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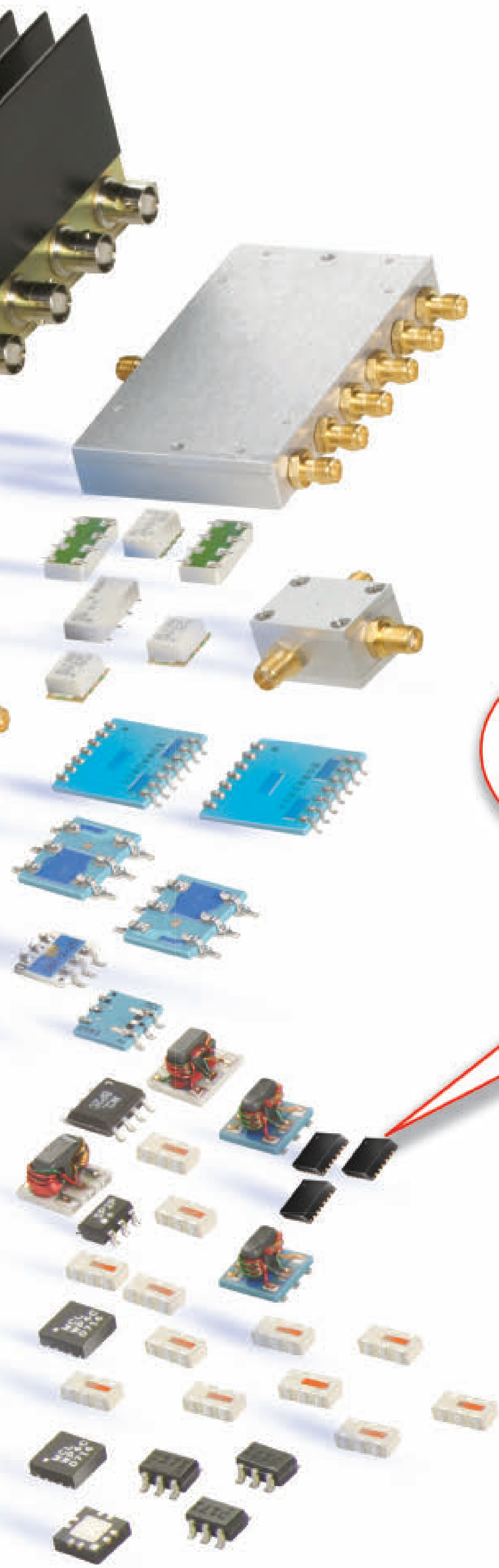

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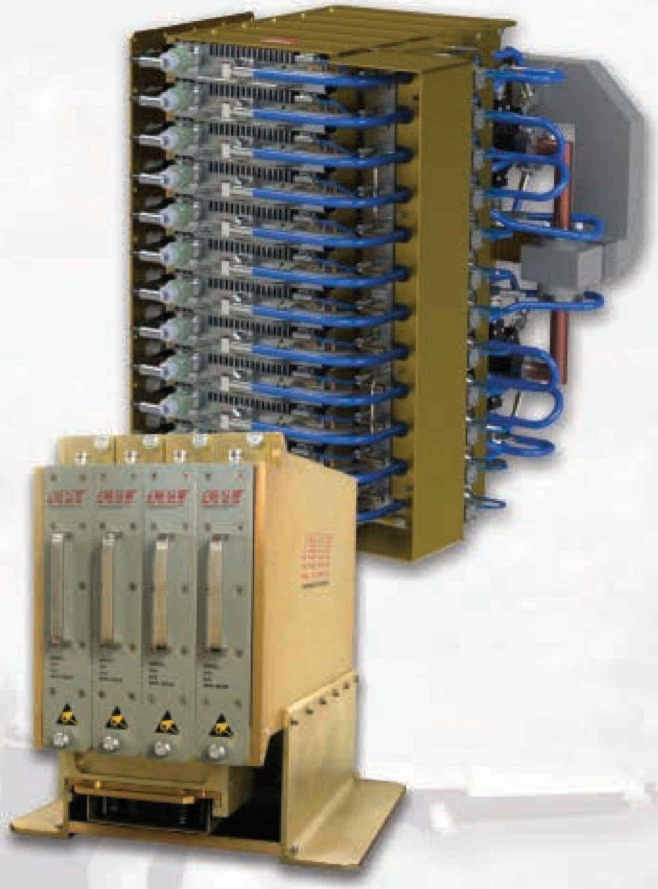

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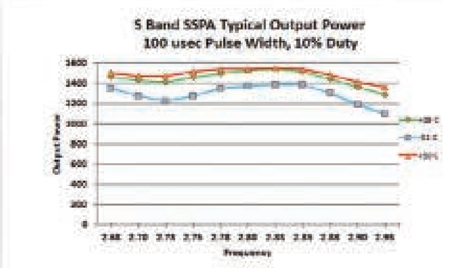

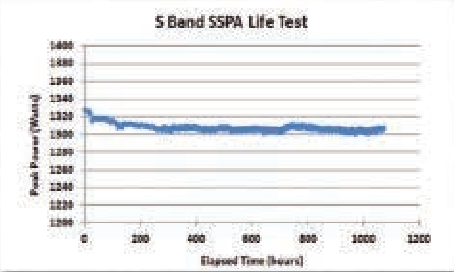

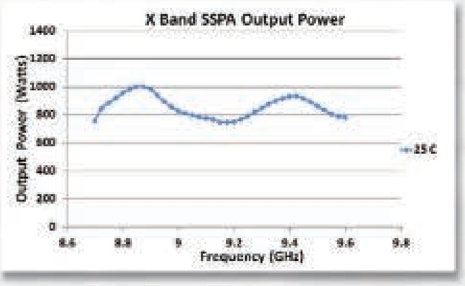

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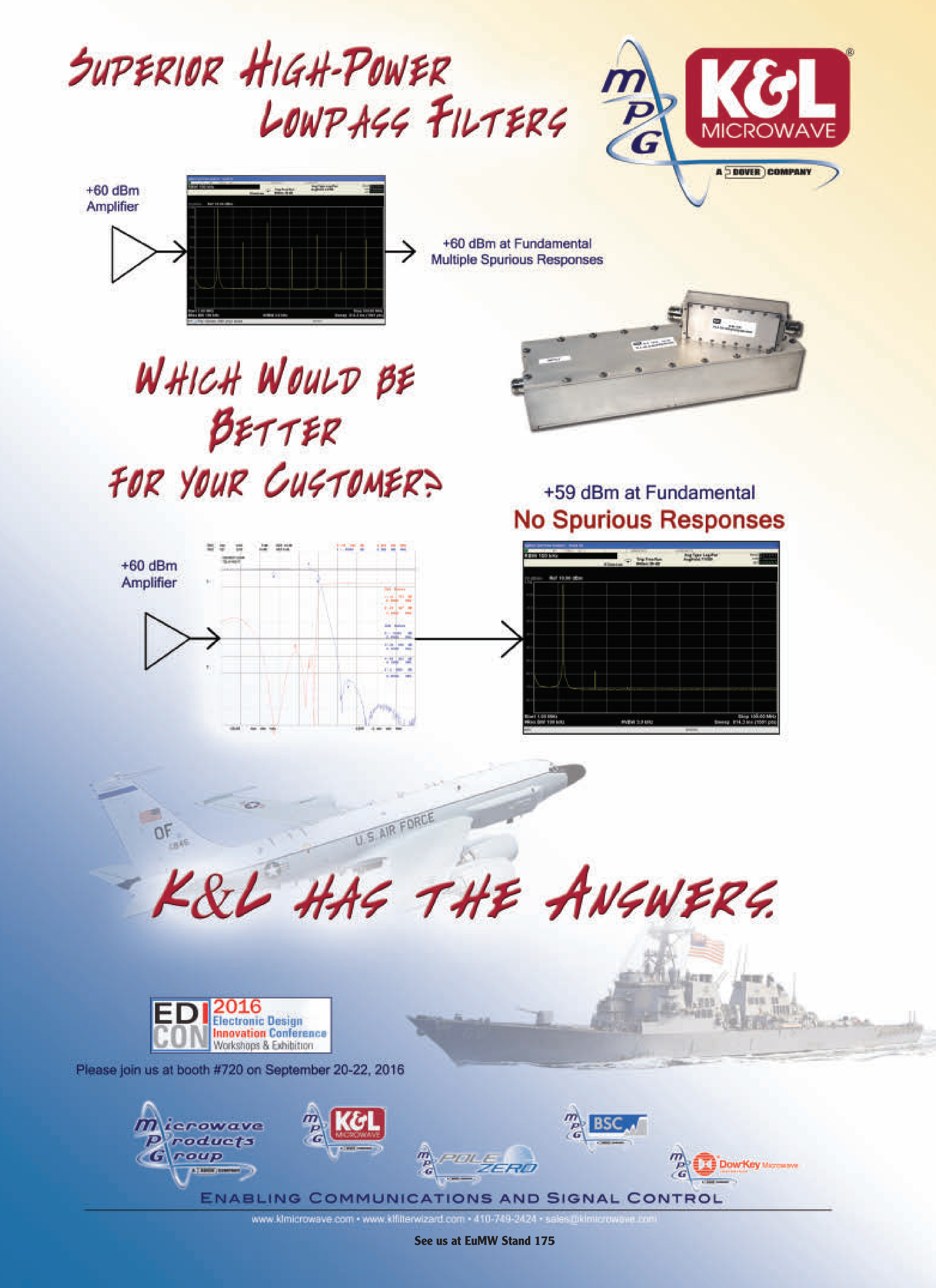
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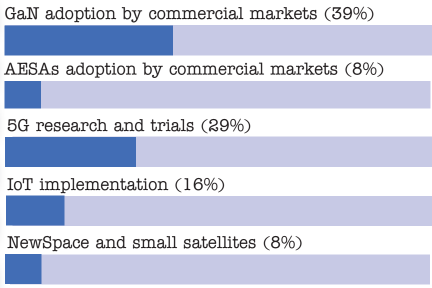

