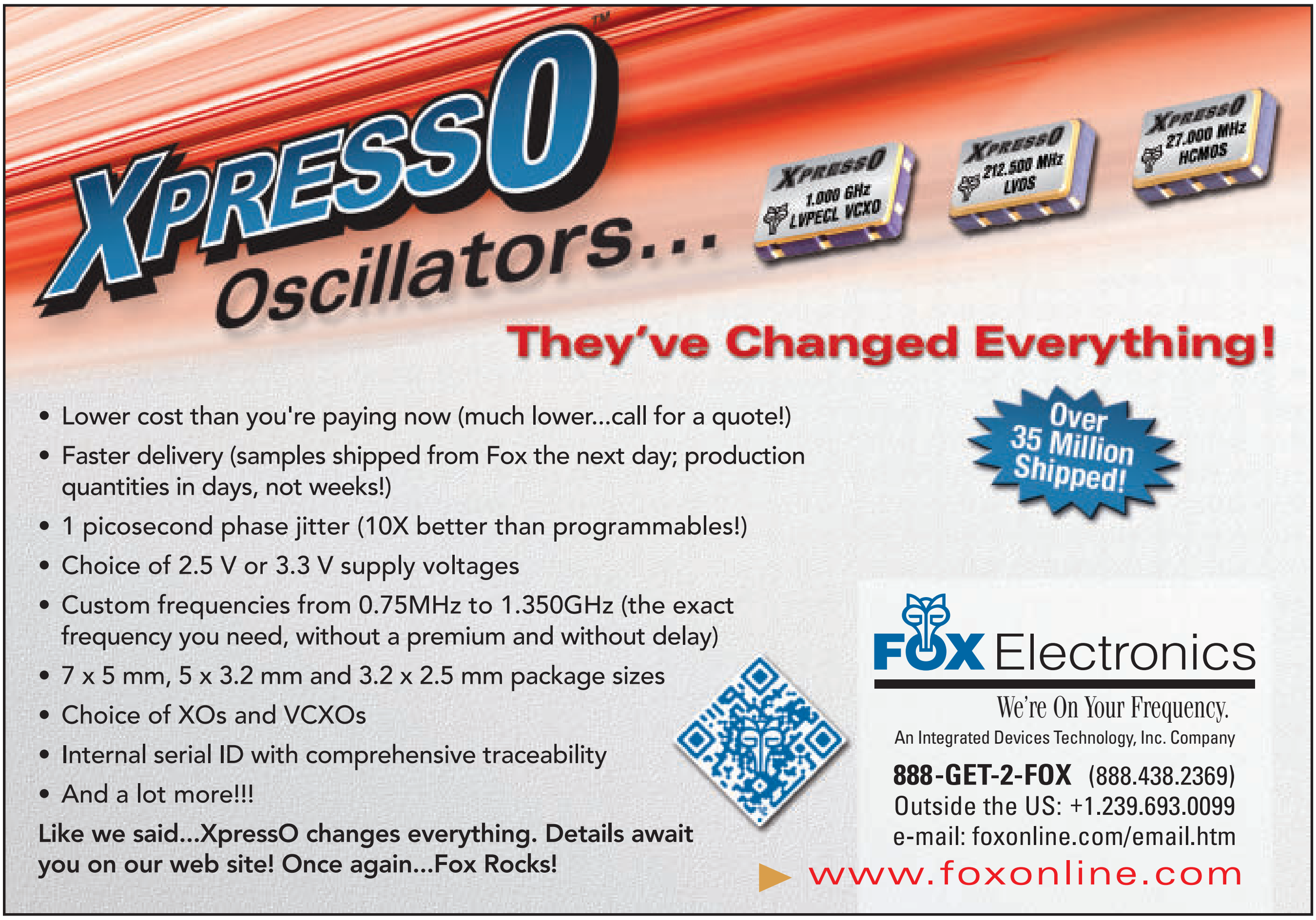
▲ *Fig. 4 Measured radiation patterns of the proposed antenna at E- (XY) and H- (YZ) planes at 2.45 (a) and 5.8 GHz (b).*

with respect to the center frequencies of 2.47 and 5.81 GHz. This satisfies the dual ISM-band (2.45/5.8 GHz) requirement for RFID applications. The third graph of Figure 3 also shows that both resonating frequencies can be individually tuned.

The normalized E- (XY) and H- (YZ) plane radiation patterns of the antenna at 2.45 and 5.8 GHz (see ***Figure 4***) are forward-directed, with the backward radiation suppressed by around 9 dB at 2.45 GHz and 22 dB at 5.8 GHz. The cross-polarization levels for both E- and H- planes are less than –12 dB. The patterns are well behaved and directional with high polarization purity in the forward direction and good front-to-back ratio, which is an important characteristic for RFID handheld readers.[3] These characteristics are maintained across both bands. Maximum gains of 3.1 and 3 dBi are achieved in the lower and upper bands respectively, with a less than 0.5 dBi gain variation.

CONCLUSION

A new CPW-fed folded RFID antenna is described. The antenna design process is discussed in detail, explaining the antenna operating principles and providing equations that



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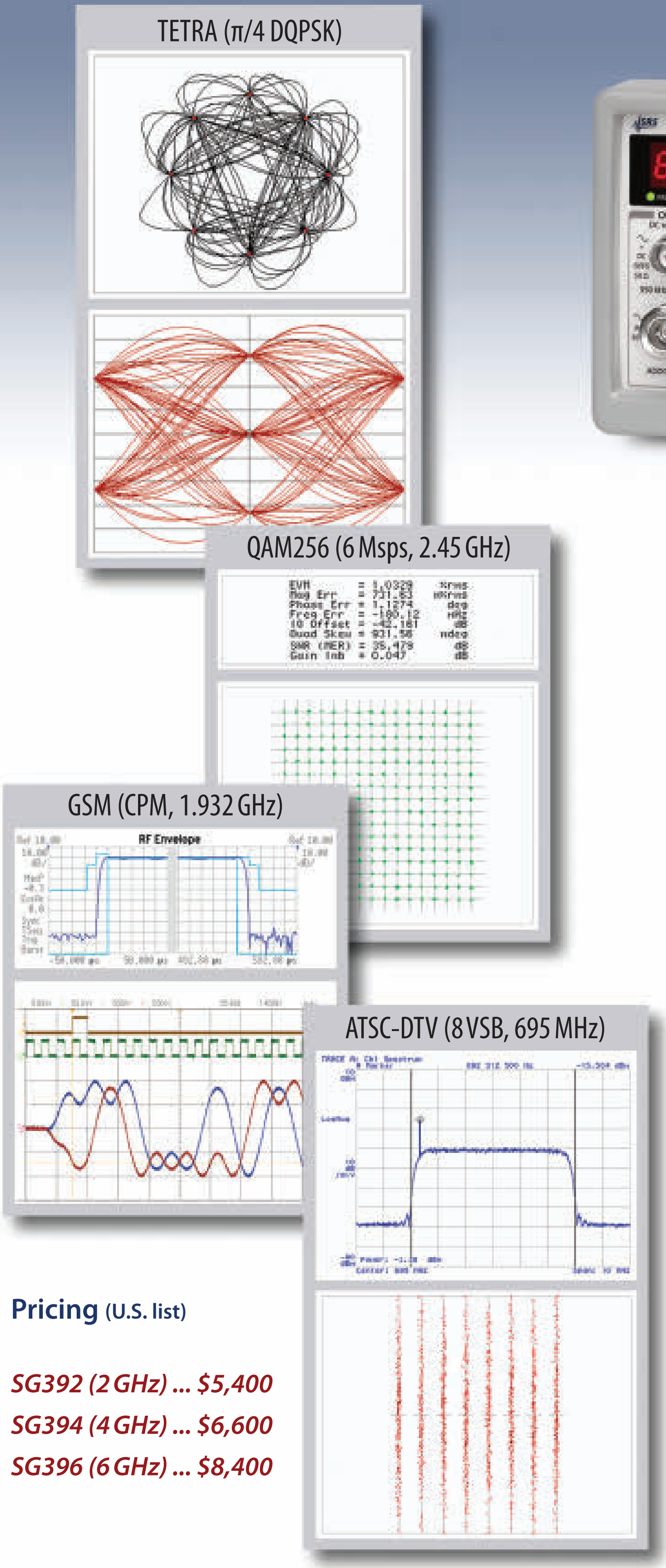

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govern the dimensions. A prototype antenna demonstrates an impedance bandwidth broad enough to cover both the 2.45 and 5.8 GHz ISM bands, and has a forward-directed radiation pattern with good polarization purity, front-to-back ratio and peak gain. With these characteristics, the proposed antenna should find wide use in multi-band compact handheld RFID readers. ■

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A Miniaturized Impedance Transformer on PES for Flexible RFICs

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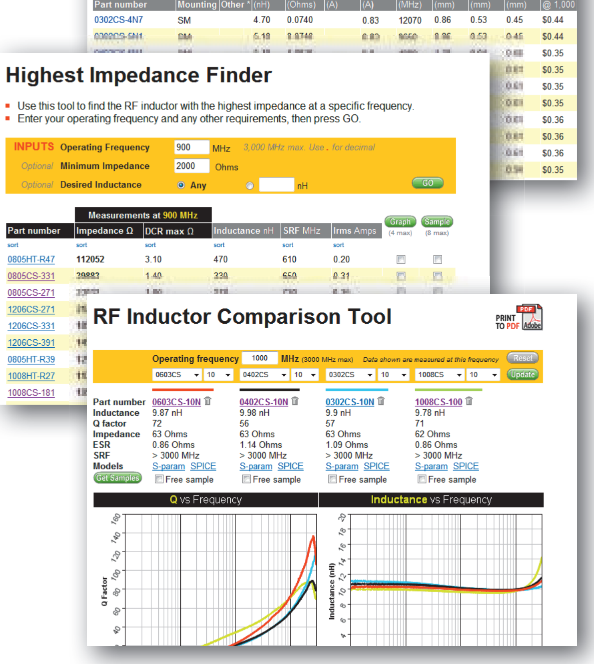
A transmission line employing a periodic structure was fabricated on a polyether sulfone (PES) substrate and its RF characteristics were investigated. A fishbone-type transmission line, employing a comb-type ground plane (FTLCGP) structure, was designed to reduce the wavelength. The FTLCGP structure on PES substrate showed a wavelength much shorter than for a conventional coplanar waveguide on PES. The FTLCGP structure on the PES substrate showed an attenuation constant α lower than 0.2 Np/mm, up to 40 GHz, which was much lower than for a transmission line on a commercial silicon substrate. Using the FTLCGP structure, a miniaturized impedance transformer was fabricated on a PES substrate for flexible RFIC applications. The size of the impedance transformer was 0.45 mm^2, which was 57.5 percent of the size of the transformer fabricated by conventional coplanar waveguide on PES substrate. The return and insertion losses were 43 and 0.74 dB, respectively, at a center frequency of 22 GHz and the return loss values were better than 10 dB and the insertion loss was better than 1.1 dB up to 46.4 GHz.

Flexible electronics have drawn significant attention, owing to their variety of applications, such as flexible displays, smart tags and wearable products.[1] In the development of a transparent flexible display for mobile communications, RF devices should be integrated into a transparent flexible substrate. Recently, polyether sulfone (PES) has drawn attention for flexible displays, due to its good heat-resisting property, high transparency and good flexibility.[2,3] The glass transition temperature (T_g) of PES is 230°C and it shows stable electrical and mechanical properties at high temperature, which enables the fabrication of electron devices at a relatively high temperature.[2,3] For a short time, the electrical and mechanical properties of the PES do not change at even 300°C. Therefore, unlike other flexible substrates such as polycarbonate (PC) and polyethylene terephthalate (PET), soldering and bonding processes of electronic devices on PES can be easily performed, which facilitates the packaging process. In addition, a very thin PES substrate, with a thickness of less than 100 µm, can be used for fabrication of electronic devices due to its stability, which is very effective for the miniaturization of RF components. Furthermore, the PES shows a contraction ratio less than 0.2 percent, even if it is exposed to a high temperature environment for a long time, which enables precise processes such as for a microelectromechanical system (MEMS).



Part number	Mounting	Other *	(nH)	(Ohms)	(A)	(A)	(MHz)	(mm)	(mm)	(mm)	@ 1,000
0302CS-4N7	SM		4.70	0.0740		0.83	12070	0.86	0.53	0.45	$0.44

Highest Impedance Finder

- Use this tool to find the RF inductor with the highest impedance at a specific frequency.
- Enter your operating frequency and any other requirements, then press GO.

INPUTS Operating Frequency 900 MHz *3,000 MHz max. Use . for decimal*
Optional Minimum Impedance 2000 Ohms
Optional Desired Inductance ● Any ○ nH

	Measurements at 900 MHz					Graph (4 max)	Sample (8 max)
Part number	Impedance Ω	DCR max Ω	Inductance nH	SRF MHz	Irms Amps		
sort	sort	sort	sort	sort	sort		
0805HT-R47	112052	3.10	470	610	0.20	☐	☐
0805CS-331							
0805CS-271							
1206CS-271							
1206CS-331							
1206CS-391							
0805HT-R39							
1008HT-R27							
1008CS-181							

RF Inductor Comparison Tool

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Operating frequency 1000 MHz (3000 MHz max) *Data shown are measured at this frequency*

0603CS 10 | 0402CS 10 | 0302CS 10 | 1008CS 10

Part number	0603CS-10N	0402CS-10N	0302CS-10N	1008CS-100
Inductance	9.87 nH	9.98 nH	9.9 nH	9.78 nH
Q factor	72	56	57	71
Impedance	63 Ohms	63 Ohms	63 Ohms	62 Ohms
ESR	0.86 Ohms	1.14 Ohms	1.09 Ohms	0.86 Ohms
SRF	> 3000 MHz	> 3000 MHz	> 3000 MHz	> 3000 MHz
Models	S-param SPICE	S-param SPICE	S-param SPICE	S-param SPICE
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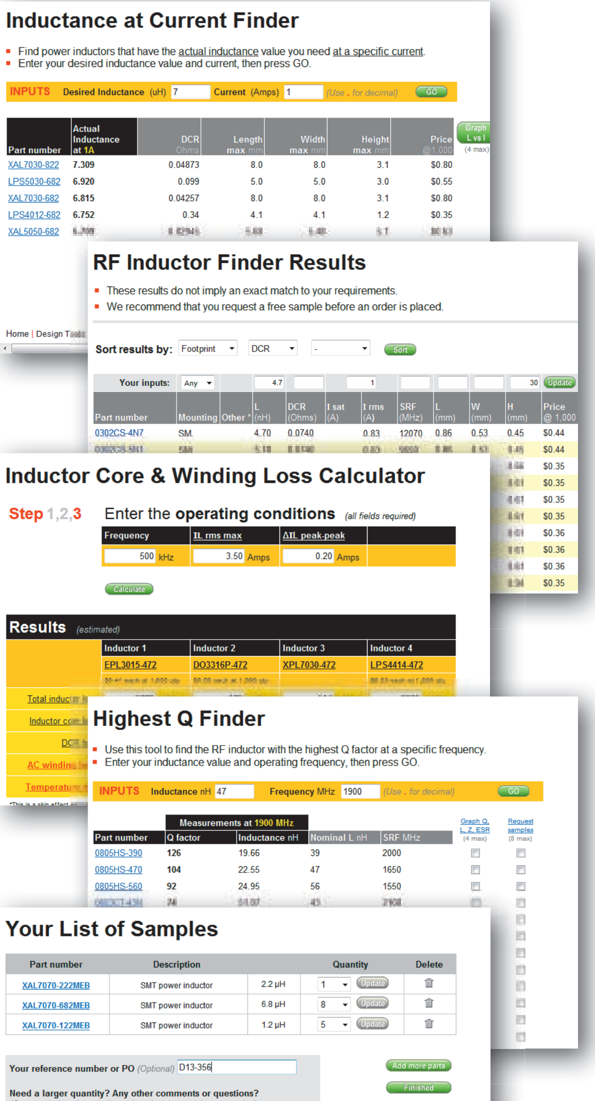

Inductance at Current Finder

- Find power inductors that have the actual inductance value you need at a specific current.
- Enter your desired inductance value and current, then press GO.

INPUTS Desired Inductance (uH) 7 Current (Amps) 1 *(Use . for decimal)*

Part number	Actual Inductance at 1A	DCR Ohms	Length max mm	Width max mm	Height max mm	Price @1,000
XAL7030-822	7.309	0.04873	8.0	8.0	3.1	$0.80
LPS5030-682	6.920	0.099	5.0	5.0	3.0	$0.55
XAL7030-682	6.815	0.04257	8.0	8.0	3.1	$0.80
LPS4012-682	6.752	0.34	4.1	4.1	1.2	$0.35
XAL5050-682						

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RF Inductor Finder Results

- These results do not imply an exact match to your requirements.
- We recommend that you request a free sample before an order is placed.