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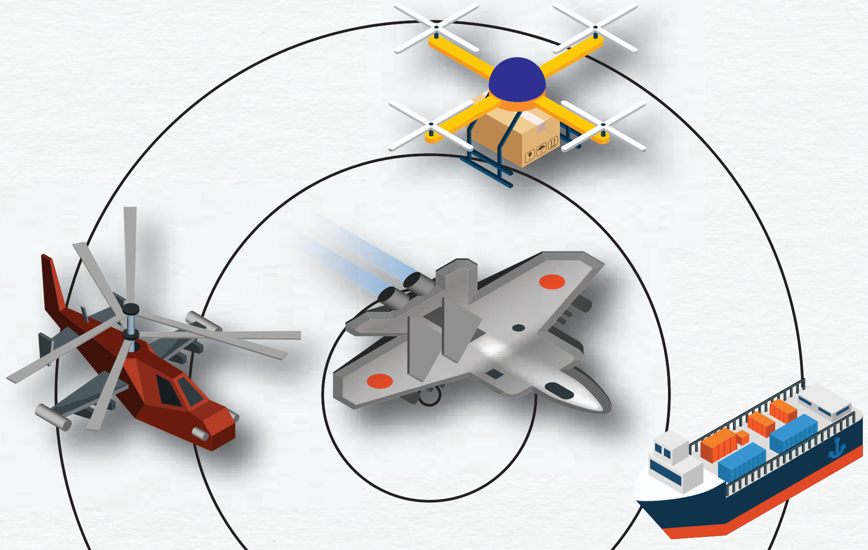


Cover Feature
Invited Paper

The 5G mmWave Radio Revolution

Amitava Ghosh
Nokia Bell Labs, Arlington Heights, Ill.

The future of mobile communication will be very different from what we see today, with wireless data traffic projected to increase 10,000 fold within the next 20 years, due to increased usage of smartphones, tablets, new wireless devices and the Internet of Things (IoT). To meet this ever-increasing demand in capacity and to support 5G requirements of greater than 10 Gbps peak and edge rates greater than 100 Mbps for extreme mobile broadband (eMBB) applications, one has to use new spectrum beyond sub-6 GHz frequencies. Due to the availability of large bandwidths at mmWave frequencies, the 5G requirements for eMBB can be met using a simple air interface and high dimension phased arrays. mmWave systems also face inherent challenges, such as high penetration loss, higher sensitivity to blockage and diminished diffraction, which the system must overcome. There are multiple ongoing research and channel measurement activities around the world on 5G mmWave systems, including METIS2020,[1] COST2100/COST,[2] ETSI mmWave SIG,[3] MiWEBA,[4] mmMagic[5] and NYU WIRELESS.[6, 7, 8] In this article, we examine the practical use of mmWave spectrum for 5G and ultra-dense network deployments.

Radio spectrum is a scarce resource and is the lifeblood of the cellular industry. 5G will exacerbate the situation, promising a wider range of use cases and related applications, including 8K video streaming, augmented reality (AR), different ways of data sharing and various forms of machine type applications (vehicular safety, different sensors and real-time control) requiring ultra-low latency. Demand for wireless data traffic will probably grow 10,000 fold within the next 20 years, and without suitable new spectrum it will be difficult to make all the promised new use cases and applications happen. The cellular industry is exploring several ways to address these challenges; one promising path is the utilization of underused mmWave frequency spectrum for future 5G networks, coupled with the densification of networks. By their nature, those high frequencies provide much more bandwidth than the spectrum below 6 GHz that is currently being used for mobile communication, and mmWave is more amenable to small cell deployments. Bands having a worldwide primary or co-pri-

mary allocation to mobile service have the most potential for spectrum designation. In the United States, the FCC recently published rules which opened up 10.85 GHz of spectrum for flexible use wireless broadband. The rules create 3.85 GHz of licensed flexible use spectrum in the 28 to 40 GHz bands and an unlicensed band from 64 to 71 GHz[9] (see ***Figure 1***). The FCC also released a Further Notice of Proposed Rule Making (FNPRM) on the following new bands: 24 to 25, 32, 42, 48, 51, 70 and 80 GHz.[9]

While mmWave frequencies start around 30 GHz and go through 300 GHz, 5G deployments are expected only up to around 100 GHz. For "low band" mmWave systems with up to a 40 GHz carrier frequency, larger bandwidths can be achieved by aggregating multiple carriers. For example, 10 × 100 MHz carriers can be aggregated to achieve a bandwidth of 1 GHz. Bandwidths from 500 MHz to 2 GHz are envisioned to be realized at mmWave frequencies above 40 GHz without the use of carrier aggregation. The narrow beams operated at these high frequencies impose challenges a mmWave system must overcome; user devices need to be acquired and tracked all of the time, using a narrow beam antenna, while mitigating shadowing with base station diversity and rapid rerouting around obstacles when it occurs.

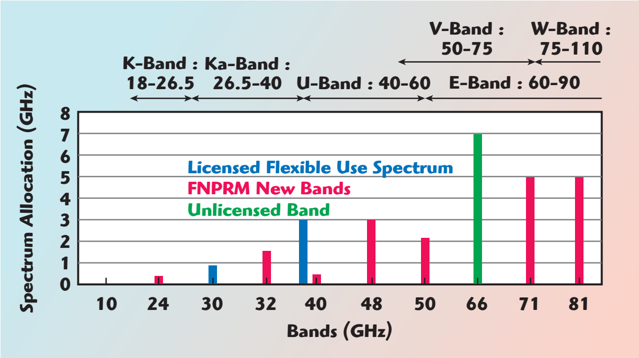


Fig. 1 Proposed 5G mmWave spectrum.

5G mmWave systems are currently targeted to be deployed in the following environments:

- Urban micro (UMi), comprising street canyons and open squares with cell radii less than 100 m and access points (AP) mounted below rooftops
- Suburban micro (SMi), with residential houses in a suburban setting with cell radii around 200 m and APs mounted at 6 to 8 m
- Indoor hotspots (InH), comprising indoor offices and cubicles and indoor shopping malls which are 3 to 5 stories high and APs at 2 to 3 m.

The first step in designing a 5G system at mmWave is to understand the channel characteristics of the above deployment scenarios. Multiple companies, European research consortiums[1-5] and academia[6] have conducted measurements campaigns for 5G channel modeling, along with ray tracing measurements. The findings of this extensive effort were published at GLOBECOM 2015.[10] The measurements indicate that smaller wavelengths introduce increased sensitivity in the propagation models due to the scale of the environment and show frequency dependent path loss and certain large scale parameters. Dif-

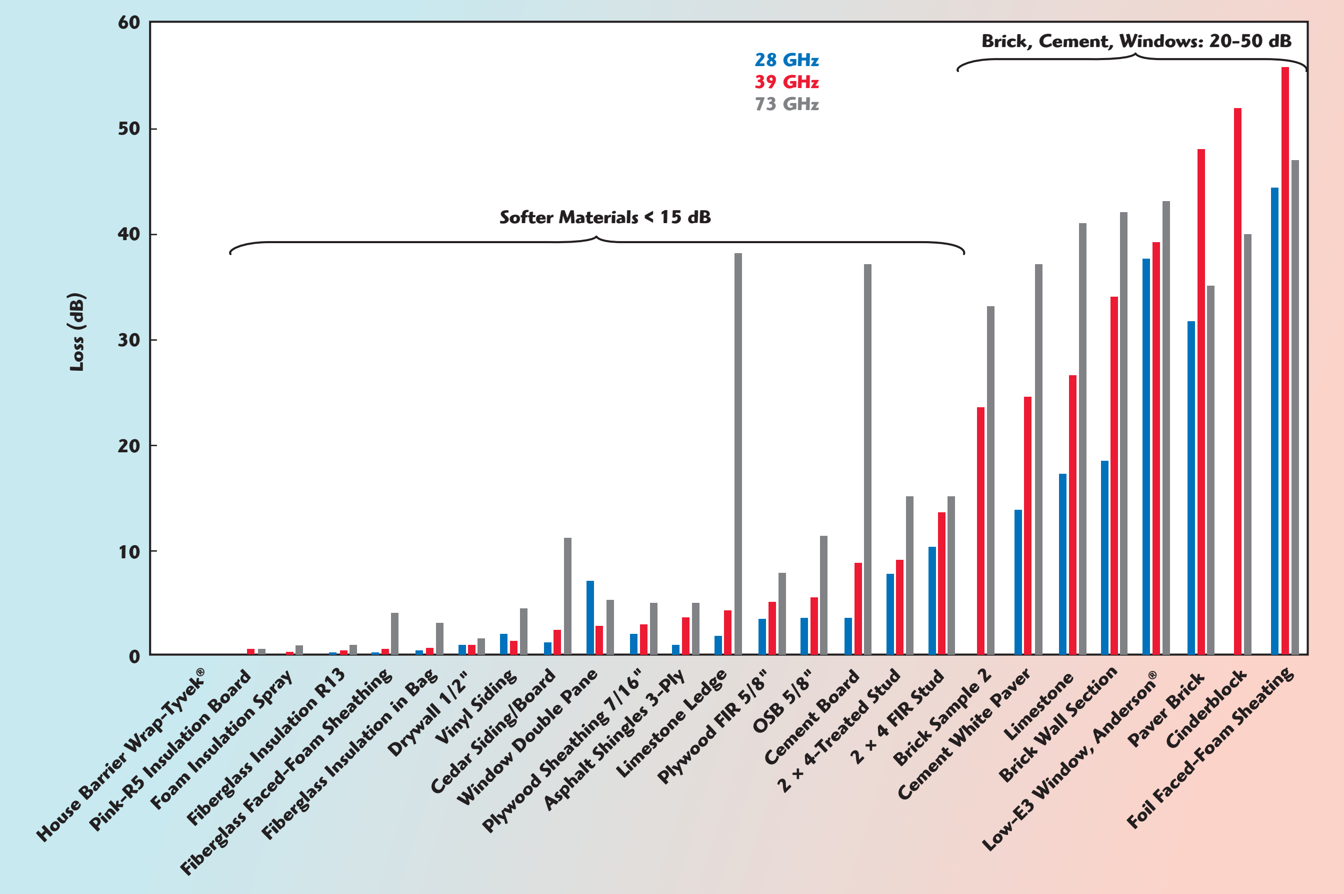


Fig. 2 Penetration loss vs. frequency.

TABLE 1

MODULATION FOR mmWAVE BANDS

3 to 40 GHz	> 40 GHz
CP-OFDMA	Null CP SC

TABLE 2

NUMEROLOGY FOR 5G mmWAVE SYSTEM

Spectrum Band	3 to 40 GHz	20 to 100 GHz	
Maximum Carrier Bandwidth (MHz)	200	400	1600
Waveform	OFDM	OFDM	NCP-SC
Clock Rate (Mchip/s)	245.76	491.52	1966.08
Sub-Carrier Spacing (kHz)	120	240	960
Ts (µs)	8.335	4.17	1.04
Maximum (I)FFT Size	2048	2048	2048
# Symbols per Subframe	14	28	120
Sub-Frame Length (µs)	125	125	125
CP (µs)	0.6	0.3	—
CP Overhead	6.7%	6.7%	—

fraction, the bending of rays around building corners and roofs, decreases with frequency and is no longer a dominant effect in outdoor channels above approximately 10 GHz. Atmospheric and rain losses are frequency dependent but are small: less than approximately 2 dB for worst-case rain for cell radii less than 100 m, even at 100 GHz. One of the important considerations in channel modeling is penetration loss, which is highly dependent on materials and tends to increase with frequency (see ***Figure 2***).

The shadow fading and angular spread parameters are larger and the boundary between line-of-sight and non-line-of-sight depends on the local environment as well as antenna height. The small-scale characteristics of the channel, such as delay and angular spread, and the multipath richness of the channel are somewhat similar over frequency, which is encouraging for extending the existing 3GPP models to wider frequency ranges. The standardization of 5G channel models in 3GPP is complete[11] and was primarily based on the GLOBECOM white paper.

5G mmWAVE AIR INTERFACE

Time division duplex (TDD) is the preferred duplexing method in mmWave cells because it eliminates the need for paired spectrum and is more flexible handling the elastic demand of uplink and downlink traffic. To maximize mobile broadband capacity, the 5G waveforms should be based on cyclic prefix orthogonal frequency division multiplexing (CP-OFDMA) and its variants, like in LTE (4G). 5G mmWave systems will use the same waveforms for both uplink and downlink. For bands above 40 GHz, a single carrier (SC) based waveform is preferred, to

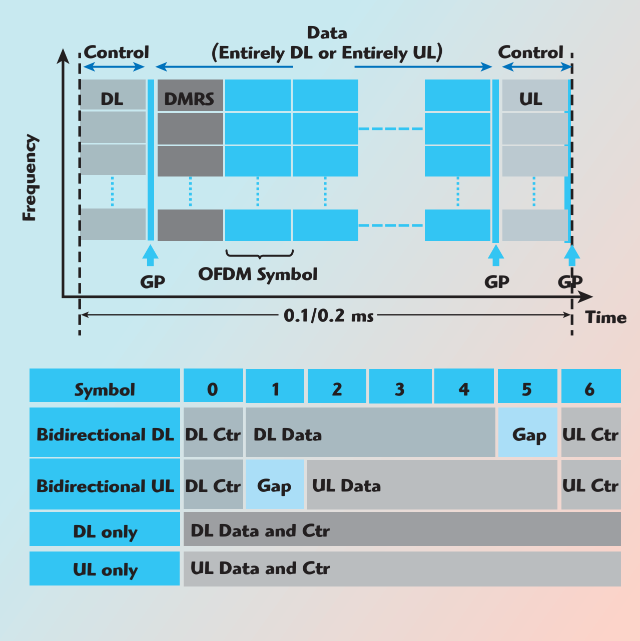
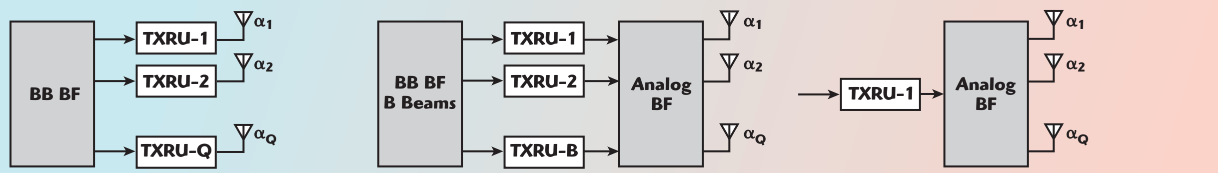


Fig. 3 Low latency frame structure for 5G mmWave.



Digital (Baseband) Beam Forming	Hybrid Beam Forming	Analog (RF) Beam Forming
Adaptive Tx/Rx Weights at Baseband	Adaptive Tx/Rx Weights at Both Analog and Baseband Domains	Adaptive Tx/Rx Weights at RF to Form a Beam
Each Antenna Element or Antenna Port Has a Transceiver Unit High Number (>8) of Transceiver Units	Each RF Beam Has a Transceiver Unit; Moderate Number of Transceiver Units for Capacity (e.g., Up to 8)	One Transceiver Unit and One RF Beam with High Antenna Gain (Coverage)
"Frequency Selective" Beam Forming	Combination of Analog and Baseband Beam Forming	"Frequency-Flat" Beam Forming
Best for Capacity and Flexibility (Subject to High Power Consumption & Cost Characteristics When Bandwidth Increases)	Optimization Between Both Coverage and Capacity	Best for Coverage (Low Power Consumption & Cost Characteristics)

Fig. 4 Baseband, RF and hybrid architecture properties for massive MIMO.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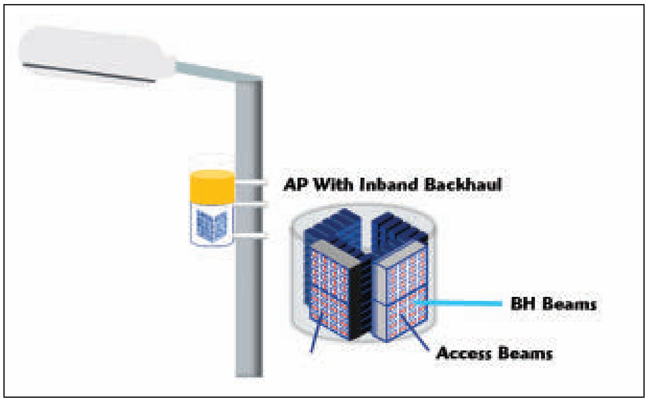

▲ *Fig. 5 Access point with inband backhaul.*

maximize power amplifier efficiency and allow efficient beam forming, minimizing switching overhead.[12] The promising SC waveforms are null CP SC (NCP-SC) or its frequency domain counterpart called zero-tail OFDM (ZT-OFDM),[13] where the regular CPs are replaced with null CPs and has nearly constant envelope properties. NCP-SC modulation is inherently efficient, like LTE's reverse link,[13] which uses DFT-spread OFDM (DFT-S-OFDM). The choice of modulation schemes at various mmWave frequency bands is illustrated in ***Table 1***.