Sort results by: Footprint DCR -

Your inputs:	Any		4.7			1				30	
Part number	Mounting	Other *	L (nH)	DCR (Ohms)	I sat (A)	I rms (A)	SRF (MHz)	L (mm)	W (mm)	H (mm)	Price @ 1,000
0302CS-4N7	SM		4.70	0.0740		0.83	12070	0.86	0.53	0.45	$0.44

Inductor Core & Winding Loss Calculator

Step 1,2,**3** Enter the **operating conditions** *(all fields required)*

Frequency	IL rms max	ΔIL peak-peak
500 kHz	3.50 Amps	0.20 Amps

Calculate

Results *(estimated)*

	Inductor 1	Inductor 2	Inductor 3	Inductor 4
	EPL3015-472	DO3316P-472	XPL7030-472	LPS4414-472

Highest Q Finder

- Use this tool to find the RF inductor with the highest Q factor at a specific frequency.
- Enter your inductance value and operating frequency, then press GO.

INPUTS Inductance nH 47 Frequency MHz 1900 *(Use . for decimal)*

	Measurements at 1900 MHz				Graph Q, L, Z, ESR (4 max)	Request samples (8 max)
Part number	Q factor	Inductance nH	Nominal L nH	SRF MHz		
0805HS-390	126	19.66	39	2000	☐	☐
0805HS-470	104	22.55	47	1650	☐	☐
0805HS-560	92	24.95	56	1550	☐	☐

Your List of Samples

Part number	Description		Quantity	Delete
XAL7070-222MEB	SMT power inductor	2.2 µH	1	
XAL7070-682MEB	SMT power inductor	6.8 µH	8	
XAL7070-122MEB	SMT power inductor	1.2 µH	5	

Your reference number or PO *(Optional)* D13-356

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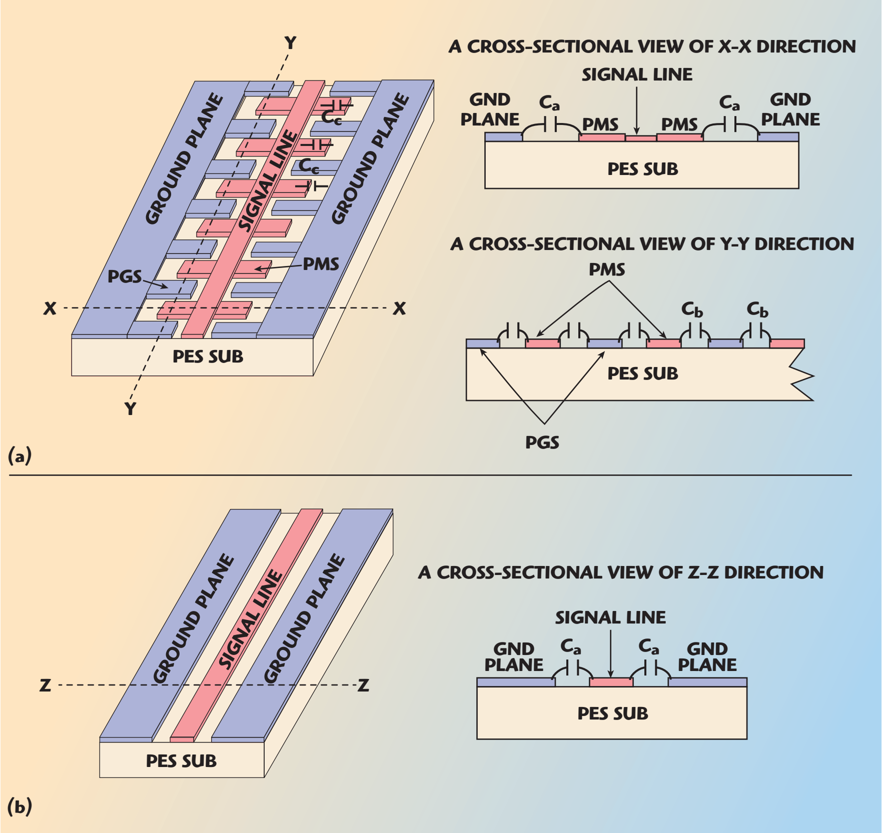

▲ *Fig. 1 The FTLCGP structure (a) and a typical coplanar waveguide (b).*

Besides the above-mentioned properties, the PES shows good water resisting qualities. For this reason, PES is well suited for transparent flexible displays used in mobile communications and several groups have employed the PES substrate to evaluate the electrical properties of oxide films.[4]

In mobile communication flexible display applications, RF passive components[5,6] as well as active devices should be integrated in PES substrates. An impedance transformer[7] is a key device for impedance matching between RF devices. In this work, a miniaturized impedance transformer, employing a periodic structure, was fabricated on a PES substrate for impedance matching on a flexible RFIC and its RF characteristics were investigated. This is the first known report of an impedance transformer fabricated on a flexible PES substrate.

RF CHARACTERISTICS OF TRANSMISSION LINE EMPLOYING PERIODIC STRUCTURE ON PES

According to previous results,[8] a coplanar waveguide on a PES substrate showed a wavelength much longer than the one on commercial silicon substrate, due to the low permittivity of PES, which is unfavorable to integrate RF passive components on a PES substrate because of its large circuit size. The wavelength at 20 GHz, for a coplanar waveguide on silicon and PES substrate, was 5.71 and 9.29 mm, respectively. Here, a transmission line employing a periodic structure was fabricated on PES to reduce the wavelength. A fishbone-type transmission line employing a comb-type ground plane (FTLCGP) was designed. Until now, various types of periodic structures have been studied for application to RF circuits. The FTLCGP structure was also fabricated on PCB for low impedance transmission lines in S-Band.[6] The FTLCGP structure fabricated on the conventional PCB successfully operated as a transmission line up to S-Band. However, according to measured results, the FTLCGP structure on a conventional PCB such as Teflon showed a very narrowband characteristic at millimeter wave frequencies and it could not be used as a transmission line. In this work, the FTLCGP structure was fabricated on a PES substrate, and it successfully operated as a transmission line on a PES substrate up to 50 GHz.

TABLE I

WAVELENGTH OF TRANSMISSION LINES ON PES

Frequency (GHz)	FTLCGP (mm)	CPW Without Periodic Structure (mm)
10	9.22	18
20	4.81	9.29
30	3.25	6.33
40	2.4	4.85
50	1.91	3.94

Figure 1 shows the structures of a FTLCGP and a typical coplanar waveguide without periodic structure on the PES substrate. As shown, the FTLCGP consists of a fishbone-type signal line and comb-type ground planes. The fishbone-type signal line consists of a central line with periodic metal strips (PMS) and the comb-type ground plane consists of a ground plane and periodic ground strips (PGS). The PMSs are placed alternately with the PGSs. The conventional coplanar waveguide has only a periodical capacitance (C_a) between the line and ground plane, while the FTLCGP has additional capacitances, C_b as well as C_a, due to the electromagnetic coupling between PMS and PGS. In addition, the FTLCGP has a periodical shunt capacitance C_c because PMS operates as an open stub at the operating frequency. Therefore, the FTLCGP exhibits a wavelength (λg) shorter than the conventional coplanar waveguide, because λg is inversely proportional to the periodical capacitance between signal line and ground. In other words, $\lambda g = 1/[f(LC)^{0.5}]$.

Table 1 shows the wavelength of transmission lines on PES. For a fabrication of transmission lines on PES, Au/Ti was deposited on PES substrate 200 µm thick and the thickness of the Au/Ti was 2 µm. For the FTLCGP, the length and width of PMS/PGS are 160 and 30 µm, respectively, and the distance between PMS and PGS is 30 µm. The signal line width is 70 µm. As shown in the table, the FTLCGP structure shows wavelengths much shorter than for the conventional co-


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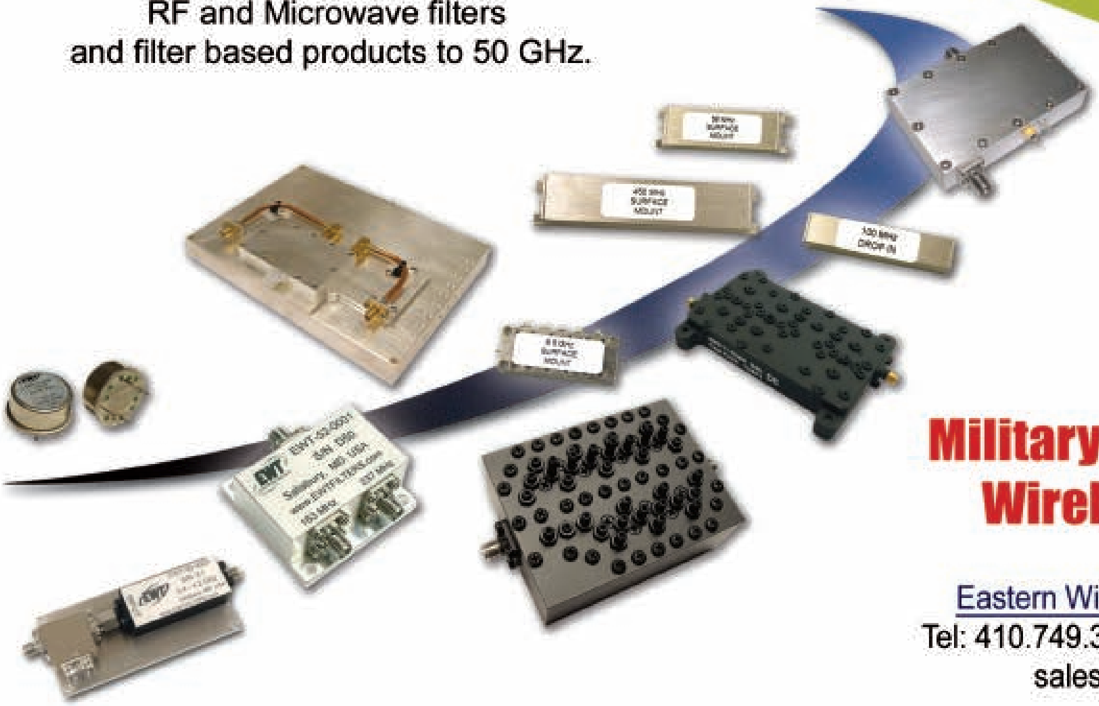
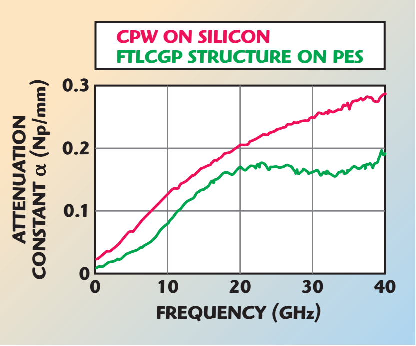


planar waveguide. The wavelength at 20 GHz of the FTLCGP structure on PES is 4.81 mm, which is shorter than for a coplanar waveguide on silicon substrate. For example, the wavelength at 20 GHz of a conventional coplanar waveguide on silicon substrate with a thickness of 600 μm is 5.71 mm.

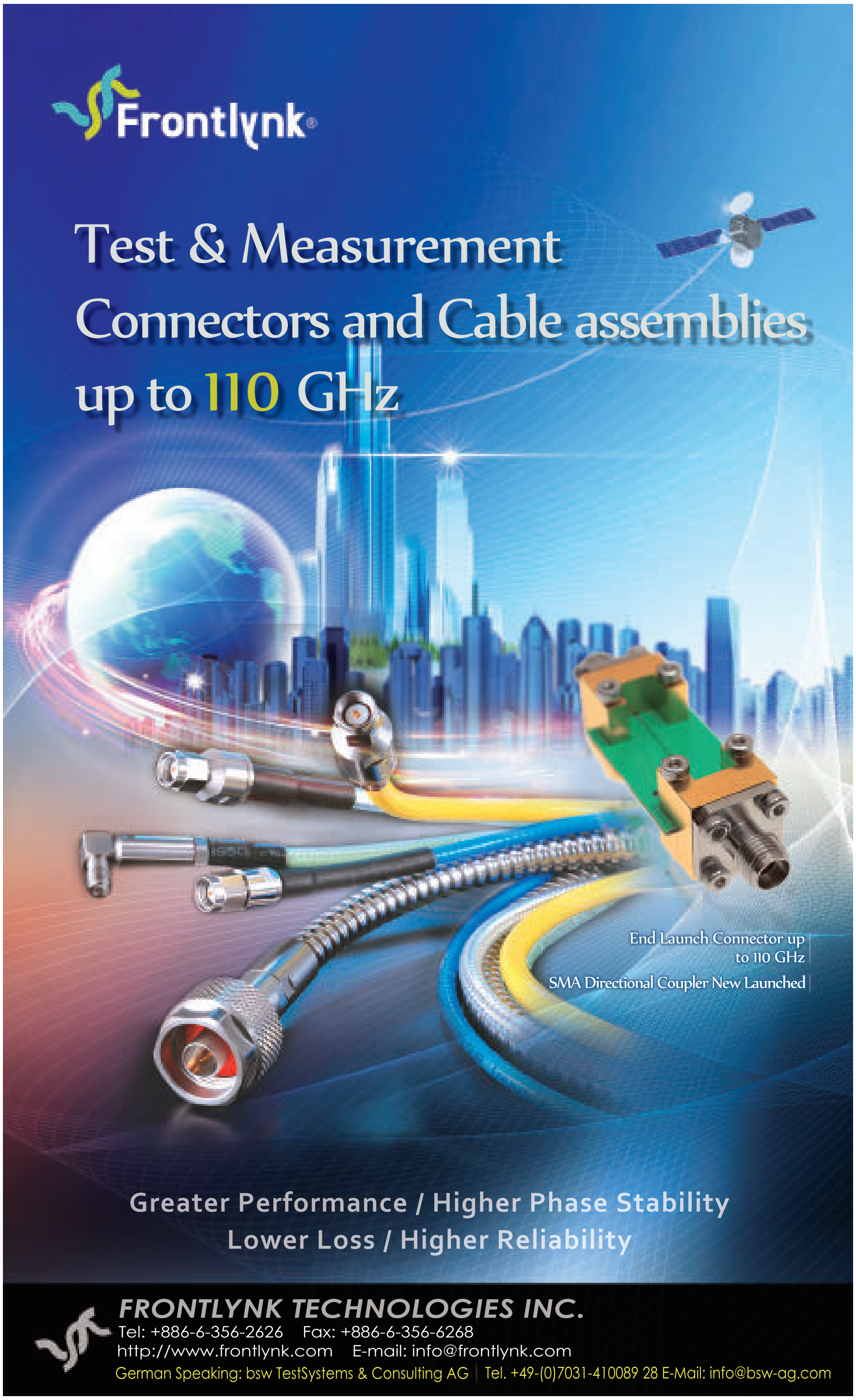
In order to investigate the suitability of the FTLCGP structure for RF applications, the loss of the transmission line was measured at 20 GHz. ***Figure 2*** shows the measured attenuation constant α of the FTLCGP structure on PES. The insertion loss was measured for a 50 Ω impedance and it was normalized to the characteristic impedance of the transmission line. For comparison, the data for a coplanar waveguide on commercial silicon substrate was also plotted, because a silicon substrate is the most popular semiconducting substrate for commercial RFIC applications. As shown, the FTLCGP structure on PES shows a comparatively low loss, compared with the silicon substrate. It shows an attenuation constant α lower than 0.2 Np/mm up to 40 GHz. This low loss of the transmission line on PES originates from its excellent electrical insulating properties. In the case of the coplanar waveguide on silicon substrate, there is a current flowing from line to ground plane through the silicon substrate due to a relatively high conductivity of the silicon substrate, which causes a relatively high loss of electromagnetic energy.[5] In the case of the transmission line on PES, however, there does not exist a current flowing from line to ground plane through the PES substrate due to its good electrical insulating characteristic.