Another important requirement of the 5G mmWave system is to achieve a 10× reduction in the latency of the air interface, compared to 4G. The primary mechanism for meeting this 1 ms latency is the frame structure of the 5G TDD system (see ***Figure 3***). Transmissions are organized into radio frames with 10 ms duration. A radio frame consists of an integer multiple of sub-frames with a predefined number of OFDMA symbols, which depends on the numerology adopted for 5G systems. Three sub-frames types are supported: downlink (DL) only, uplink (UL) only and bidirectional sub-frame. The sub-frame length, in OFDMA symbols, is common for all sub-frame types for a given sub-carrier spacing value. Each sub-frame contains demodulation reference signals (DMRS) for demodulating DL or UL data, DL and UL control and separate reference signals for demodulating broadcast control signals. Both the data and control signals are user-specific beam formed, along with the respective user-specific DMRS. In addition, a dynamic TDD operation can be supported where each sub-frame could be UL, DL or backhaul and can be configured differently from AP to AP. The choice of numerology for 5G mmWave system is guided by channel characteristics and the beam forming methodology at these bands. Smaller cell sizes at higher frequencies and narrow beamwidths imply lower delay spreads and allow shortening the cyclic prefix. Further, short symbol duration with larger subcarrier spacing maximizes beam switching opportunities and enables efficient TDMA control. Finally, the base clock rate of 2^N of the base sampling rate used in LTE facilitates multi-mode implementation with LTE and simplifies implementation. ***Table 2*** provides some exam-

ple numerology based on the above principles.

MASSIVE MIMO

Massive multiple-input-multiple-output (MIMO) is the extension of traditional MIMO technology with a few controllable antennas (typically less than eight) to antenna arrays having a large number of controllable antennas (16 or more). At mmWave, the number of antenna elements at the APs can vary from 128 to more than 1,000. The main benefit of massive MIMO is the enhancement in both capacity and coverage. At sub-6 GHz frequencies, the system is more interference limited, and capacity-enhancing solutions with massive MIMO single user (SU) and multi user (MU) MIMO become essential. At mmWave, coverage-enhancing solutions are essential to compensate the higher path loss at these frequencies. To provide the desired wider area coverage from a single radio and antenna, the antenna system needs to dynamically steer the beam to the user devices inside the cell coverage area.

Of the variety of means to steer antenna beams, the most attractive for this frequency band is an electronically steered array (ESA), also referred to as a phased array. Phased arrays require active phase—and often amplitude—control of the antenna elements. The small wavelength at mmWave frequencies implies that the antenna elements of a phased array will be closely spaced, and the supporting circuitry is well served by modern, highly integrated monolithic microwave integrated circuits (MMIC). The phased array is envisioned to provide a wide field of view, somewhere between 90 and 120 degrees azimuth range; elevation coverage range is expected to be smaller in many applications, although the design should not preclude a range comparable to azimuth. The size of the array will vary with the deployment scenario or application, i.e., it will depend on the desired system gain. The phased array architecture must therefore support scalable solutions in which multiple phased array MMICs and antennas can be combined to form larger or smaller arrays.

Phased arrays can be designed around various RF architectures, particularly the phase and amplitude steering and combining of the antenna element signals. Phase steering can occur at baseband, RF or a combination of baseband and RF, known as a hybrid architecture (see ***Figure 4***). Having a full digital baseband unit behind each antenna provides the most flexibility but requires the most hardware, particularly analog-to-digital and digital-to-analog converters. Because the converters consume a large amount of power at the higher bandwidths of mmWave, the RF or hybrid approaches are more likely for first-generation 5G mmWave systems.

mmWave APs and integrated wireless backhaul will fit in small boxes that are easy to install on lamp posts, walls or small masts (see ***Figure 5***). This concept is suitable for both the UMi and SMi environments.

To overcome high diffraction and penetration losses and blockages at

mmWave frequencies, a cluster network concept is envisioned where a set of coordinated APs work together to provide ubiquitous coverage through AP diversity. In the event of blockage due to shadowing, one AP will rapidly hand off the user device (UD) to another AP in the cluster. These handoffs may be quite frequent as the UD moves through the network. Moving obstacles, hand motion and changes in orientation may all contribute to multiple, successive handoffs. mmWave APs can also be deployed with a sub-6 GHz overlay using LTE-Pro and/or 5G new radio (NR) to provide dual connectivity to both systems. With dual connectivity, the user can be simultaneously connected to both systems, so that the radio link connectivity is maintained even if the mmWave system is blocked.

The performance of the mmWave system is simulated in a SMi environment with varying numbers of antenna elements and different values of penetration loss. The neighborhood layout in ***Figure 6*** shows a suburban grid with 16 blocks and 20 houses per block, totaling 320 houses. There is one AP per block and 10 active customer-premises equipment (CPE) per AP site. ***Figure 7*** shows the downlink user and edge throughput at 39 GHz with 800 MHz bandwidth, as the number of AP antenna elements per polarization is varied from eight to 128, and the number of antennas at the CPE is fixed to two. The figure shows that:

- Using outdoor CPEs, the network approaches the desired 500 Mbps UL, 500 Mbps DL mean CPE throughput
- Larger antenna arrays and sectorization at the APs improves performance significantly. Performance using indoor CPEs at 39 GHz is challenging due to the high penetration loss.

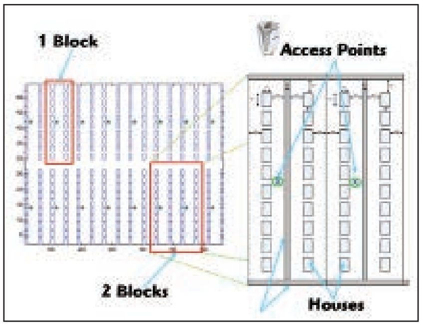

Fig. 6 SMi layout with 320 houses.

PROOF OF CONCEPT

Several proof of concept (PoC) mmWave systems were developed to prove the theoretical work and gain further knowledge about how a mmWave system behaves in the field. A first version, shown at Mobile World Congress 2015, used a steerable lens antenna and demonstrated tracking of moving users. A bidirectional system operating at 73 GHz with a 1 GHz bandwidth, it achieved a peak throughput of 2.3 Gbps using single input, single output (SISO). The design supports IP bearer data with a one-way latency of less than 1 ms. It was field tested in outdoor and indoor environments in Japan and the U.S., with peak throughput exceeding 2 Gbps and a maximum range of 160 to 200 m. At Mobile World Congress 2016, Nokia demonstrated the next version, a unidirectional 15 Gbps sys-


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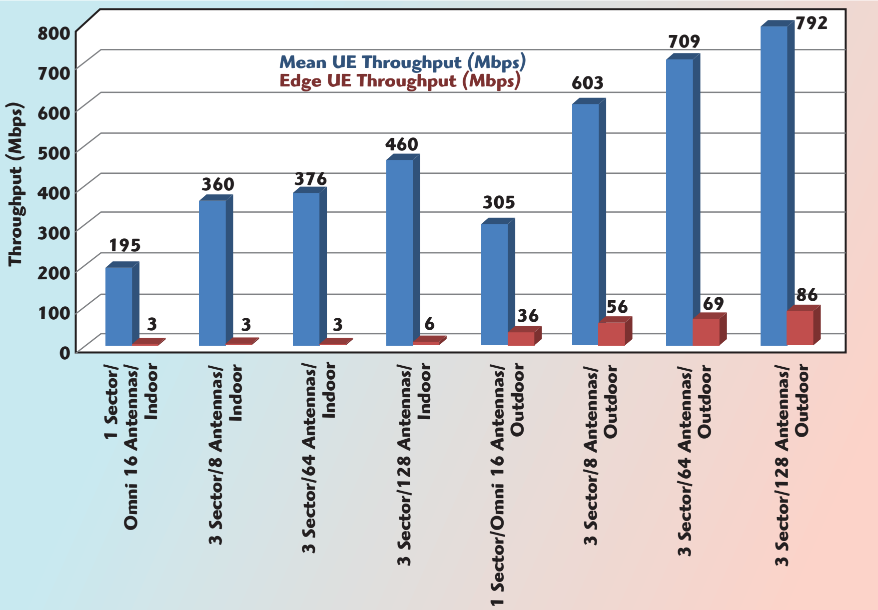
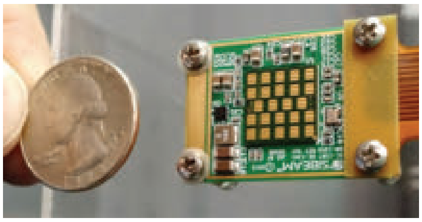
tem incorporating 2-stream MIMO in a 2 GHz bandwidth.

As a next step, the antennas were miniaturized to better match the expected phased arrays used at both the AP and UE. At the 2016 Brooklyn 5G Summit, Nokia demonstrated beam scanning using a phased array at 60 GHz with the 1 GHz bandwidth system. Because the element spacing decreases with higher frequencies (~ 2.5 mm at 60 GHz), an 8 × 8, λ/2-spaced antenna array could easily fit into an area smaller than 20 sq mm, as shown in ***Figure 8***. A fully integrated 16 element, 90 GHz phased array ASIC was developed at Nokia Bell Labs, and the ASIC die was assembled directly on an organic PCB substrate that housed the patch antennas. The integrated array demonstrated an EIRP of 34 dBm at 90 GHz and a receiver noise figure of 7 dB per element. The system can establish multi-gigabit wireless links at distances of tens of meters. This low cost, integrated solution does not require any waveguide components or expensive materials and follows a traditional die-on-PCB assembly process.

Nokia is pushing spectral efficiency to get the most capacity out of the spectrum, demonstrating spectrum efficiencies up to 100 bps/Hz at 28 GHz. This will make wireless transmission of large data files far more economical than what is currently achievable. The prototype uses a novel physical layer



▲ *Fig. 7 Full buffer DL mean user and edge throughput for various SMi environments at 39 GHz with 800 MHz bandwidth.*



▲ *Fig. 8 12-element phased array showing the small size of the array. Source: SiBeam Inc.*

technology, including massive MIMO, that guarantees huge system capacity and spectral efficiency. It achieved a peak transmission rate of over 50 Gbps across a short range, while supporting latency requirements as short as 250 µs. At that speed, a 50 GB movie can be downloaded in less than eight seconds.

CONCLUSION

The use of mmWave spectrum in wireless communication is considered revolutionary, and this article examines the state-of-art in mmWave communication for the wireless industry, covering spectrum options, channel characteristics, air interface design and massive MIMO architectures. Proof-of-concept systems have been developed and are essential to show how the challenges of a mmWave system can be overcome. The next step is commercial deployment, with first trials of specific 5G use cases in early 2017. Ideally, a simple and low cost small cell solution, using a fully flexible baseband technology, massive MIMO and phased arrays at mmWave will be feasible by the year 2020. This solution will help achieve the promise of 5G and the many new applications and use cases it will enable.■

ACKNOWLEDGMENT

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References

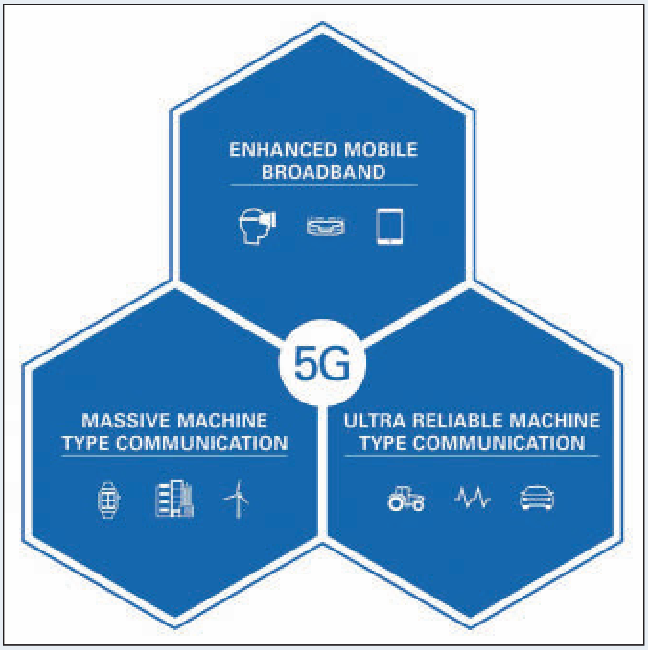
1. METIS2020, Deliverable D1.4 v3, "METIS Channel Model," July 2015. www.metis2020.com/wp-content/uploads/METIS_D1.4_v3.pdf.
2. COST, www.cost2100.org/.
3. ETSI, "New ETSI Group on Millimetre Wave Transmission Starts Work," www.etsi.org/news-events/news/866-2015-01-press-new-etsi-group-on-millimetre-wave-transmission-starts-work.
4. MiWEBA, Deliverable D5.1 "Channel Modeling and Characterization," June, 2014, www.miweba.eu/wp-content/uploads/2014/07/MiWEBA_D5.1_v1.011.pdf.
5. mmMagic, 5g-ppp.eu/mmmagic/.
6. T. S. Rappaport et al., "Wideband Millimeter-Wave Propagation Measurements and Channel Models for Future Wireless Communication System Design," *IEEE Trans. Communications*, Vol. 63, No. 9, pp. 3029–3056, September 2015.
7. T. S. Rappaport et al., "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!," in *IEEE Access*, Vol. 1, pp. 335–349, 2013.
8. G. MacCartney et al., "Indoor Office Wideband Millimeter-Wave Propagation Measurements and Channel Models at 28 GHz and 73 GHz for Ultra-Dense 5G Wireless Networks," *IEEE Access*, October 2015.
9. FCC Spectrum Frontiers (mmW) Order on 28/37/39/64-71GHz and Further Notice of Proposed Rulemaking (FNPRM): transition.fcc.gov/Daily_Releases/Daily_Business/2016/db0714/FCC-16-89A1.pdf.
10. 5G Channel Model White Paper, Globecom 2015, www.5gworkshops.com/5GCM.html.
11. 3GPP TR38.900, www.3gpp.org/ftp//Specs/archive/38_series/38.900/38900-100.zip.
12. Amitava Ghosh et al., "Millimeter-Wave Enhanced Local Area Systems: A High-Data-rate Approach for Future Wireless Networks," *IEEE Journal on Selected Areas in Communications*, Vol. 32, Issue 6, June 2014.
13. Stephen Larew, Timothy A. Thomas, Mark Cudak and Amitava Ghosh, "Air-Interface Design and Ray Tracing for 5G Millimeter Wave Communications," *Proceedings of IEEE Globecom Workshop*, 2013.

Most Valuable Product

Second-Generation VST is Smarter for Today's RF Test Challenges

National Instruments
Austin, Texas

In 2012, NI announced the PXI vector signal transceiver (VST), the world's first instrument to combine an RF vector signal generator and analyzer with a user-programmable FPGA into a single PXI module. The combination of the VST's excellent RF performance and unique software experience enabled customers to reduce test cost and accelerate productivity in a wide range of applications: from wireless test to electronic warfare (EW). Its LabVIEW-programmable FPGA enabled many test optimizations, including power amplifier (PA) test with built-in output power leveling, spectral and demodulation measurement acceleration and other real-time signal processing algorithms.



▲ *Fig. 1 Three use cases driving 5G technology vectors and standards.*

Looking to the future, the changing requirements for RF and wireless test equipment are accelerating at an ever-increasing pace. Nowhere do we see this more clearly than in the International Telecommunication Union's (ITU) defined use cases for 5G (see ***Figure 1***). The first is enhanced mobile broadband (eMBB), which will drive peak data rates upwards of 10 Gbps through a combination of wider bandwidth, higher-order modulation and MIMO/beam forming technologies. The second use case, massive machine-type communication (mMTC), will connect a wide range of devices in more industrial IoT (IIoT) applications, and it will drive new mobile technologies such as LTE for machine-to-machine (M2M) communications and narrowband IoT (NB-IoT). The third use case defines ultra-reliable machine-type communication (uMTC), in which the key requirements are latency and packet error rates. Although these strong trends deal mainly with

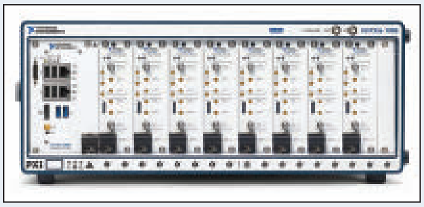
cellular technology, they also drive new connectivity standards such as 802.11ad/ax, personal area networks and near field communication (NFC). These technological developments introduce new challenges for professionals designing and testing state-of-the-art devices and components for RF and wireless systems. Higher throughput demands wideband instruments, lower cost requires faster measurements and higher reliability introduces the need for new test techniques.

To tackle these challenges, NI has introduced a second-generation VST, the PXIe-5840. With 1 GHz of instantaneous bandwidth, the second-generation VST offers five times the bandwidth of the first-generation VST. The PXIe-5840 VST offers EVM performance better than -50 dB, output power to +23 dBm and a wider frequency range, from 9 kHz to 6.5 GHz. Similar to the first-generation VST, the PXIe-5840 VST features a LabVIEW-programmable FPGA. The new instrument's Virtex-7 FPGA offers approximately five times the number of DSP slices as the initial generation and allows customers to customize the instrument firmware in advanced test and design applications. The second-generation VST also does all of this in only two PXI slots, allowing engineers to configure PXI systems with up to eight modules per PXI system.

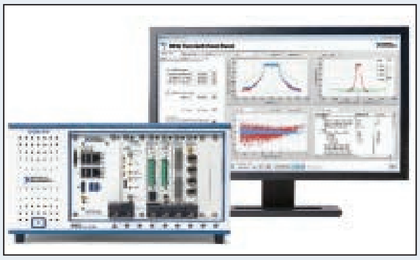
CELLULAR, SEMICONDUCTOR AND PROTOTYPING

Next generation wireless device and transceiver test is one application that the VST is designed to address. The latest evolution of standards like LTE-Advanced Pro and 802.11ax introduce both new carrier-aggregation requirements and higher-order MIMO configurations. The second-generation VST's smaller footprint and solution, with engineers able to configure up to eight MIMO test systems in a single 18-slot PXI chassis (see ***Figure 2***). For carrier aggregation applications, the VST's wide bandwidth enables engineers to generate widely spaced LTE carriers with a single instrument. As a result, engineers can replace test setups involving multiple signal generators and multiple signal analyzers with a single instrument.