▲ *Fig. 2 Measured attenuation constant α.*

RF CHARACTERISTICS OF IMPEDANCE TRANSFORMER EMPLOYING A PERIODIC STRUCTURE ON PES

Using the FTLCGP structure on PES, a miniaturized impedance transformer was developed for flexible RFIC applications. ***Figure 3*** shows a photograph of the single section λ/4 impedance transformer on a PES substrate. Au/Ti was deposited on a PES substrate 200 μm thick and the thickness of the Au/Ti was 2 μm. The characteristic impedance Z_0 of the transformer is given by $Z_0 = (Z_{c1}Z_{c2})^{0.5}$ where Z_{c1} and Z_{c2} are the source and load impedance, respectively.[7] In this work, the impedance transformer was designed to transform an impedance of 70 Ω into a standard impedance of 50 Ω. Therefore, Z_0 is 59 Ω. For a Z_0 of 59 Ω, the length of PMS/PGS is 160 μm and signal line width is 0.45 mm. At a center frequency of 22 GHz, the length of the λ/4 transformer is 1 mm. Therefore, the size of the impedance transformer is 0.45 mm², which is 57.5 percent of the size of a transformer fabricated with a conventional



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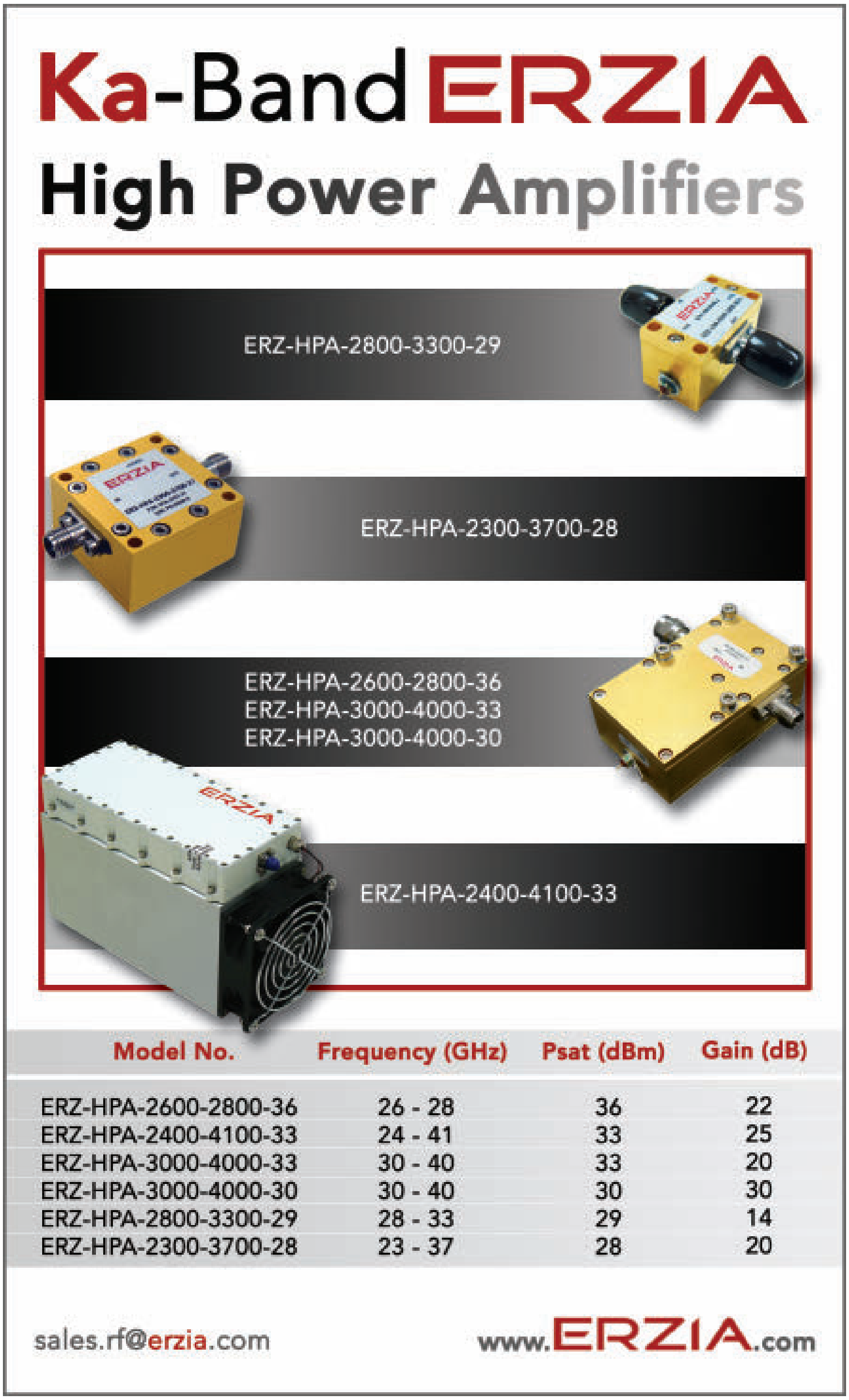
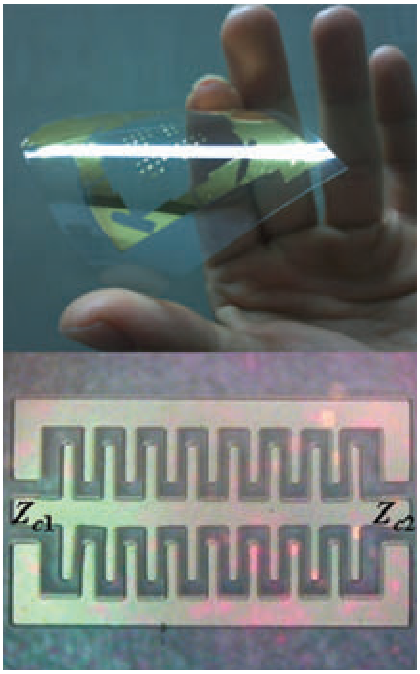
coplanar waveguide on PES. If a $\lambda/4$ transformer with a Z_0 of 59 Ω is fabricated with a conventional coplanar waveguide on a PES substrate, the signal line width and length are 0.34 and 2.3 mm, respectively, and its size is 0.782 mm^2. The sizes of impedance transformers on a PES substrate are summarized in ***Table 2***.

Figure 4 shows the measured return loss and insertion loss of the transformer. The insertion and return loss were measured at a port impedance of 50 Ω, and it was normalized by source and load impedance, Z_{c1} and Z_{c2}. As shown, an excellent RF performance can be observed from the transformer. The return and insertion losses are 43 and 0.74 dB, respectively, at a center frequency of 22 GHz, return loss values better than 10 dB up to 46.4 GHz and insertion loss better than 1.1 dB in the same frequency range.

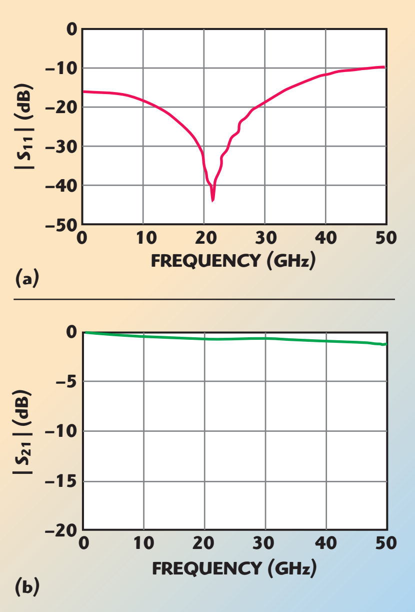


CONCLUSION

A FTLCGP structure was fabricated on a PES substrate and its RF characteristics were investigated. The FTLCGP structure on PES showed a wavelength much shorter than conventional coplanar waveguide on PES. The wavelength of the conventional coplanar waveguide on PES is 9.29 mm at 20 GHz, while the wavelength of the FTLCGP structure on PES is 4.81



▲ *Fig. 3 Photograph of the single section $\lambda/4$ impedance transformer using the FTLCGP structure on a PES substrate.*



▲ *Fig. 4 Measured RF performance of the impedance transformer on a PES substrate, return loss (a) and insertion loss (b).*

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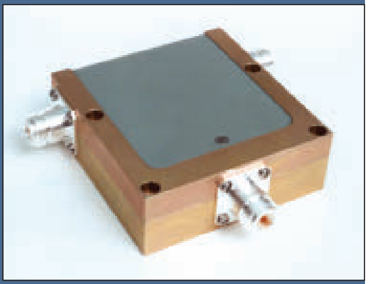

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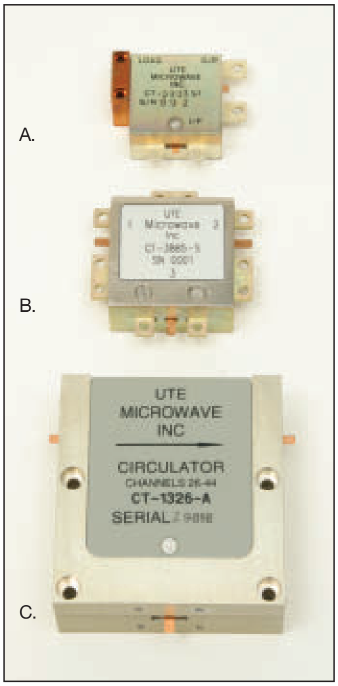

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TABLE II

SIZE OF IMPEDANCE TRANSFORMER ON PES SUBSTRATE

Items	Z_0=59Ω		Size (mm²)
	Signal Line Width (mm)	Length (mm)	
CPW Without Periodic Structure	0.34	2.3	0.782
FTLCGP Structure	0.45	1	0.45

mm at the same frequency. The FTLCGP structure on PES showed an attenuation constant α lower than 0.2 Np/mm up to 40 GHz, which was much lower than for a transmission line on commercial silicon substrate. Using the FTLCGP structure on a PES, a miniaturized impedance transformer was fabricated on a PES substrate for flexible RFIC applications. The impedance transformer was designed to transform an impedance of 70 Ω into a standard impedance of 50 Ω. The size of the impedance transformer was 0.45 mm², which was 57.5 percent of the size of the transformer fabricated with a conventional coplanar waveguide on PES. Excellent RF performance could be observed from the impedance transformer. The return and insertion losses were 43 and 0.74 dB, respectively, at a center frequency of 22 GHz. The return loss values were better than 10 dB and the insertion loss were better than 1.1 dB up to 46.4 GHz. ■

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Third-Order Fully Canonical Microstrip Bandpass Transversal Filter with Source-Load Coupling

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The design of a compact third-order fully canonical transversal microstrip bandpass filter (BPF) is described. It consists of two microstrip shorted stub loaded resonators (SSLR), where the fundamental mode is the even mode. By utilizing the resonance properties of the transversal filter and the introduction of source-load (S-L) coupling, the filter design incorporates two transmission zeros above and one below the passband. This improves passband selectivity and the rejection of unwanted signals above the passband.

In recent years, high-performance planar bandpass filters have found wide application in many RF/microwave circuits and systems. In these filters, transmission zeros at finite frequencies are needed to improve the passband selectivity and reject unwanted signals. For this purpose, a transversal filter is described by Rosenberg and Amari,[1] where the signal couples to several resonators, providing more than one main path for the signal between the source and load. In the transversal filter, however, the source/load must couple to all resonators, while at the same time avoiding intercoupling between resonators. Transmission zeros can be realized due to counteraction among several main path signals. Stub loaded dual-mode filters with S-L coupling are special second-order fully canonical transversal filters.[2-5,7] The practical implementation of a transversal filter, however, is difficult when the order is higher than two. Martinez-Mendoza et al.[6] describe a third-order fully canonical transversal filter combining waveguide and microstrip techniques with two transmission zeros below and one above the passband, but the use of waveguide makes this filter much larger than conventional planar filters. Liao et al.[7] describe how the extended-doublet filter can operate as a third-order transversal filter if intercoupling between the resonators is avoided; however, this structure has poor stopband performance. Zhou et al.[8] describe a compact third-order transversal microstrip filter that incorporates a dual-mode open-loop resonator and a slot line resonator with S-L coupling. A disadvantage of having a slot line etched in the ground plane, however, is that the whole structure must be suspended far from other ground conductors for the slot resonator to be effective.

In this article, we discuss the design of a third-order fully canonical transversal microstrip BPF incorporating two SSLRs with S-L coupling. It has two transmission zeros above and one below the passband. This greatly improves the selectivity of the passband and the rejection of unwanted signals above the passband. We analyze the resonance characteristics of the SSLR using odd and even-mode

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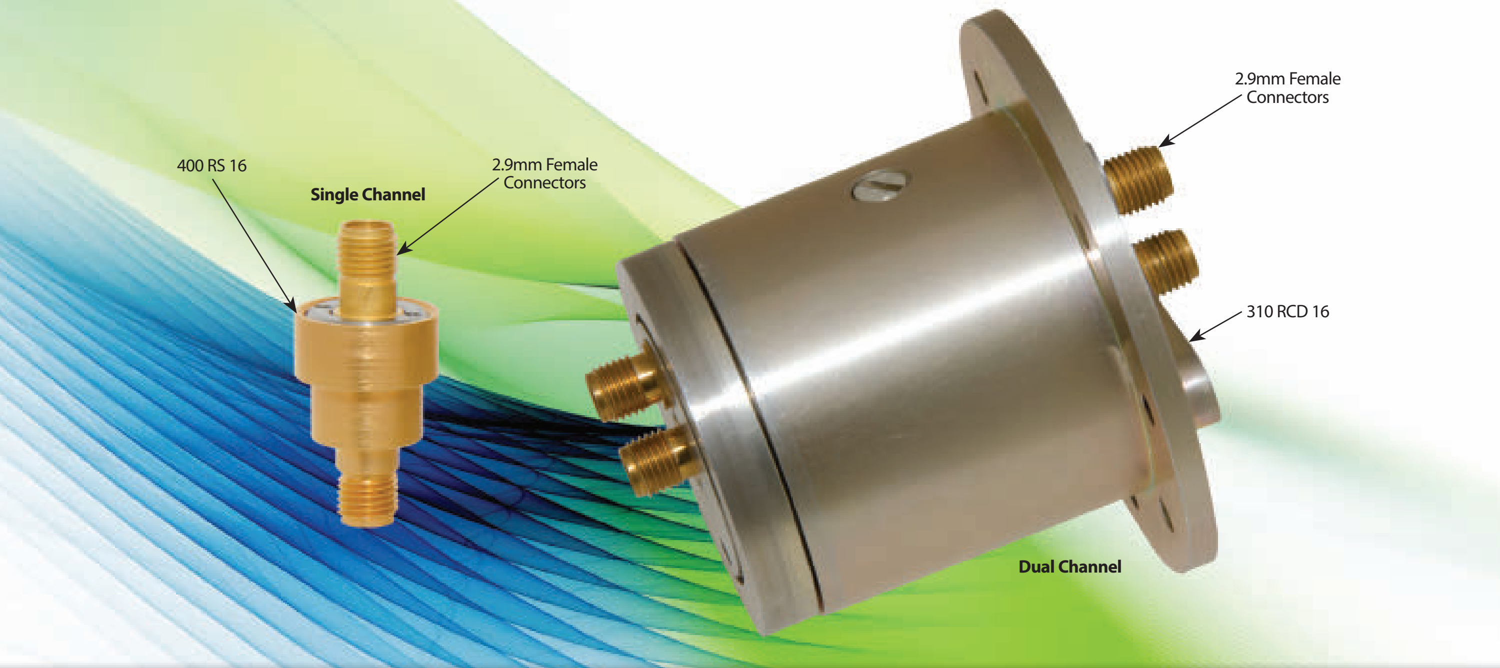

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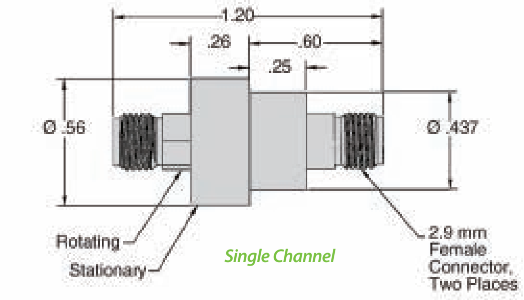

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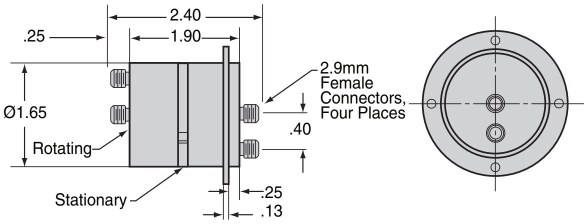

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VSWR	DC - 10 GHz	1.20 : 1 MAX.
	10 - 26 GHz	1.35 : 1 MAX.
	26 - 40 GHz	1.75 : 1 MAX.
WOW	1.05 MAX.	
INSERTION LOSS	DC - 10 GHz	0.2 dB MAX.
	10 - 26 GHz	0.4 dB MAX.
	26 - 40 GHz	0.6 dB MAX.
PEAK POWER	Equal to connector rating	

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DUAL CHANNEL SPECIFICATIONS:

ELECTRICAL	Channel 1	Channel 2
FREQUENCY	7.0 - 22.0 GHz	29.0 - 31.0 GHz
VSWR	1.50:1 MAX.	1.70:1 MAX.
WOW	0.15	0.25
INSERTION LOSS	0.5 dB MAX.	1.0 dB MAX.
ISOLATION	Channel to Channel	50.0 dB MIN.

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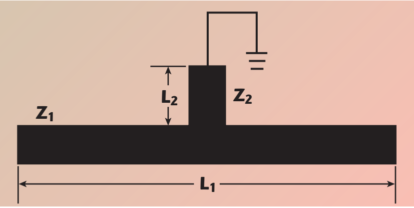


▲ *Fig. 1 SSLR schematic.*

analysis, design a transversal filter using SSLRs and verify the results through simulation and measurement. A 1.45 GHz three-order transversal microstrip BPF with 80 MHz bandwidth and 20 dB in-band return loss is designed. Measured results agree well with the simulations. The size of the filter is less than 0.092 λg × 0.12 λg, where λg is the guided wavelength on the substrate, making it smaller than the filters described in the references.

ANALYSIS OF THE SHORTED STUB LOADED RESONATOR

Figure 1 shows the schematic of the SSLR, which comprises a half-wavelength resonator and a shorted stub shunted at the midpoint. Z_1, L_1, Z_2 and L_2, denote the characteristic impedances and lengths of the half-wavelength resonator and shorted stub in the SSLR, respectively. Because the SSLR is symmetrical in structure, odd- and even-mode analysis can be used. The first resonant frequency is an even-mode. The resonant condition is given by

$$\tan(\theta_2)\tan(\theta_1/2) = \frac{Z_1}{2Z_2}(\text{at } f = f_e) \tag{1}$$

where θ_1 and θ_2 are the electrical lengths of the half-wavelength resonator in the SSLR and the shorted stub, respectively. f_e is the even-mode resonant frequency of the SSLR. For the case where $Z_1 = 2Z_2$, the resonant frequency can be expressed as

$$f_e = \frac{c}{2(L_1 + 2L_2)\sqrt{\varepsilon_{eff}}} \tag{2}$$

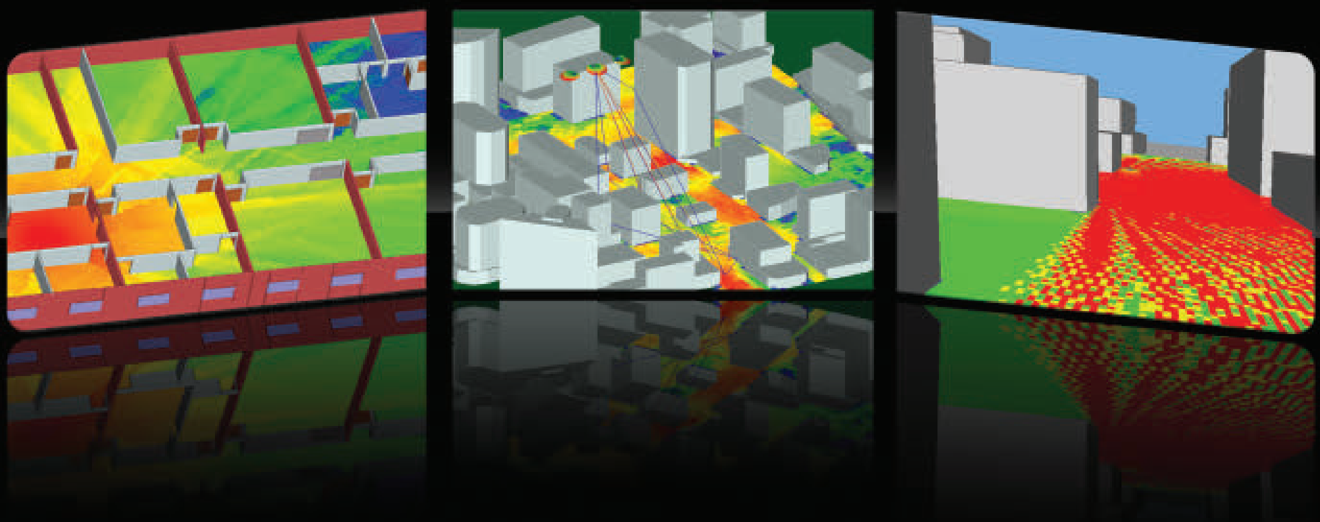
For the odd-mode, the resonant characteristic is almost the same as that of the half-wavelength resonator, which is mainly determined by L1. The odd-mode resonant frequency of the SSLR is given by

$$f_o = \frac{c}{2L_1\sqrt{\varepsilon_{ff}}} \tag{3}$$

By properly choosing the values of L_1 and L_2 using Equations 2 and 3, we can operate the even-mode and/or odd-mode of the SSLR together to define the passband of the filter. When L_2 is slightly more than zero, the SSLR can be operated as a dual-mode resonator.

DESIGN OF THE THIRD-ORDER TRANSVERSAL FILTER

The third-order transversal filter can be analyzed by using the theory of a second-order transversal filter. For a second-order transversal filter, one resonator is designed to work at odd resonance frequency (f_0) and even resonance frequency (f_e). The counteraction of signals in two main paths creates an inherent transmission zero at one side of the passband. An additional transmission zero can be created by introducing S-L coupling. For the dual-mode SSLR, external coupling for the odd-mode resonance is larger than for the even-mode



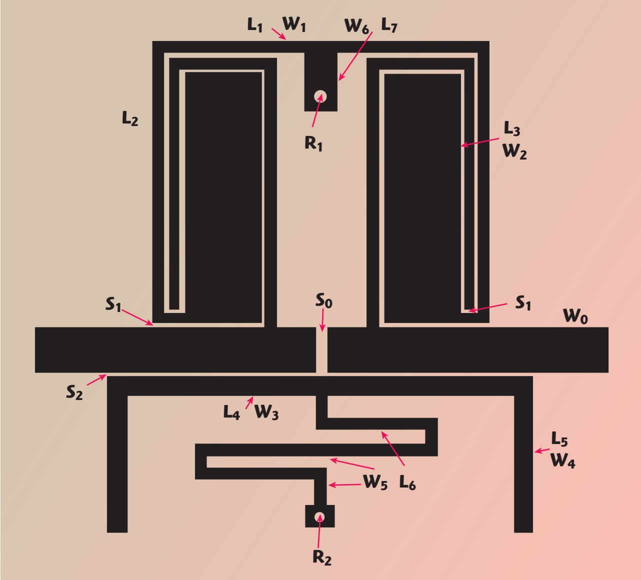


Fig. 2 Layout of the third-order fully canonical transversal filter.

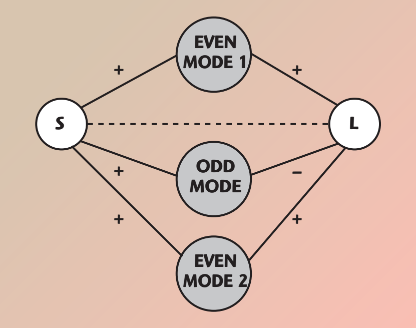


Fig. 3 Corresponding coupling scheme of the third-order fully canonical transversal filter.

resonance. Thus, for a third-order transversal filter with S-L capacitive coupling, the proper means to realize two transmission zeros above and one below the passband is to place one odd-mode resonant frequency between two even-mode resonant frequencies.

The layout of the filter is shown in ***Figure 2***. It consists of two SSLRs with the S-L coupling. The SSLR on the top is a dual-mode resonator, and the other SSLR is an even-mode resonator. In the passband, the filter operates at f_{01}, f_{e1} and f_{e2}. The coupling scheme for a third-order transversal filter is shown in ***Figure 3***. The signal is coupled to three modes at the same time, providing three main paths for the signal between the source and load, with no coupling between each of the modes. Three transmission zeros can be created near each band due to the three main path signals and S-L coupling counteraction. The coupling matrix can be written as

$$\begin{bmatrix} 0 & M_{Se1} & M_{Se2} & M_{So1} & M_{SL} \\ M_{Se1} & M_{e1e1} & 0 & 0 & M_{Le1} \\ M_{Se2} & 0 & M_{e2e2} & 0 & M_{Le2} \\ M_{So1} & 0 & 0 & M_{o1o1} & M_{Lo1} \\ M_{SL} & M_{Le1} & M_{Le2} & M_{Lo1} & 0 \end{bmatrix} \qquad (4)$$

Since the three-order transversal filter exhibits symmetry, the relationship $M_{Se1} = M_{Le1}$, $M_{Se2} = M_{Le2}$ and $M_{S01} = -M_{L01}$ holds. The gap between source and load (S_o) is introduced to provide the proper S-L coupling coefficient M_{SL} for generating an additional zero. The location of the additional zero can be controlled by adjusting the value of So. The coupling coefficient M_{So1} and M_{Se2} can be adjusted by changing S_1 and S_2. M_{Se1} can be adjusted by changing S_1 and L_6. M_{e1e1}, M_{e2e2} and M_{o1o1} can be adjusted with the dimensions of the SSLRs. As shown in Equation 3, the second odd-mode f_{o2} shifts lower in frequency as the length of half-wavelength resonator is increased.

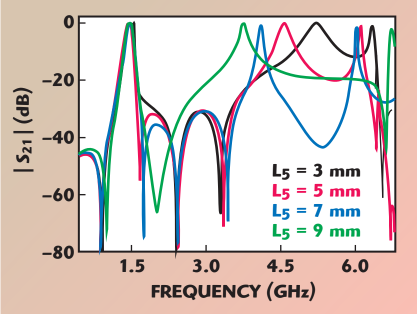


Fig. 4 Simulated S_{21} of the filter for four values of L_5.

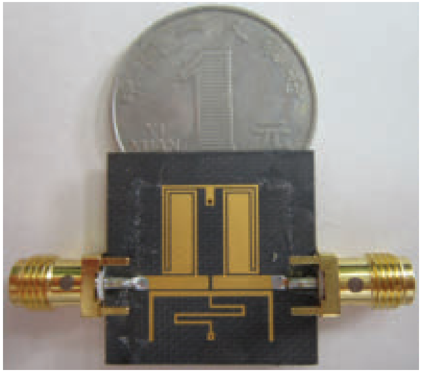


Fig. 5 Photograph of the fabricated BPF.

SIMULATION AND MEASUREMENT

To illustrate the procedure, a second-order generalized Chebyshev filter was designed with a passband return loss of 20 dB and three transmission zeros at normalized frequencies of the complex s-plane 6.86, 2.4 and –17.5. The 3 dB bandwidth is 80 MHz at the center frequency of 1.45 GHz. The filter exhibits the two transmission zeros above and one below the passband. The corresponding coupling coefficients are

$$\begin{bmatrix} 0.0000 & 0.65567 & 0.42427 & -0.75494 & -0.00460 \\ 0.65567 & 1.54350 & 0.00000 & 0.00000 & 0.65567 \\ 0.42427 & 0.00000 & -1.33800 & 0.00000 & 0.42427 \\ -0.75494 & 0.00000 & 0.00000 & -0.38485 & 0.75494 \\ -0.00460 & 0.65567 & 0.42427 & 0.75494 & 0.00000 \end{bmatrix} \qquad (5)$$

S_{21} of the filter is simulated in ***Figure 4*** for four values of L_5, showing that the out-of-band spurious response can be controlled by the length of half-wavelength resonator of the even-mode SSLR.

The final dimensions of the fabricated filter are: $L_1 = 11$ mm, $L_2 = 10$ mm, $L_3 = 9$ mm, $L_4 = 14$ mm, $L_5 = 5$ mm, $L_6 = 19.2$ mm, $L_7 = 2.05$ mm, $W_1 = 0.3$ mm, $W_2 = 2.9$ mm, $W_3 = 0.6$ mm, $W_4 = 0.5$ mm, $W_5 = 0.3$ mm, $W_6 = 1$ mm, $W_o = 1.52$ mm, $R_1 = 0.3$ mm, $R_2 = 0.2$ mm, $S_o = 0.4$ mm, $S_1 = 0.2$ mm and $S_2 = 0.2$ mm. The substrate has a relative dielectric constant of 2.2 and a thickness of 0.508 mm. ***Figure 5*** is a photograph of the fabricated filter. Its physical dimensions are only about 14 × 17.5 mm, which corresponds to 0.092 λg × 0.12 λg, where λg is the guided wavelength at the center frequency 1.45 GHz.

Figure 6 shows the simulated and measured performance of the filter. The simulated/measured minimum insertion loss

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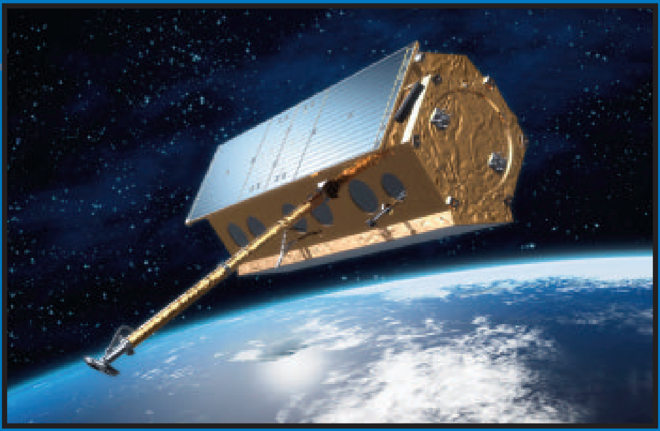

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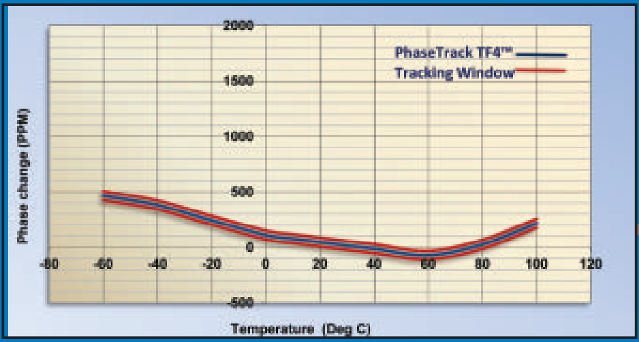

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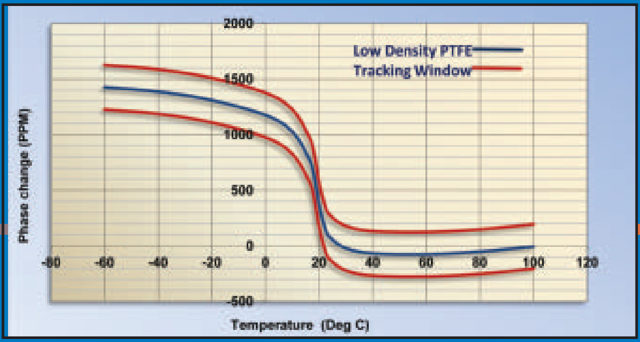

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is 1.5 dB, and the simulated/measured minimum return loss is 20 dB/17 dB. The measured bandwidth is 75 MHz. Three transmission zeros are realized at 0.97, 1.6 and 1.7 GHz. The measured spurious mode is at 3.2 f_0. The shift of the passband frequency and other discrepancies are attributed to fabrication tolerances.