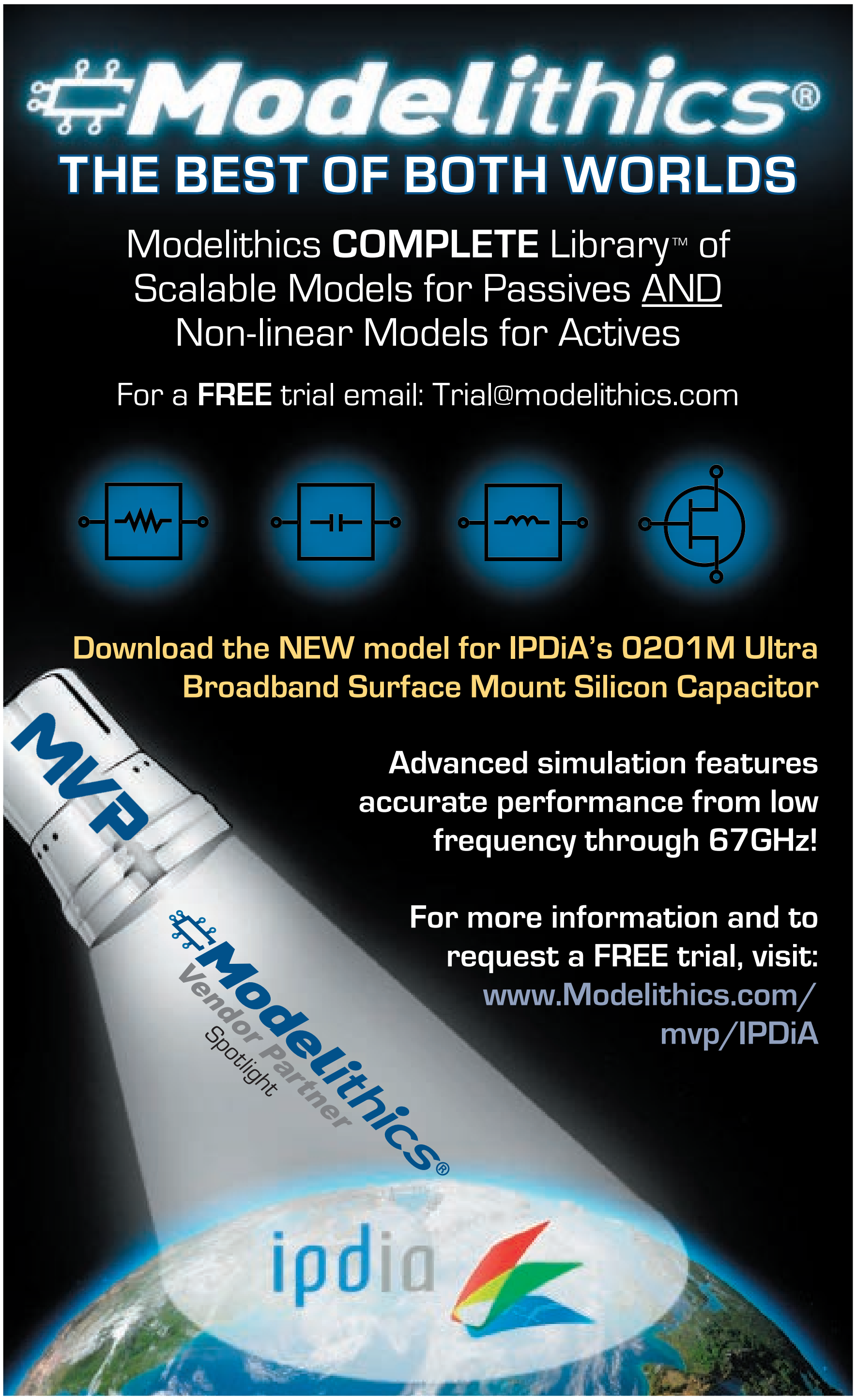
The second-generation VST's wide bandwidth is important in semiconductor test applications. Especially for PA and front-end module (FEM) testing, the bandwidth requirements for the instrument often exceed the bandwidth of the signal. For example, when testing RF power amplifiers (PA) operating in or near saturation, the VST measures the PA's output signal, computes a predistorted

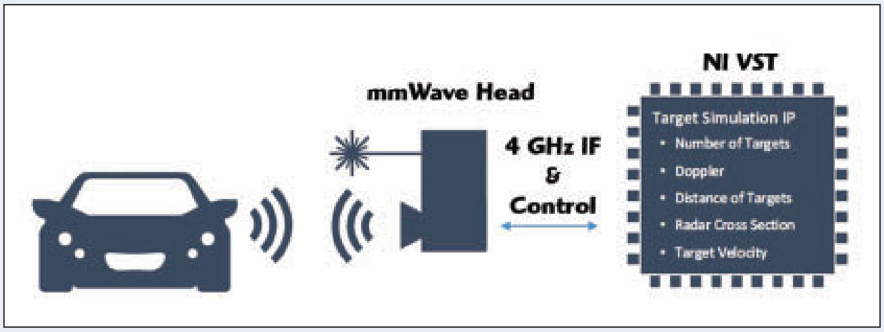


▲ *Fig. 2 Compact 8x8 MIMO system with eight VSTs.*



▲ *Fig. 3 Digital predistortion setup.*





▲ *Fig. 4 Radar system setup using a custom millimeter wave head.*

signal following a digital predistortion (DPD) model and then applies the new signal to the DUT. As a result, when the signal goes through the nonlinear PA, the output will have minimum spectral regrowth. Advanced DPD algorithms often require the predistorted signal to have three to five times the bandwidth of the original RF signal. The new PXIe-5840 VST can measure signals with bandwidth requirements around 500 MHz for a 100 MHz LTE-Advanced signal and 800 MHz for a 160 MHz 802.11ac/ax signal. By exploiting the power of the VST's FPGA, this whole process can run in hardware, in real time, empowering PA engineers to apply custom DPD to every DUT, even in high volume manufacturing test environments (see ***Figure 3***).

NI's platform for FPGA development simplifies the process of modifying the VST's firmware on its FPGA. This empowers researchers to use the VST to process RF signals in real time, for applications ranging from EW systems to radar target emulators. In a radar target emulator, engineers can program the VST to capture a stimulus signal from a radar system under test; introduce one or more targets of various sizes; add delays, Doppler shifts and other effects to the signal in real time; and immediately generate the response back to the radar receiver (see ***Figure 4***).

Designers and users of automotive radar systems, for example, understand well that the consequences of just one of their systems not performing properly can prove disastrous. They need to run long validation routines for driver assistance systems, sometimes exceeding 10,000 hours. Without reliable test emulation platforms, like the one that the second-generation VST provides, engineers would have to drive millions of km, with all kinds of obstacles and in many different scenarios, to test the possible events that would lead their vehicle's radar and networking systems to a critical failure.

Although the next wave of RF and wireless technologies is introducing significant design and test challenges, NI designed the second-generation VST to solve them. With unrivaled bandwidth, a smaller form factor and the largest and most customizable test platform, the PXIe-5840 VST empowers engineers to meet these RF test challenges.

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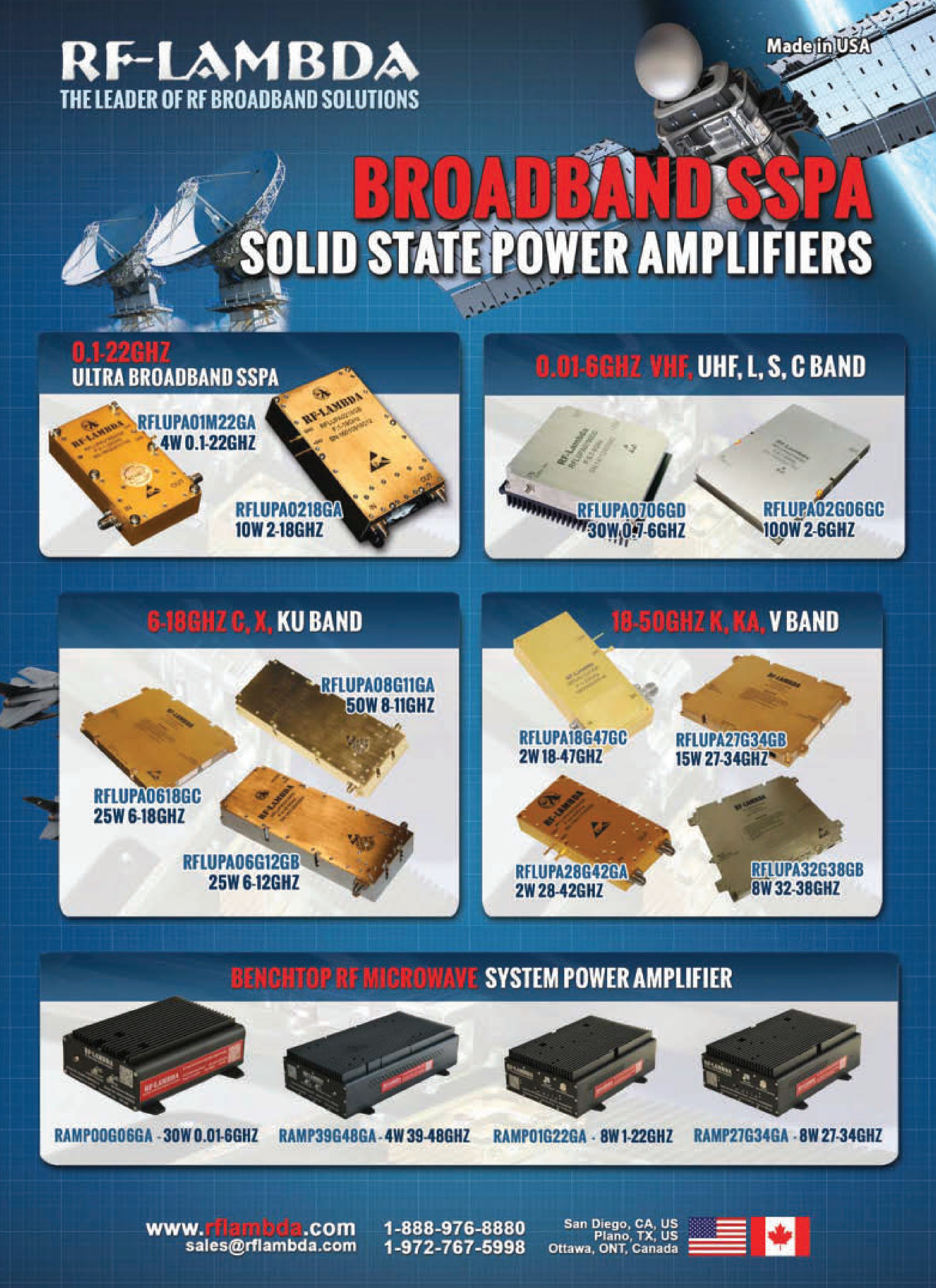
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5G and the IoT: 5 Trends and Implications

Dudy Cohen
Ceragon Networks, Tel Aviv, Israel

If industry experts are correct, 5G will hit the market at the very beginning of the next decade.

Despite some uncertainties, 5G is creating buzz among mobile operators and communications service providers (CSP) that want to get in on the ground floor. And while 5G isn't slated to be finished and commercially deployed until 2020, initial trials should start in 2018. Consequently, smart operators and providers are learning all they can about 5G now to understand how they will need to evolve their backhaul strategies to create more effective and financially viable business models.

As one of the key new services in 5G networks, the Internet of Things (IoT) will influence the number of connected devices that will enter the marketplace. Additionally, the IoT will impact 5G traffic patterns as well as quality of service (QoS) requirements, all of which will also affect backhaul requirements and specifications. The aggregate data demand from the IoT will be very different from the smartphone oriented experience of 3G and 4G. Capacity demands will grow, and more base stations will have to be deployed in order to achieve the quality of service that is essential for the IoT to be successful.

Here are five key trends and characteristics of the underlying 5G networks that pose specific and well-defined challenges to the network infrastructure as IoT expands:

More Capacity per Device

One of the main goals of 5G services is to provide ultra-high capacity per end device, which means operators are going to need to add more spectrum, improve spectrum efficiency or roll out more infrastructure. With the rise in IoT devices, such as autonomous cars and manufacturing networks, the need for increased capacity will be crucial.


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More Devices and New Types of Devices

The exponential growth in the number of "standard" devices (for example, smartphones, tablets, computers, smart home devices and wearables) is expected to continue, and the average number of devices per person is expected to increase. In 2014, Strategy Analytics estimated that 12 billion internet-connected devices would be used worldwide by the end of the year — an average of 1.7 devices for every person on the planet. By 2020, they forecast that number to jump to 33 billion, bringing the number of connections per person to more than 4.3 devices.

The mass introduction of the IoT and machine-to-machine services will create a large increase in the number of connected devices, adding non-human controlled devices to the mix and resulting, as forecast by GSMA, in an exponential increase in the total number of connected devices. With the increase of non-human controlled devices, one of the goals of 5G will be to be able to service these additional capacity requirements.

Higher Capacity and Street-Level Deployment

Multiplying the increase in capacity per device by the expected growth in the number of IoT connected devices results in a huge increase in capacity density (the required capacity per a given area). This forecast increase could multiply by 1,000 compared to the capacity density in current 4G/4.5G networks.

The clear effect of the increase is that more capacity per cell site — both at the radio access network (RAN) and at the backhaul layer — will be necessary. However, increasing a site's capacity by 1,000× is not feasible. Since the forecast move to higher RAN frequencies will also require smaller coverage areas per cell site, the mobile grid will become much denser than it is today. This grid will incorporate the addition of macro cells as well as small cells on poles, towers, rooftops — also mass deployment at the street level, utilizing street furniture and light poles as physical infrastructure.

These issues will present several challenges to wireless transport networks. First, there will be a need for higher capacity wireless backhaul links per cell site. While current wireless backhaul links serve requirements of hundreds of Mbps, future links will be required to support ten Gbps and more. Additionally, denser wireless backhaul links will also be required, due to the condensed cell site grid. This demands better utilization of wireless backhaul spectrum, since frequency reuse will be highly limited as links get closer to each other. Finally, the mass deployment of street level sites will require high capacity non-line-of-sight (NLOS) microwave backhaul links, as well as quickly installed, low footprint, low power consumption equipment.

Mission Critical Applications Require Mission Critical Backhaul

Until recently, many of the services provided over mobile networks have been infotainment-oriented. However, new 5G service types, such as autono-

mous driving, tactile Internet and many M2M applications, must be served by mission-critical networks. The risks of failure are too great.

"Five nines" availability as well as complete coverage, ultra-low latency and tight security will be standard requirements for public mobile 5G networks and wireless backhaul infrastructure—just as these are required in public safety and utility networks today.

Virtual, Cloud Based Services and Network Architecture Will Change

When 5G arrives, wireless backhaul will work to increase its position as the most flexible and cost-effective backhaul technology for mobile networks, but that status will not be achieved without serious technical advancement.

The changeover to 5G will be a good opportunity for operators to retool their network and service architecture, in order to enjoy the benefits of new cloud architecture. Specifically, there will be major savings in capital expenditure and operating expenses in addition to a very quick time to market for new services and revenue streams.

Using cloud technology, it will also be much easier for network providers to address new challenges. This will be especially important as a larger number of people become more reliant on IoT devices, like connected home security systems, smart appliances, energy meters, game consoles and other applications that are enriching the lives of consumers in markets around the world.

TECHNICAL IMPLICATIONS

So, what are the technical implications of these five trends for radio frequency and microwave components?

One of the implications is that backhaul systems will have to move to higher frequencies in order to increase capacity and avoid congestion, as the current backhaul frequencies populate access services as well as backhaul. Current common wireless backhaul frequency bands include microwave frequencies, typically 6 to 42 GHz (for short haul communications) as well as millimeter waves—mostly E-Band (70 and 80 GHz).

This transition to higher frequency bands such as W-Band (100 GHz) and D-Band (140 GHz) will require intensive efforts in radio frequency integrated circuit (RFIC) design in addition to the development of new modems. New research regarding wave propagation patterns at these frequencies, as well as interference, will also be essential.

Additionally, the move to higher frequencies will necessitate full system integration, where companies will be able to leverage their ability to make in house chip-sets and bring their products to market much faster.

CONCLUSION

While 5G can offer game-changing benefits to connected users, the ultimate success of 5G hinges on wireless operators and their technology partners, who together can overcome 5G's many challenges and build mobile networks for the future. Mobile operators must understand and plan for higher capacity requirements, denser cell site grids, street-level deployments, network virtualization and mission critical applications. Driving wireless transmission to a new era is a must, in order to overcome these 5G challenges.■


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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

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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DefenseNews

Cliff Drubin, Associate Technical Editor

The F-35 is so Stealthy, it Produced Training Challenges, Pilot Says

VIEW VIDEO

The F-35 Lightning II is so stealthy, pilots are facing an unusual challenge. They're having difficulty participating in some types of training exercises, a squadron commander told reporters.

During a recent exercise at Mountain Home Air Force Base, Idaho, F-35 squadrons wanted to practice evading surface-to-air threats. There was just one problem: No one on the ground could track the plane.

"If they never saw us, they couldn't target us," said Lt. Col. George Watkins, the commander of the 34th Fighter Squadron at Hill Air Force Base, Utah.

The F-35s resorted to flipping on their transponders, used for FAA identification, so that simulated anti-air weapons could track the planes, Watkins said.

"We basically told them where we were at and said, 'Hey, try to shoot at us,' " he said, adding that without the transponders on, "most likely we would not have suffered a single loss from any SAM threats while we were training at Mountain Home."

"When we go to train, it's really an unfair fight for the guys who are simulating the adversaries," Watkins continued. "We've been amazed by what we can do when we go up against fourth-gen adversaries in our training environment, in the air and on the ground."

Watkins said he can take four F-35s and "be everywhere and nowhere at the same time because we can cover so much ground with our sensors, so much ground and so much airspace. And the F-15s or F-16s, or whoever is simulating an adversary or red air threat, they have no idea where we're at and they can't see us and they can't target us."