CONCLUSION

A compact third-order fully canonical microstrip transversal filter incorporating a dual-mode SSLR and an even-mode SSLR with S-L capacitive coupling is described. Two transmission zeros above and one below the passband are created to improve the selectivity of the passband and reject unwanted signals. Measured results agree closely with simulation and validate the proposed structure and design method. ■

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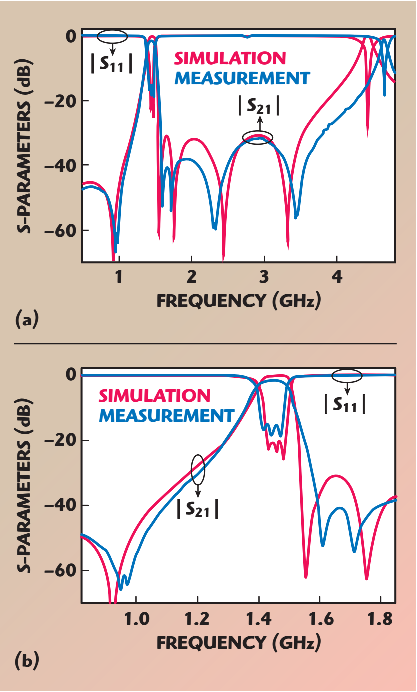

▲ *Fig. 6 Measured and simulated frequency responses. Wideband response (a); Narrowband response (b).*

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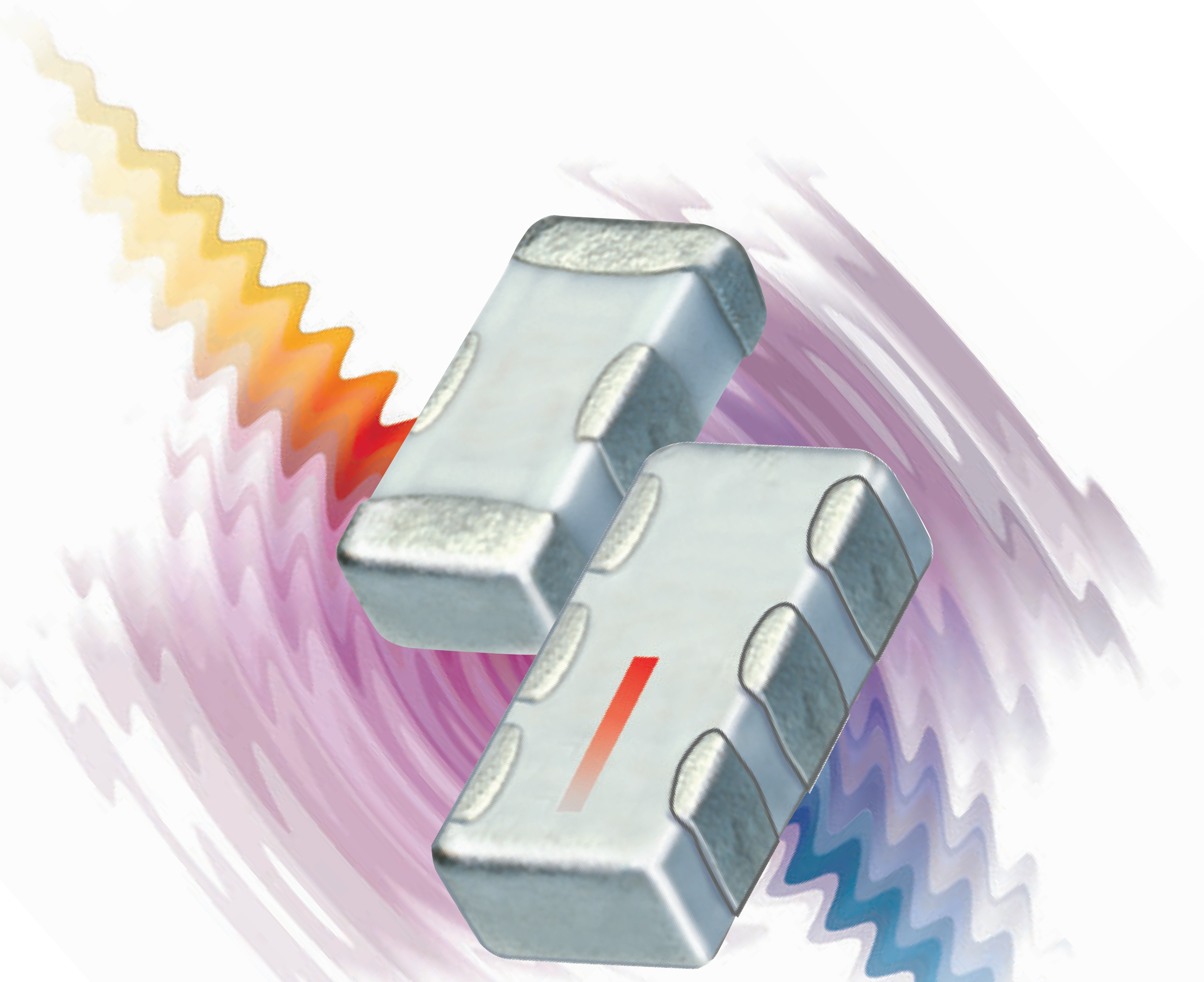

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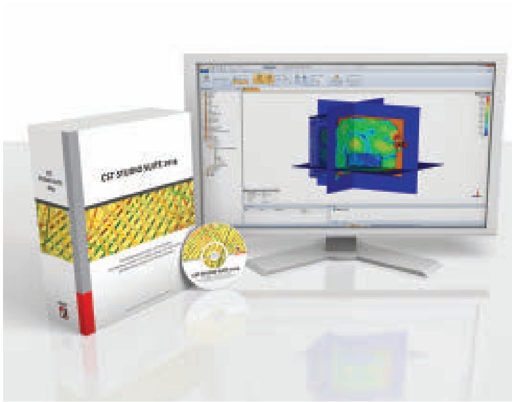


CST STUDIO SUITE 2014: EM Simulation for Integrated Design

CST – Computer Simulation Technology

Different components require different simulation methods – this much has been known since the earliest days of EM simulation. For the last decade, CST has been addressing this problem by combining multiple simulation tools into a single product, CST STUDIO SUITE®, with a single user interface for all solvers. In addition, most practical systems are made up of multiple components, each best suited to a different solver technology. In response, the company introduced the System Assembly and Modeling (SAM) framework for simulating multi-component systems.

CST STUDIO SUITE 2014 builds on these features, offering a more efficient approach to simulating both individual components and full systems. The aim is to give users an integrated design environment: rather than designing each element in turn and only combining them at the final stage, the full system behavior can be instead taken into account much earlier in the design workflow. With SAM, engineers can identify and resolve potential issues such as detuning, signal integrity (SI) and power integrity (PI) problems, and electromagnetic interference (EMI) at an early stage and thus obtain a more robust design.

SYSTEM ASSEMBLY AND MODELING

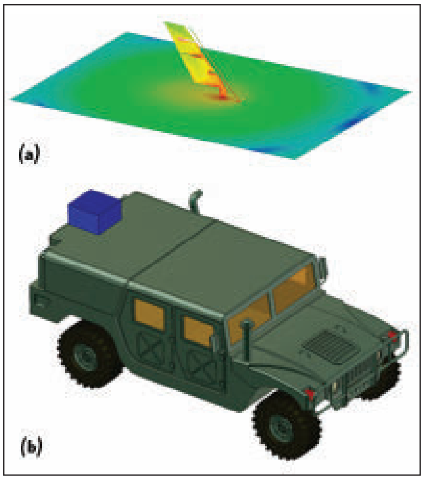
At its core, SAM is built on two ideas: breaking down complex systems into individual elements, and splitting the simulation workflow into a set of fundamental tasks to be carried out automatically. The flexible configuration of the workflow sequence allows the user to easily define both simple simulation series and more complex nested workflows including feedback. These workflow cycles allow effects such as heating, thermal expansion and Lorentz forces to be fed back into the EM field solvers, making it easier to analyze applications such as filters and cavities which can be very sensitive to deformation.

To make it easier to build up the system, the library of RF and microwave 'blocks' in CST DESIGN STUDIO™ has been enlarged to include more components such as amplifiers, couplers and waveguide elements. These can be connected together with models from other CST modules and from tools such as IBIS and

SPICE to form systems for circuit simulation, or converted with a single button press into a combined 3D model for full-wave simulation. Once the blocks are in place, the next step is to define the tasks. CST STUDIO SUITE 2014 introduces wizards to make it easier to set up SAM projects, especially for field source and multiphysics projects, as well as improved SAM integration for PCBs.

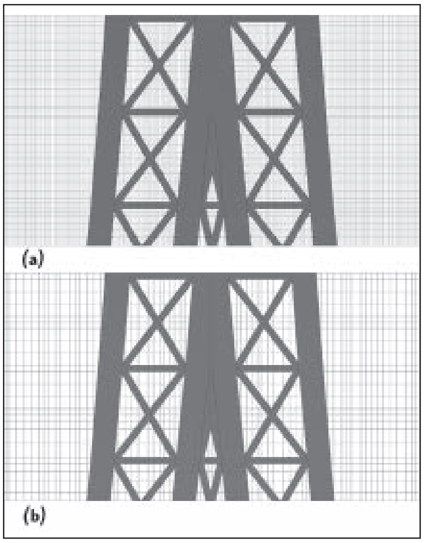
NEAR FIELD SOURCES

Near field sources offer a compact, precise representation of the field around a component – for instance, an antenna or a PCB. These components are often much smaller and more detailed than the structure surrounding them; for example, in vehicles, vessels, masts and industrial equipment. Simulating the components accurately in isolation from the rest of the model, then using their equivalent near field source representation in their environment allows the most appropriate solver type and mesh settings to be applied to each part of the system separately. This approach makes it possible to simulate larger and more complex problems accurately within an acceptable time frame.



▲ *Fig. 1 The surface current distribution on a blade antenna (a), and the equivalent near field source (blue box) representing the antenna on a vehicle (b).*

Previous versions included broadband near field sources in the time domain solver – CST STUDIO SUITE 2014 introduces them to the frequency domain solver and integral equation solver. ***Figure 1*** offers one application of the new hybrid approach – the antenna is simulated with a time domain solver, a versatile general purpose solver, while the full vehicle is simulated using the integral equation solver, which offers better performance for electrically large structures. Near field sources are, of course, compatible with SAM, allowing the transfer of fields between solvers to be carried out automatically.



▲ *Fig. 2 The mesh around a lattice tower with the old mesh engine (a) and the new mesh engine (b) at a similar level of accuracy.*

ROBUST, EFFICIENT MODELING

Accurate simulation requires a mesh that models the structure precisely; fast simulation requires a low mesh cell count. To improve the speed of simulation without compromising on the accuracy, the 2014 version of CST MICROWAVE STUDIO® (CST MWS) introduces new meshing algorithms for the hexahedral, tetrahedral and surface meshes.

The Perfect Boundary Approximation (PBA)® and Thin Sheet Technique (TST)™ have long been part of CST's hexahedral mesh engine. The new hexahedral mesh supplements these with a more intelligent approach to discretizing the structure, which can significantly reduce the cell count on complicated structures such as the lattice tower shown in ***Figure 2*** without compromising on accuracy.

The tetrahedral mesh engine is also improved. As well as representing curved structures more accurately and reducing the cell count, the new mesh engine now supports an octree approach. This means that complex

models which might once have been difficult to mesh, such as complex imported CAD data, can now be meshed robustly with reduced user effort.

WORKFLOW INTEGRATION

A key aspect of using simulation efficiently as a design tool is being able to fit your tools into your pre-existing design workflow. CST STUDIO SUITE 2014 includes several new features for importing, manipulating and exporting model data to and from other tools. New formats supported for import include Siemens NX, SolidWorks, Solid Edge and Parasolid 3D CAD files, and ODB++ 8.0 and Zuken CR-8000 PCB layout files. Imported geometries can be edited more easily with new picking tools, and the user can now adjust the required accuracies and tolerances when exporting the redesigned, optimized model back into CAD software.

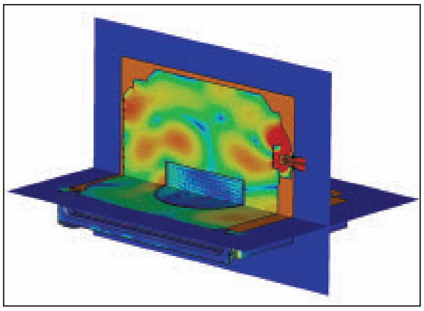
VERSION CONTROL

A particular challenge for many engineers working in large teams is keeping track of the changes to the various model files that make up the project. When different people are working on different components of a system, it's often the case that by the time one element has been designed, the system around it has changed.

With version control, new in CST STUDIO SUITE 2014, the modeler will now automatically alert the user when an external CAD model is updated. The user is then able to choose whether to update the model or keep using the old data. The new imported elements are highlighted in the navigation tree.

HIGH PERFORMANCE COMPUTING

For users with very demanding simulation needs, CST STUDIO SUITE 2014 improves the high performance computing (HPC) capabilities of the time domain solver. GPU and CPU computing can now be used in tandem, delivering simulation performance superior to either method when used alone. Cluster computing using MPI is also more efficient, with the ability to parallelize more of the calculation.



▲ *Fig. 3 E-fields inside a microwave oven in the XY and YZ planes.*

NEW MATERIAL TYPES

A wide range of different material models are needed to simulate the vast diversity of materials found in the world. New in CST STUDIO SUITE 2014 are materials with time-dependent conductivity and temperature-dependencies, as well as improved support for thin film, wire mesh and dispersive loss tangent materials.

PLOTS AND FIELD RESULTS

To use simulation efficiently, the engineer has to be able to analyze the results. CST STUDIO SUITE 2014 includes several upgrades to the data visualization tools to make processing of data easier at a qualitative and quantitative level, helping the designer to understand the physical characteristics of the device in order to improve its design. These improvements include faster, more versatile multi-parameter plots, the ability to visualize fields on several cut planes at once (see ***Figure 3***) and a new visualization engine for voxel models such as human body models.

CST STUDIO SUITE 2014 contains a host of new features developed to support integrated design and improve the performance of the software. With improved CAD import features, better simulation performance and new SAM set-up wizards, electromagnetic simulation using CST STUDIO SUITE can be integrated into more workflows more effectively than ever before.

VENDORVIEW

CST – Computer Simulation Technology,
www.cst.com.

FLORIDA RF Labs

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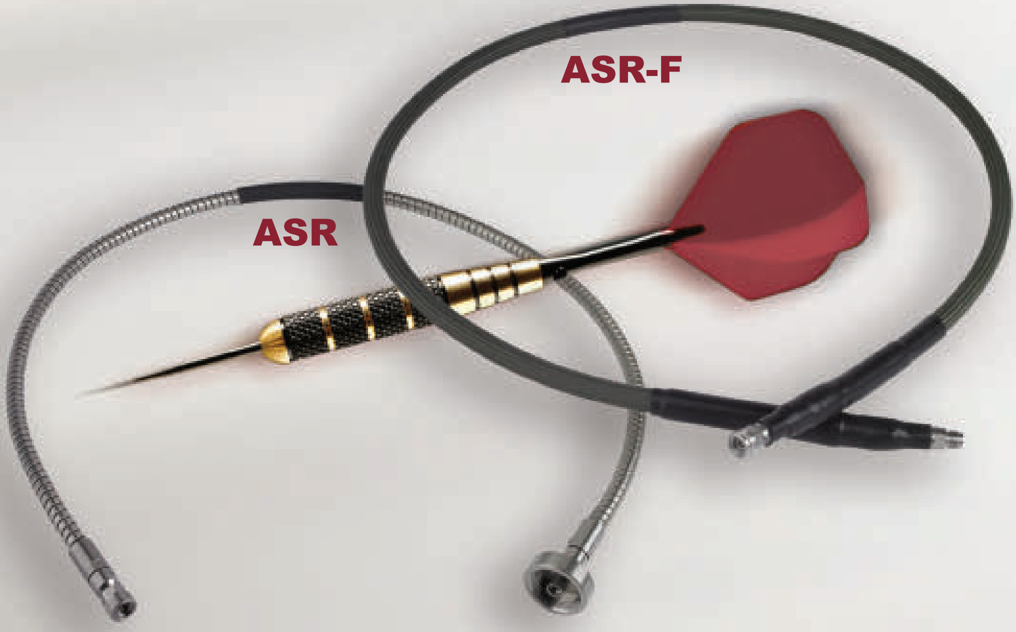

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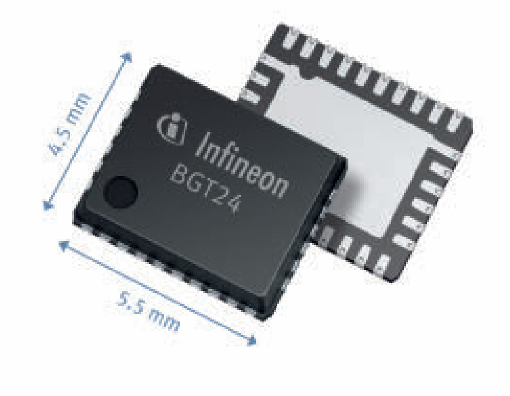


Single-Chip 24 GHz Radar Front End

Infineon Technologies AG
Neubiberg, Germany

Infineon has put its first generation of single-chip 24 GHz radar ICs into mass production. The chip is based on a 0.18 µm SiGe:C bipolar process technology with a cut-off frequency of 200 GHz and is designed to operate in the 24 GHz ISM band. The new product family features the highest integration of radar system-on-chip transceivers on the market and a companion receive only chip, which collectively provide system designers with the flexibility to achieve cost and performance targets in a diverse range of applications.

The range of potential sensing applications for the new device family includes:

- Level monitoring in storage tanks (both solids and liquids)
- Smart lighting control
- Security systems
- Intelligent door openers
- Collision avoidance on industrial vehicles

The three devices in the family are the BGT24MTR11 with a single transmit and single receive channel, the BGT24MTR12 with a single transmit and two receive channels and the BGT24MR2, with twin receivers. Moving from a single receiver system to two or more receive channels allows implementation of systems that are able to detect not only the range and the speed of a target but also its angular position relative to the radar sensor's location.

24 GHz radar systems are well-suited to adjusting the intensity of street, industrial and office lights by detecting moving objects or people in the designated area, thus enabling energy efficient lighting. The ability of the BGT24MTR11 to cover transmit frequencies up to 26 GHz facilitates high accuracy in tank and silo level metering systems. These kinds of systems especially benefit from the use of radar, as radars are not sensitive to splashing liquid or dust. Radar-based door opening systems can easily distinguish between someone approaching the door or a passerby. Therefore very energy efficient systems can be created if radar is used for sliding doors.

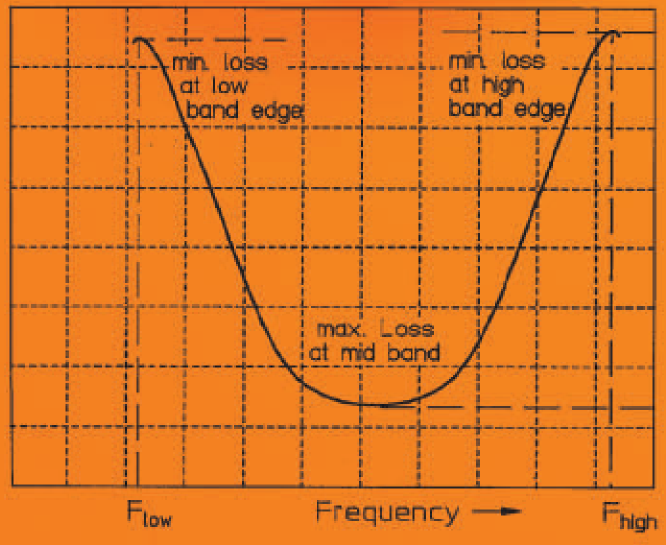
Another application is intruder alarms, where 24 GHz radar can detect a person typically at a distance of up to 50 m compared to 10 m for commonly used infrared (IR) systems, thus a much bigger area can be covered with only one sensor. An additional benefit of using radar is that it is not only able to detect that something is moving but also can determine the location and the speed of the moving object.

Figure 1 shows the block diagram of the BGT24MTR11, which can be used to represent the whole family of ICs. Infineon integrated almost the complete analog radar front end into the transceiver ICs, including a voltage controlled oscillator (VCO) with prescaler outputs for frequency control, transmitter chain including amplifiers for both transmitter (TX) and local oscillator (LO) outputs, as well as the complete

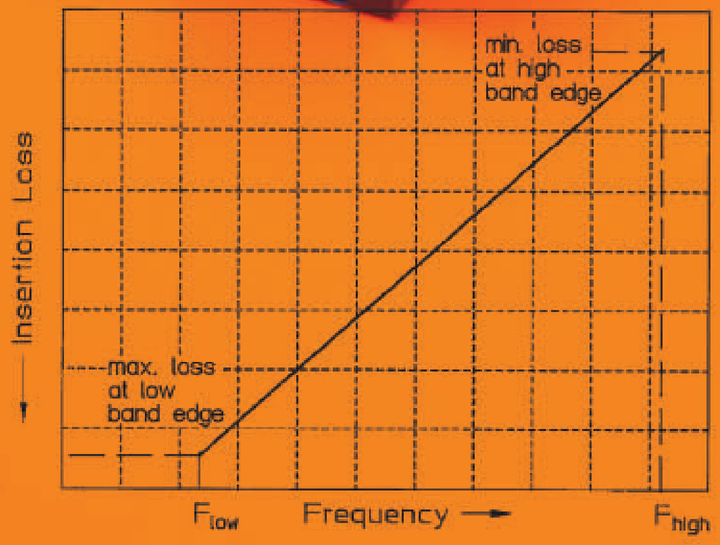
Spectrum Elektrotechnik GmbH
80905 Munich, Germany * P.O. Box 450533
Phone: +49-89-3548-040 * Fax: +49-89-3548-0490
Email: sales@spectrum-et.com
WWW.SPECTRUM-ET.COM

Fine Grain Equalizers and Gain Amplitude Equalizers

Adjustable Equalizer. The fixed insertion loss versus frequency is specified. All units will be set to meet this predetermined curve. Additionally, if the system requires a similar but a slightly different loss curve, a certain number of adjustments will be available to change the nominal attenuation curve. The type of adjustments can be to rise or to lower the maximum attenuation value, shifting the maximum value of the response from the center to lower or higher frequencies, or establishing a change of the attenuation at the band edges, upper, lower or both. A unit can be designed to meet all these requirements for adjustment.



Fundamental Parabolic Equalizer Response



Fundamental Linear Equalizer Response

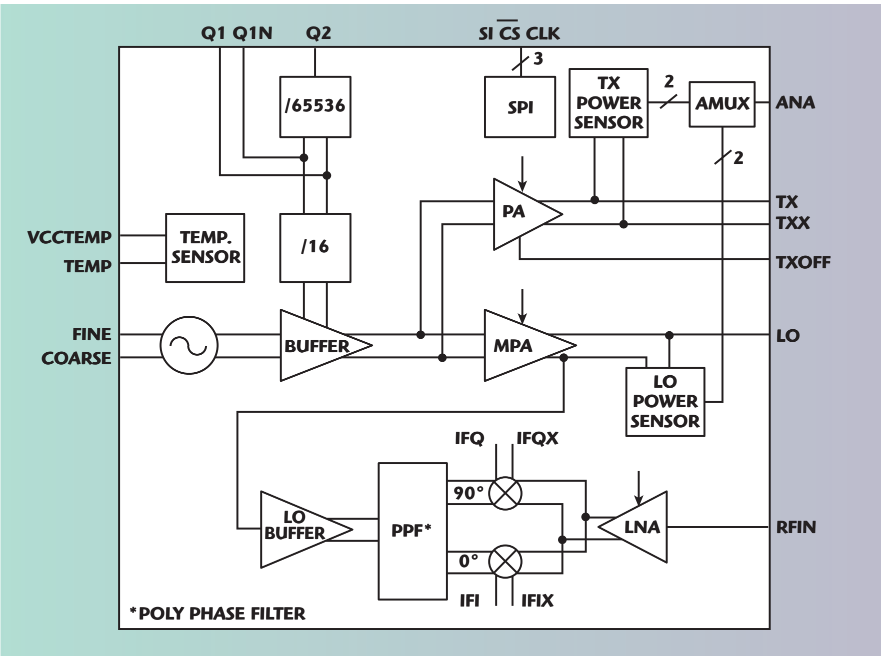


Fig. 1 Block diagram of the BGT24MTR11.

receiver section including low noise amplifier (LNA) and mixer. Only the antennas are left to be implemented by the system designer.

The VCO is a free running, fundamental oscillator. It can be controlled by two tuning inputs, one for coarse pre-adjustment and one for fine-tuning. There are two prescalers available in the VCO section of the chip. The first prescaler has an output frequency of 1.5 GHz and can be used to feed an RF-PLL for frequency control. The second prescaler has a 23 kHz square-wave output that may be used by a microcontroller-based software loop.

The TX section consists of a power amplifier with a differential output. Its maximum output power is 11 dBm and can be reduced in eight steps down to 2 dBm. The BGT24 radar ICs have been designed with FMCW radar in mind, therefore a part of the TX signal is used as the LO-signal for the on-chip mixer. The receiver section has a single-sideband noise figure of 12 dB and a voltage conversion gain of 26 dB. The gain of the LNA can be reduced by a gain-step of 5 dB. The built-in quadrature downconversion mixer translates the RF signal directly to zero-IF.

Additionally the chip features power sensors both on TX-outputs and LO-outputs, as well as a temperature sensor that supports the implementation of a software based loop to control the VCO. The settings of the different internal building blocks can be controlled via an SPI interface. The chip is housed in a standard 32 pin RoHS compliant VQFN-package with the option of lead tip inspection. With that the solder joints can be visually inspected and no special X-ray machines or processes are needed for production assembly.

Infineon's single-chip, analog front end ICs reduce the required board area by up to 70 percent compared to discrete solutions in the market. The BGT24MTRxx family simplifies designs and improves time to market by superseding external component matching and space consuming RF transmission lines. The resulting compact design, system flexibility and cost effectiveness of the solution make the BGT24MTRxx family useful for improving performance in existing applications and replacing alternative technologies.

**Infineon Technologies AG,
Neubiberg, Germany
+49 89 234 24462,
www.infineon.com.**

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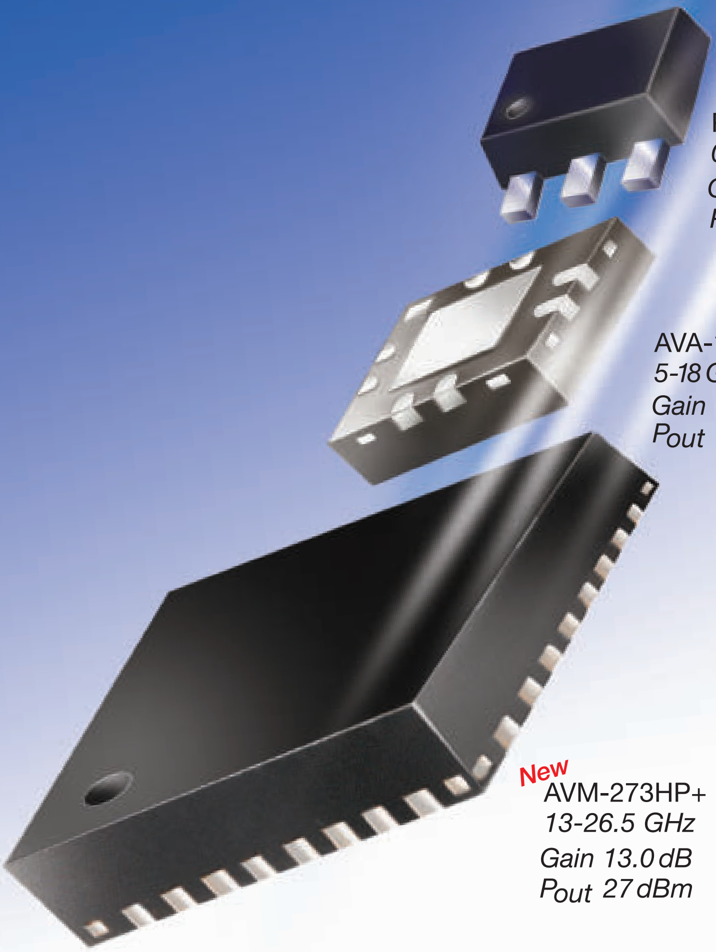

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New
AVM-273HP+ $27.95 ea. (qty. 10)
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Gain 13.0 dB
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Mini-Circuits' New AVM-273HP+ wideband, 13 dB gain, unconditionally stable microwave amplifier supports applications from 13 to 26.5 GHz with 0.5W power handling! Gain flatness of ±1.0 dB and 58 dB isolation make this tiny unit an outstanding buffer amplifier in P2P radios, military EW and radar, DBS, VSAT, and more! Its integrated application circuit provides reverse voltage protection, voltage sequencing, and current stabilization, all in one tiny package!

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

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

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478 rev M

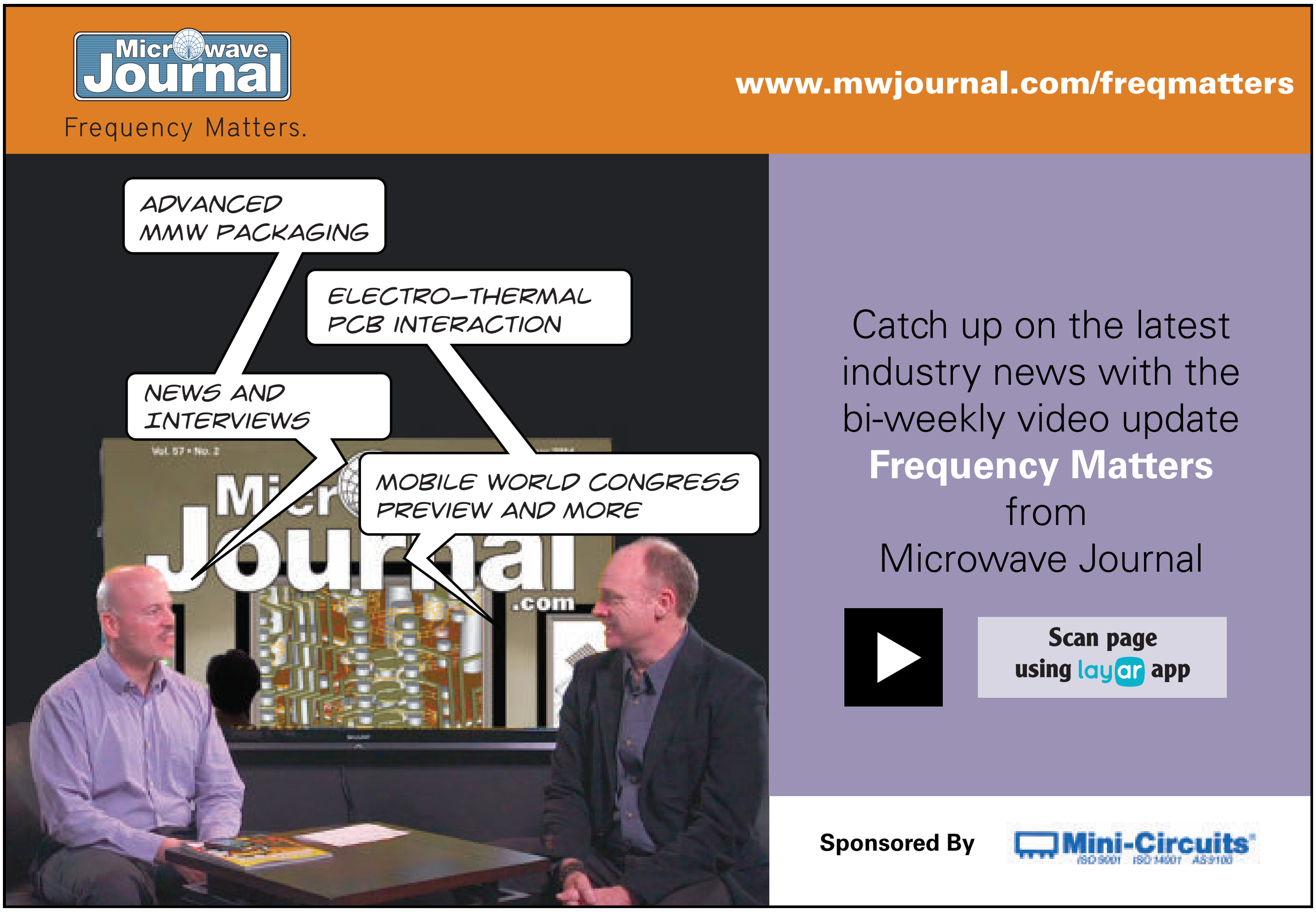
E-Band Mixer with LO Multiplier

Spacek Labs model M80-5X2B is an E-Band mixer covering the two radio bands of 71 to 76 GHz and 81 to 86 GHz. The mixer includes an integrated LO doubler so that the customer need only supply a 39 GHz source with +16 dBm of power.

Spacek Labs can also supply a phase-locked source with the assembly. The conversion loss over the band is 6 dB typical and 10 dB maximum, with an IF frequency range of 2 to 8 GHz. The input P1dB is –6 dBm typical, and the bias is +12 V DC at 10 mA.

Overall dimensions are 1.67" × 1.68" × 1.07". In addition, with extensive in-house design and manufacturing capabilities, Spacek Labs can equip the mixer with LO sources, amplifiers and filter technologies to meet any high performance project needs. Spacek Labs, an ISO 9001:2008 certified company, has been delivering standard and custom millimeter-wave components and sub-assemblies for over 32 years.

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



Software and Mobile Apps

FieldFox's Remote App

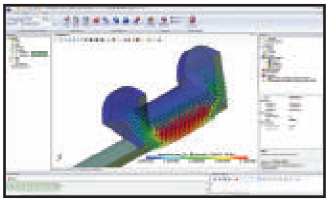
VENDORVIEW

FieldFox's remote control capability, Option 030, enables viewing and control of the instrument via the Remote Viewer iOS application. With a wireless LAN or cellular broadband data connection using an iOS device, the FieldFox analyzers can now be placed in areas where users do not wish to stay long due to extremely harsh or unsafe conditions. Additionally, if one technician or engineer has trouble making a measurement or determining the source of a problem, another can step in to remotely troubleshoot and solve the problem.

Agilent Technologies Inc.,
www.agilent.com.

Simulation and Analysis Software

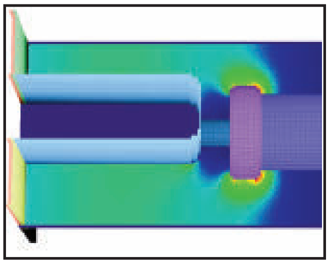
VENDORVIEW



AWR's V11 of Analyst-MP™ (MP for multiphysics) expands the capabilities of its Analyst™ 3D FEM EM simulation and analysis software to now account for large-scale, multiphysics applications like particle accelerators. Analyst-MP's diverse and unique solver technologies are the result of more than a decade of development in collaboration with the U.S. DoD and DoE and have been employed to analyze extremely complex high-frequency, multiphysics structures at U.S. national labs/accelerators. Visit www.awrcorp.com/products/analyst/analyst-mp for more information.

AWR Corp.,
www.awrcorp.com.

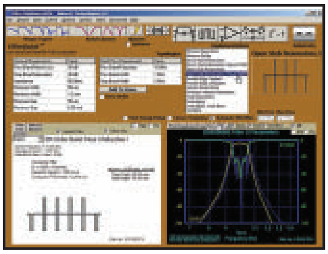
Microwave Heating Software



Field Precision has released an updated version of Aether, its 3D electromagnetics suite. The program can now export RF power-density profiles directly to the HeatWave program for thermal analysis. Aether is a unified finite-element package that handles all stages of solutions: mesh generation, field calculation and interactive analysis. The program has three operation modes that cover the full spectrum of applications: pulse mode (pulsed-power devices), res mode (resonant frequencies and Q factors of complex structures) and RF mode (frequency-domain simulations of microwave and RF devices).

Field Precision LLC,
www.fieldp.com.

Filter Software Updates

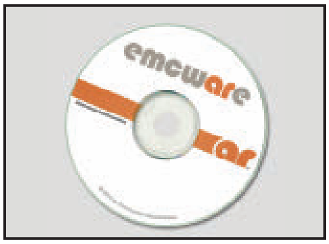


Nuhertz Technologies announces the release of FilterSolutions 2014®. In this release, Nuhertz completes the integration of interconnects to all Microwave Office® library models, adding to the 2013 integration of the Modelithics model libraries. Changes to the program include a new menu item for open stub resonators (for both FilterSolutions and FilterQuick) and schematic notes for lumped elements. FilterSolutions directly integrates with AWR, CST, Modelithics and Sonnet Software, achieving improved modeling accuracies, accounting for electromagnetic effects and providing tools for system integration.

Nuhertz Technologies,
www.nuhertz.com.

CISPR Test Configurations

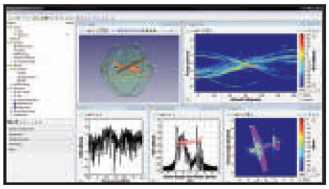
VENDORVIEW



AR RF/Microwave Instrumentation emcware's latest release expands on an already great platform with the addition of CISPR custom test configurations. Enhancements include predefined receiver setups and report generation to standards such as: CISPR 11, 13, 22, 15 and 32. emcware also retains a user friendly environment with all of its previous functionality allowing users maximum flexibility to create their own test configurations or modify existing ones. Download the free software at www.arworld.us/html/IRC_software_details.asp?swid=23.

AR RF/Microwave Instrumentation,
www.arworld.us.

Radar Signature Analysis Software



Delcross Technologies announced the first commercial release of Signa, a software toolkit for advanced radar signature analysis. Signa delivers efficient electromagnetic (EM) simulation of complex radar cross sections (RCS) for targets that are tens to thousands of wavelengths in size. In addition to RCS, Signa generates range profiles and inverse synthetic aperture radar (ISAR) images of targets, useful for identification of significant target scattering features. The toolkit is available for Windows or Linux.

Delcross Technologies LLC,
www.delcross.com.

Literature App

The free-of-charge PDFolio app fits hand-in-glove with the HUBER+SUHNER portfolio, available in the Apple iTunes and Google Play stores. This app enables customers to download HUBER+SUHNER publications in PDF format – individually or in a package. The app comprises approximately 170 documents and these are sub-divided into three markets (communication, transportation and industrial), as well as by three technologies (radio frequency, fiber optics and low frequency).

HUBER+SUHNER,
www.hubersuhner.com.

R&S NEWS App

VENDORVIEW

NEWS, the technical magazine on Rohde & Schwarz innovations for more than 50 years, is now also available as a free app for iPad and Android tablets. All articles from the current and previous issues can be retrieved within a matter of seconds. Modern navigation options and a clear section structure make it easy to find the article you want. Zooming, graphics and pictures ensure comfortable reading. Other advantages include integrated multimedia components such as videos and direct access to additional online content.

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www.rohde-schwarz.com.


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Innovations in EDA

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Presented by: Agilent Technologies
Live webcast: 2/6/14

Top 3 LTE/LTE-A UE Testing Challenges
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Live webcast: 2/13/14

Agilent in Aerospace/Defense

Understanding Low Phase Noise Signals
Live webcast: 2/20/14

Technical Education Training

TriQuint GaN Solutions for Commercial and Defense Applications
Presented by: Richardson RFPD
Live webcast: 2/25/14

Technical Education Training

PCB Material Selection for High Speed Digital Design
Presented by: Isola
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Past Webinars On Demand

RF/Microwave Training Series

Presented by: Besser Associates

- Passive Components: Dividers, Couplers, Combiners
- RF and Microwave Filters

Market Research Webinar Series

- Technology Trends for Land-Based Electronic Warfare Systems

Technical Education Training Series

- Freescale and Scintera: The Small Cell Transmitter Solution Provider
- What Have You Been Missing in Your Pulsed Network Analyzer Measurements?
- Interference 101
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- Novel Very-Near-Field Measurement Technique to Test Large Directional Antennas in Minutes
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Presented by: Agilent Technologies

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CST Webinar Series

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- Simulating Dielectric and Conductor Loss Components Including the Influence of Trace Edge and Surface Roughness Topography
- Traveling Wave Tube Design with Simulation
- EMC Simulation in the Design Flow of Modern Electronics
- Wireless Power Transfer and Microwave Energy Harvesting
- Electromagnetic Simulation of Composite Materials and Cable Harnesses in Aircraft
- MIMO Antenna Systems for Advanced Communication
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- Advanced Passive Intermodulation (PIM) Measurement System
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Components

Power Detectors

ADI introduced two RF power detectors with wide dynamic range and best-in-class accuracy and temperature stability. The ADL5903 is an optimal solution for a variety of high frequency systems requiring accurate measurement of signal power independent of waveform characteristics. The ADL5506 is a complete subsystem for the measurement of RF signals in a wide range of wireless terminal devices. Both are offered in small packages with low-power operation, making them ideal for designs that are constrained by space or power.

Analog Devices Inc.,
www.analog.com.

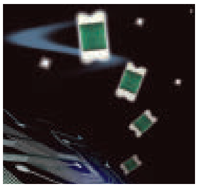
Bias Tees

VENDORVIEW

As a vital link in utilizing a single coaxial cable to carry both RF signals and DC power, the new ABT series of bias tees from AtlanTecRF bring this capability to systems operating at frequencies up to 50 GHz. With RF connector choices of 2.92mm, SMA and Type N the actual frequency bands offered range from 10 MHz to 2.5 GHz through to 50 KHz to 50 GHz with DC voltage capability to 100 V and current capacity to 2.5 A.

AtlanTecRF,
www.atlantecrf.com.

Multilayer Organic Capacitors



AVX Corp. has doubled the capacitance of its 0603 multilayer organic capacitor (MLOC) series, extending the highest-rated capacitance value from 2.5 to 5.1 pF. Ideal for applications including RF power amplifiers, low noise amplifiers, filter networks and instrumentation, AVX's 0603 MLO™ capacitors exhibit low ESR, high SRF and high Q and are capable of supporting frequencies well above 5 GHz. Expansion matched to PCBs for improved reliability, the series also exhibits low dielectric absorption (0.0015 percent) and capacitance tolerances as tight as ±0.02 pF.

AVX Corp.,
www.avx.com.

Low Frequency Attenuators

Coaxial Components Corp. introduced DC to 4 GHz attenuators. By utilizing an innovative alternative to high-cost stainless-steel production, Coaxicom's attenuators provide a cost-effective solution for general applications and in-field use. The low-frequency attenuator line is available in TNC (4910-(db)) and BNC (2910-(db)) series with an average power rating of 2 W. The attenuators are available in reverse polarity, between series adapters, as well as 50 or 75 Ω. They are RoHS and REACH compliant and range from 1 to 30 dB.

Coaxial Components Corp.,
www.coaxicom.com.

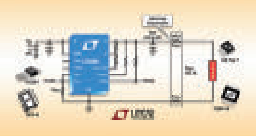
PIN Diode Switch

Model S9L-51-0BX is a 3 W CW SP17T PIN diode switch that operates from 4.5 to 5 GHz. It has 30 dB of isolation with 3 dB insertion loss and a 1.5:1 VSWR. The device is controlled via 5 bits of TTL compatible logic with a switching speed of 1.0 µSec. The unit requires a power supply of +5/-12 V DC at +500/-200 mA of current. The package measures 3.5" × 3.5" × 0.8".

G.T. Microwave Inc.,
www.gtmicrowave.com.

LDO

VENDORVIEW



Linear Technology Corp. announced the LT3086, the latest addition to the LDO+™ family, offering significant functionality previously unavailable in linear regulators. The 40 V, 2.1 A low dropout linear regulator (LDO) includes current monitoring with externally settable current limit and temperature monitoring with external control of thermal limit temperature. The device includes a programmable power good status flag, cable drop compensation and easy paralleling. The current reference in the LT308x LDO family provides regulation, independent of output voltage.

Linear Technology Corp.,
www.linear.com.

Coaxial Termination

The AMCOL-2-7/8 coaxial termination is designed to safely absorb high-power microwave and RF signals in a wide variety of operational systems and test and measurement applications. It has a specified operating frequency range of DC to 3.1 GHz, with a power handling capability of up to 50 W and a maximum return loss of 27 dB. The 50 Ω termination has overall dimensions of 202 × 60 mm and is equipped with an anodised aluminium heatsink.

Link Microtek,
www.linkmicrotekeng.com.

High Frequency Couplers

Due to advances in circuit technology, Marki now offers stripline couplers with frequencies as high as 67 GHz. The C10-0667, C16-0667, and C20-0667 offer high 17 dB typical directivity from 6 to 67 GHz with coupling values of 10, 16 and 20 dB, respectively. They come in a small 1.050" long package with 1.85 mm connectors.

Marki Microwave Inc.,
www.markimicrowave.com.

Hi-Q Capacitors

Passive Plus offers extended-values for the traditional Hi-Q high power, low ESR/ESL, low noise, high self-resonance ultra-stable performance capacitors. Usually used for wireless broadcasting equipment, mobile base stations, GPS portables, MRI coils and radar, these capacitors are 100 percent RoHS compliant and offered in magnetic and non-magnetic terminations. They are designed and manufactured to meet the requirements for MIL-PRF-55681 and MIL-PRF-123.

Passive Plus Inc.,
www.passiveplus.com.

Faraday Isolator

QuinStar Technologies Inc. introduced its QIF series full band Faraday isolator which is available in six waveguide bands covering the frequency range of 26.5 to 110 GHz. QIF series isolators provide a minimum of 25 dB isolation and typically more than 30 dB isolation, with insertion loss of 1.3 dB maximum for Ka-Band and 2.2 dB maximum for W-Band. The QIF series isolators can handle power levels of 1 W at W-Band to 2 W at Ka-Band.

QuinStar Technologies Inc.,
www.quinstar.com.

Programmable Attenuator

VENDORVIEW

Renaissance has developed a new solid state programmable attenuator, 19A3BA, that can be used to perform cellular fading simulations. The device operates from DC to 3 GHz with 5.5 dB insertion loss and can attenuate 100 dB in 1 dB steps. The attenuator can handle 20 dBm over -40° to +85°C.

Renaissance/HXI,
www.rec-usa.com.

USB & Ethernet Programmable

ATTENUATORS

0–30, 60, or 90 dB 1 MHz to 6 GHz from $395

Mini-Circuits programmable attenuators give you more options and more freedom with both USB and Ethernet control. Available in versions with maximum attenuation of 30, 60, and 90 dB with 0.25 dB attenuation steps, all models provide precise level control with accurate, repeatable performance for a wide range of test applications. Our unique designs maintain linear attenuation change per dB over the entire range of attenuation settings. Supplied with user-friendly GUI control software and everything you need for immediate use out-of-the-box, Mini-Circuits programmable attenuators offer a range of solutions to meet your needs and fit your budget. Visit minicircuits.com for detailed performance specs, great prices, and off-the-shelf availability!

RoHS compliant

	Models	Attenuation Range	Attenuation Accuracy	Step Size	USB Control	Ethernet Control	RS232 Control	Price $ ea.
	RUDAT-6000-30	0 – 30 dB	±0.75 dB	0.25 dB	✓	-	✓	$395
NEW	RCDAT-6000-30	0 – 30 dB	±0.75 dB	0.25 dB	✓	✓	-	$495
	RUDAT-6000-60	0 – 60 dB	±1.00 dB	0.25 dB	✓	-	✓	$625
	RUDAT-6000-90	0 – 90 dB	±1.70 dB	0.25 dB	✓	-	✓	$695
NEW	RCDAT-6000-60	0 – 60 dB	±0.30 dB	0.25 dB	✓	✓	-	$725
NEW	RCDAT-6000-90	0 – 90 dB	±0.40 dB	0.25 dB	✓	✓	-	$795

Mini-Circuits®

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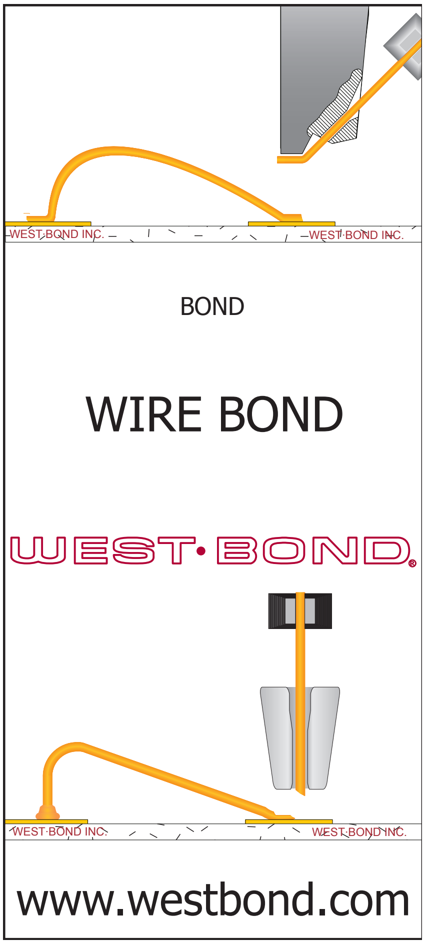
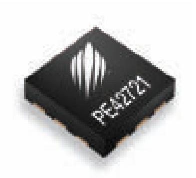
523 Rev Org



New**Products**

SPDT

VENDOR**VIEW**



Richardson RFPD Inc. announced immediate availability and full design support capabilities for a new absorptive 75 Ω RF single-pole, double-throw (SPDT) switch from Peregrine Semiconductor Corp. The PE42721 is manufactured on Peregrine's UltraCMOS process, a patented variation of silicon-on-insulator (SOI) technology on a sapphire substrate, offering the performance of GaAs with the economy and integration of conventional CMOS.

Peregrine Semiconductor Corp., distributed by Richardson RFPD Inc., www.psemi.com.

WLAN FEM

VENDOR**VIEW**

Skyworks introduced a highly integrated 5 GHz WLAN front end module for reference designs targeting smartphones and tablets in a 2.5 × 2.5 mm, QFN package. The SKY85702-11 incorporates a PA and a SPDT transmit and receive switch for mobile/portable 802.11ac applications and systems. The high performance FEM operates from a single supply voltage of 3.6 V, with an enable/disable function that allows power savings during off mode. An integrated power detector with 20 dB of dynamic range provides closed-loop power control within the system.

Skyworks Solutions Inc., www.skyworksinc.com.

High Performance Hybrid

The SQ-67 is a small, 3 dB, 90° hybrid coupler that operates from 427.5 to 477.5 MHz and is constructed with non-magnetic structure that is ideally suited for applications in medical imaging equipment where control of magnetic interference is critical. The maximum insertion loss is 0.4 dB with an amplitude unbalance of 0.7 dB maximum across the specified bandwidth. Other maximum specifications include phase unbalance of 90±3°, isolation of 20 dB and VSWR of 1.4:1 all ports.

Synergy Microwave Corp., www.synergymwave.com.

Transfer Switch

RLC Electronics offers a micro miniature transfer switch which is an extremely compact design. The switch can be provided as either a surface mount design or a connectorized unit (SMA connectors standard). These switches offer excellent electrical performance through 26.5 GHz; VSWR of 1.7:1 max, insertion loss of 0.7 dB max and isolation of 50 dB min. The switch is available in failsafe and latching configurations with a choice of three different frequency ranges and three different coil voltages.

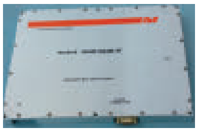
RLC Electronics Inc., www.rlcelectronics.com.

Amplifiers

Hybrid PA

VENDOR**VIEW**

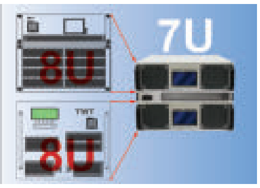
Model 50HM1G6AB-47 is a compact, wideband, Class AB solid state hybrid power amplifier module that instantaneously covers 1 to 6 GHz. It operates from a single DC voltage and provides 48 dB of typical gain with excellent gain flatness, noise figure and low intermodulation distortion for military and wireless applications.



AR RF/Microwave Instrumentation, www.arworld.us.

HPA

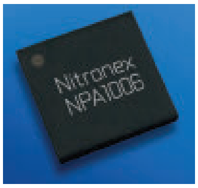
VENDOR**VIEW**



Empower's recent and unique Airborne Pulse HPA solution features UHF and L-Band pulse amplifiers tied to a shared power supply and delivering 1 and 3 kW pulse power, respectively. Each amplifier is housed in a 3U chassis, and the shared power supply is housed in a 1U chassis. This next generation solution replaces older products which totaled 16U in size – the UHF solid state amplifier was in an 8U chassis and an L-Band TWT was housed in another, separate 8U chassis.

Empower RF Systems Inc., www.empowerrf.com.

GaN Amplifier

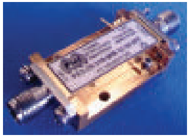


Nitronex announced the release of the NPA1006, a new broadband GaN amplifier. The NPA1006 is a 28 V, 20 MHz to 1 GHz, 15 W amplifier with 14 dB gain and 60 percent drain efficiency. It is housed in an industry-standard 6 × 5 mm DFN plastic package. The thermal resistance of the NPA1006 is 4.6°C/W, representing best in class for this power level. The NPA1006 utilizes Nitronex's 28 V NRF1 GaN HEMT process, which has been in production since 2006.

Nitronex, www.nitronex.com.

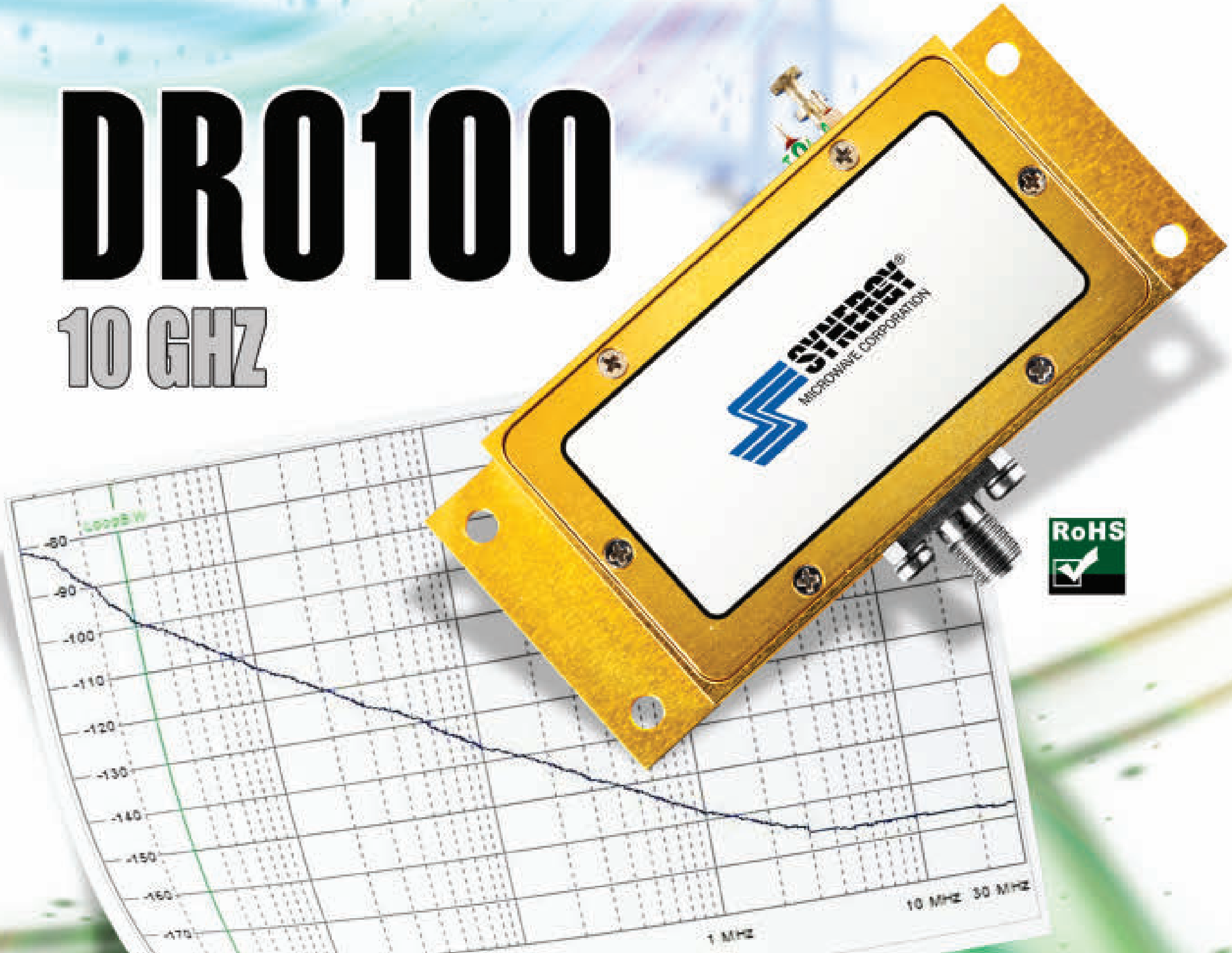
LNA

VENDOR**VIEW**

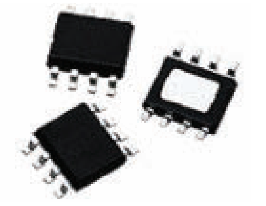


PMI model no. PE2-28-218-5R0-12-15-SFF is a 2 to 18 GHz, low noise amplifier that provides 24 dB min of gain. The noise figure is 4.5 dB max and offers an OP1dB of 14 dBm min. The operating voltage is +15 V DC and the current draw is 200 mA max. The unit is supplied with removable SMA(F) connectors in PMI's standard PE2 housing.

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


Loop BW
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
1 kHz
10 kHz
100 kHz
1 MHz
10 MHz
30 MHz
Frequency Offset
SYNERGY
MICROWAVE CORPORATION
RoHS

GaAs E-PHEMT Amplifier



RFHIC's AE618 is a new, state-of-the-art PHEMT MMIC, based on GaAs enhancement mode pseudomorphic high electron mobility transistor (E-PHEMT) which provides low current draw and very low noise. This push-pull amplifier, which contains two amplifiers, is designed for many applications including CATV, satellite, FTTH and optical node, an ideal solution for broadcasting applications for its high gain, good flatness and low noise. Email rfsales@rfhic.com for additional information, pricing and availability.

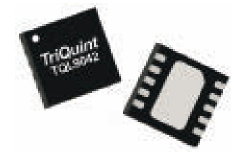
RFHIC,
www.rfhic.com.

SSPA

Covering the 2 to 6 GHz frequency band, the PTS6900 is a new solid state power amplifier (SSPA). Optimized for use in EW/ECM systems, the low band CW module produces a high power output of 150 W and has a 55 dB gain adjustable from 50 to 60 dB. This performance is achieved through an advanced design incorporating the latest 0.25 µm GaN MMIC technology and low loss power combiners. The unit measures 300 × 200 × 50 mm and weighs 4 kg.

TMD Technologies Ltd.,
www.tmd.co.uk.

LNAs



RFMW Ltd. announced design and sales support for two internally matched, high IP3 low noise amplifiers from TriQuint. The TQL9042 and TQL9043 both feature bypass switches and shut-down pins offering receivers the highest level of sensitivity performance. The TQL9042 offers 19 dB gain over 0.5 to 2 GHz with a market leading 0.42 dB noise figure. The TQL9043 provides frequency coverage from 1.5 to 2.7 GHz with >18 dB gain and 0.5 dB noise figure.

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

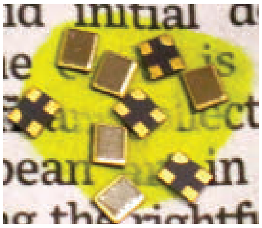
Sources

DRO

Model SOD-37301213-22-S1 is a 37 GHz dielectric resonator oscillator (DRO). The oscillator is a free running oscillator and the high frequency stability is achieved by implementing a high quality dielectric resonator. The oscillator exhibits +13 dBm output power and low phase noise of -95 dBc/Hz at 100 KHz offset. The frequency stability of the oscillator is ±3 ppm per °C or better in the temperature range of -40° to +85°C.

SAGE Millimeter Inc.,
www.sagemillimeter.com.

Clock Oscillator



Tellurian Technologies announced the development of the T6000ET packaged clock oscillator with an extended temperature range of -40° to +125°C. The T6000ET is 2.5 × 2.0 × 0.9 mm. The frequency stability over the -40° to +125°C temperature range is ±50 ppm all conditions. The T6000ET has a low current consumption of 10 mA typical with supply voltage from 1.8, 2.5 and 3.3 V. The frequency range of the T6000ET is as low as 1.25 MHz up to 100 MHz.

Tellurian Technologies Inc.,
www.telluriantech.com.

Test Equipment

RF Power Sensor

LadyBug Technologies announced its new low frequency RF power sensor. The new LB559A-LF1 sensor adds coverage below 100 kHz to LadyBug's laboratory-accuracy RF and microwave power sensor portfolio. Designed for calibration, medical and test applications, the new LB559A-LF1 sensor includes a powerful full featured Windows GUI application. Sensor features include NIST traceable calibration, a variety of connector options and support for programmatic measurements. Additional options include recorder output and hardware triggering input and output.

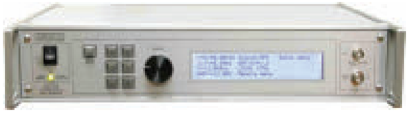
LadyBug Technologies,
www.ladybug-tech.com.

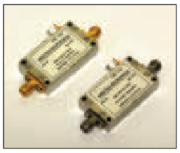
Signal Generator

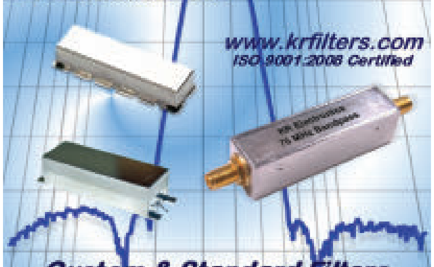
The SSG-6400HS is a DDS-based, USB and Ethernet controlled, ultra-wideband signal generator. This high performance model offers: frequency range from 250 kHz to 6400 MHz; 85 dB adjustable output power range from -75 dBm to +10 dBm; AM, PM, FM and pulse modulation; fine frequency resolution (<0.01 Hz); fine power resolution (0.01 dB); fast tuning (<300 µs); frequency/power sweeping (up, down and bi-directional); and hopping over power levels and frequencies. It is supplied with easy-to-install, easy-to-use GUI control software and API objects for Windows environments.

Mini-Circuits,
www.minicircuits.com.

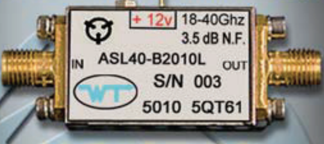
MICRO-ADS





Classified
Help Wanted



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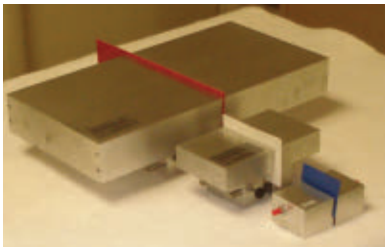
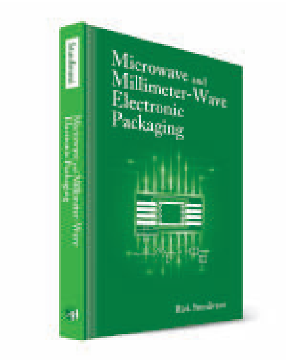
5010 5QT61





Microwave and Millimeter-Wave Electronic Packaging

Rick Sturdivant

Packaging of electronic components at microwave and millimeter-wave frequencies requires the same level of engineering effort for lower frequency electronics plus a set of additional activities which are unique due to the higher frequency of operation. This book covers the electronic packaging issues unique to microwave and millimeter-wave frequencies and reviews lower frequency packaging techniques so they can be adapted to higher frequency designs.

Microwave and Millimeter-Wave Electronic Packaging is a practical guide to all of the factors and methods that need to be taken into consideration for high frequency packaging. It covers various materials properties, interconnects, modeling, heat transfer, etc., that should be considered in designing packages plus the various types of packages such as ceramic, laminate, 3D and more. It concludes with a future horizons chapter that looks forward to newer technologies and improvements. The book provides 30 practical examples throughout the book, as well as three free downloadable software analysis programs.

This book is very appropriate for practicing engineers and technicians along with those students who are interested in this subject matter. It is a very practical guide with good examples and was put together in a logical manner so that the reader can understand all of the factors involved in packaging design.

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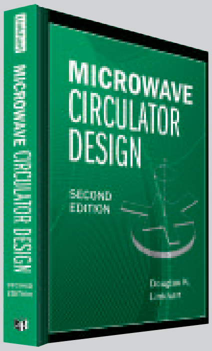

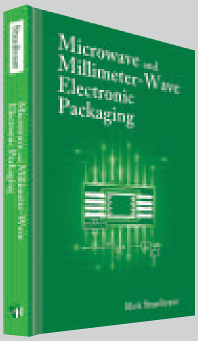


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STEM Works

micro·strip [mahy-kroh-strip]

Microstrip, a type of electrical transmission line consisting of a conducting strip separated from a ground plane by a dielectric layer known as the substrate, is used to transport microwave-frequency signals. Due to its inhomogeneous cross-section, the structure does not support a simple transverse electromagnetic (TEM) wave. Since the dielectric substrate is electrically very thin, the longitudinal field components are much smaller than transverse components, allowing for a quasi-TEM approximation (the transverse pattern of the electric and the magnetic fields).

1952. The term "microstrip" is introduced by Grieg and Engelmann of ITT Laboratories in the December IRE proceedings.

1955. Fellow ITT engineer Maurice Arditi files a patent for microwave filters based on resonant sections in a microstrip line formed by discontinuities.

1965. Harold Wheeler publishes his synthesis and analysis equations based upon a conformal mapping's approximation of the dielectric boundary with parallel conductor strips separated by a dielectric sheet.

1969. M. V. Schneider publishes "Microstrip Lines for Microwave Integrated Circuits," in *Bell System Technical Journal*, providing computational methods to obtain characteristic impedance, attenuation, guided wavelength and unloaded Q of a microstrip transmission line.

1971. Jain, Makios and Chudobiak, publish rigorous field-theoretic techniques for determining microstrip dispersion characteristics. The fast formulism together with efficient numerical algorithms permitted deeper understanding of complex modes in lossless, boxed planar structures, in connection to the classical coupled-mode theory.

1997. "Microstrip Mode Propagation on a Periodically Perturbed Ground Plane via Small Etched Holes" is presented at APMC, ushering in the era of synthetic planar transmission-line structures. The periodically loaded microstrip demonstrates a slow-wave factor exceeding the theoretical limit of the square root of relative dielectric constant of the supporting substrate, rendering significant miniaturization of a microwave device at little cost of losses.


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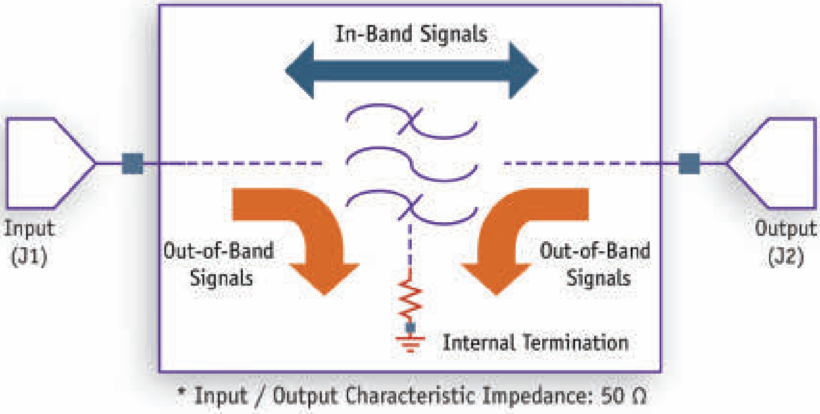

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- Potential damage to power amplifiers due to reflection of high power out-of-band energies

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		Pass Band	Stop Band	3dB Corner	Pass Band	Stop Band	(dB)	Pass Band	Stop Band
AF9438	Low Pass	1-30	50-380	32	5,000	250	0.2	1.30:1	1.60:1
AF9680	Low Pass	10-520	1040-3000	540	160	10	0.6	1.25:1	1.45:1
AF9313	Low Pass	10-870	1700-4000	1340	100	10	0.6	1.30:1	1.60:1
AF9349	Low Pass	10-150	270-1500	200	500	100	0.4	1.35:1	1.45:1
AF9255	Low Pass	10-170	300-1500	220	100	10	0.5	1.25:1	1.60:1
AF9705T	Low Pass	10-320	620-3000	500	150	25	0.5	1.25:1	1.45:1
AF9350	Low Pass	10-500	750-3000	540	400	100	0.5	1.25:1	1.50:1
AF9187	Low Pass	450-490	850-3000	620	100	10	1.0	1.40:1	1.60:1
AF9681	Low Pass	500-2500	4000-6000	2700	160	10	0.5	1.50:1	10:1

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