"That's a pretty awesome feeling when you're going out to train for combat," Watkins concluded, "to know that your pilots are in an unfair fight."

The pilots and crews at Hill have been putting the new fifth-generation fighter through its paces, in preparation for top Air Force brass declaring the plane operationally ready — a move expected within days.

Photo: SSgt. Staci Miller/Air Force

The Air Force's variant of the F-35 will make its first appearance at the famous Red Flag training exercise at Nellis Air Force Base, Nev., in January 2017, Watkins told Air Force Times. Marine Corps F-35Bs have already reached initial operating capability and participated in the exercise this year.

A New Generation of Electron Devices Makes Waves, Trillions Each Second

Normal radios operate in kilohertz (kHz) and megahertz (MHz) frequencies, bandwidths corresponding to electromagnetic oscillations in the thousands and millions of cycles per second ranges, respectively. Upping the ante, cell phones and radar systems operate in the billions of cycles per second range—that is, gigahertz (GHz) frequencies. But no one has managed to push radiofrequency technology into the trillions of cycles per second, or Terahertz (THz) range. With the Terahertz Electronics Program, however, DARPA has begun to make it possible. And as graphically depicted in the attached DARPA "fight" poster—fashioned after a promotion for the legendary bout in 1975 between Muhammed Ali and Joe Frazier in Manila, the Philippines—two promising and powerful approaches are dueling it out for possible dominance in this high-frequency electromagnetic frontier.

> Two of the highest-frequency radio components ever made bode well for ushering radio technology into the super-high-speed/high-capacity terahertz bandwidth.

In one corner is the solid-state power amplifier (SSPA), which in 2014 was certified by Guinness World Records as the world's fastest solid-state chip, able to operate at THz speeds. This device, made of the semiconductor indium phosphide (InP), also can boost the power of a wide swath of incoming signals some thirtyfold. In the other corner is a micromachined traveling wave tube amplifier (TWTA), a miniaturized device that relies on a tiny vacuum chamber in which electrons and radio signals interact. This wee bruiser can boost the power of a narrower range of THz frequencies by a factor of about 200 and was a celebrated darling of the 2016 IEEE International Vacuum Electronics Conference.

Of course, in reality this need not be a fight. "Really, the two contenders, both of them made by Northrop Grumman, are working as a tag team to collectively smack down the technical barriers that until now have made many THz applications impossible to realize," said Dev Palmer, the DARPA program manager who has overseen the two-pronged research effort. "Together, the world-record SSPA

For More Information

Visit mwjournal.com for more defense news and highly-acclaimed TWTA open the way to a THz future featuring devices that can generate, detect, process and radiate extremely high-frequency signals, and push what is possible in areas ranging from high-resolution security imaging, collision-avoidance radar, high data rate communications, and remote detection systems for dangerous chemicals and explosives."

Army Wants to Upgrade or Replace Patriot Missile Radar

VIEW VIDEO

The Army Contracting Command at Picatinny Arsenal, N.J. recently issued a request for information for the Lower Tier Air and Missile Defense Sensor (LTAMDS) project to consider upgrades or replacements to the Patriot missile radar.

The Army wants to upgrade or replace the current Patriot radar to improve its effectiveness against emerging threats and reduce maintenance costs.

The Patriot is a surface-to-air missile (SAM) that uses the Raytheon AN/MPQ-53 phased-array radar for high-to medium-altitude air defense against enemy aircraft and ballistic missiles. Army leaders want to keep Patriot in the field until at least 2040.

Army experts want new or upgraded Patriot radar systems that cost less than $50 million per installation. Solutions must be at least as mature as component and breadboard validation in relevant environments (Technology Readiness Level 5) by late 2017.

A team from the Army Aviation and Missile Research Development and Engineering Center (AMRDEC), Georgia Tech Research Institute (GTRI), University of Alabama in Huntsville (UAH), Wyle-CAS, Dynetics and Torch Technologies will evaluate industry responses in efforts to shape requirements for future Patriot radar enhancements.

> **The Army wants descriptions of proposed solutions; expected per-unit costs of radar upgrades or replacements for 80 Patriot radars over 10 years.**

Army experts are also interested in technologies critical to a Patriot radar upgrade or replacement, including high-power amplifiers, low-noise amplifiers, limiters, low-noise oscillators, AC-DC and DC-DC power supplies, antennas, cooling systems, and prototypes.

5GIC and Digital Greenwich Partner to Pioneer Smart City Technology

The University of Surrey's 5G Innovation Centre (5GIC) and Digital Greenwich, part of the Royal Borough of Greenwich, London have announced a ground-breaking partnership that will deliver the technology that will underpin future smart cities. The partnership will leverage the facilities and expertise of both parties to deliver 'Smart' resource-efficient, low-carbon, healthy and livable neighbourhoods within a city. The 5G standardised approach will provide the opportunity to scale solutions at wider city and national level.

The 5GIC is now the largest European research centre dedicated to the development of the next generation of mobile and wireless communications. Bringing together leading academic expertise and key industry partners in a shared vision, the 5GIC will help to define and develop the 5G infrastructure that will underpin the way we communicate, work and live our everyday lives in the future.

The Royal Borough of Greenwich and Digital Greenwich are working on a world-leading Smart City strategy setting out how the Council proposes to implement 'smarter' approaches to coping with future challenges related to transport, health, energy and the built environment. It will create new opportunities for businesses and local communities, securing business regeneration and growth.

Professor Rahim Tafazolli, director of 5GIC and Institute of Communication Systems, commented, "Fundamental to next generation Smart City applications is the creation of a robust communications system. Working with Digital Greenwich will enable the 5GIC to develop solutions targeted at multiple use cases in a city context. The partnership will also provide the foundation to drive standardised solutions for all of the UK to benefit from the technology.

> "...make Britain the most digitally advanced of all nations."

Minister of State for Digital and Culture, Matt Hancock, said, "We want to make Britain the most digitally advanced of all nations. We are already a world leader in the development of 5G technology, so I'm delighted by the new partnership between the University of Surrey and Digital Greenwich. Collaborations like this will help make our cities better places in which to live, work and play."

SAVELEC Project to Remotely Disable Vehicles

In its endeavour to keep the public safe, one of the key challenges facing European security services is the ability to control and stop, at distance, non-cooperative vehicles posing a threat. However, this ability presents more than a technical challenge. To comply with EU legislation, as well as adhere to ethical concerns, the technology would also have to be safe for the user, the driver (and passengers), as well as members of the public and the material infrastructure of the surrounding environment.

To address this issue the 'safe control of non cooperative vehicles through electromagnetic means' (SAVELEC) project developed a prototype device, after testing signals (magnetic pulses and microwave), which interfered with key car components, forcing it to slow down and stop. With the contribution of security forces as the ultimate end users, the researchers were able to simulate the technology's use in realistic scenarios.

> ...non-cooperative vehicles posing a threat.

Developing the technology itself first required a review and cost analysis of what was currently available on the market, as well as establishing the car components best targeted for remote interference. In lab bench testing SAVELEC evaluated signal frequency, waveform and duration—principally of electromagnetic pulses (EMP) and high power microwaves (HPM)—to determine which could best disrupt the functioning of a vehicle's electronic components.

Assessing the project's success, its coordinator, Dr. Martínez Vázquez asserted that, "An EMP/HPM car-stopping device prototype at a breadboard level was designed, fabricated and tested. Its performance was successfully demonstrated in an open field controlled track, in the presence of SAVELEC affiliated end-users."

ESSC Issues Recommendations for Horizon 2020 Work Programme on Space

The European Science Foundation's (ESF) European Space Sciences Committee (ESSC) has issued recommendations and inputs to the consultation process set up by the European Commission on the 2018-2020 Work Programme for Horizon 2020-SPACE. The committee was also asked by the European Commission to make targeted inputs to the ongoing public consultation on a Space Strategy for Europe.

Areas covered by the ESSC recommendations include the exploitation of space data, the use of 'CubeSat' miniaturised satellites and the integration of ground-based and space-based research. The committee also made recommendations on health research in space, gravitational waves research, solar system exploration, heliophysics and space weather. Space surveillance and tracking and the Copernicus and Sentinel programmes are also covered by the submissions which can be seen at www.esf.org/space.

On the European Space Strategy, the ESSC highlighted the relevance of space sciences for European citizens in the areas of security, environment, health and engineering. The

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...the use of 'CubeSat' miniaturised satellites...

committee also underlined the strategic role that space sciences can play in European technology development, innovation and industrial leadership.

Professor Athena Coustenis, ESSC Chair, said, "We're pleased to make our recommendations to the European Commission as it shapes the next phase of Horizon 2020 SPACE. Additionally we have provided the inputs of European space scientists around the priorities and opportunities that we believe are important for the European Space Strategy to address."

Vodafone and Huawei Trial 4.5G Technologies

Vodafone UK and Huawei are conducting technical trials of a new mobile technology, 4.5G (TDD+) with LTE TDD, to significantly increase the capacity and efficiency of its 4G network in urban areas, as well as lay the foundations for the introduction of 5G by 2020.

New 4 × 4 MIMO techniques eight-way transmit and receive (8T8R), together with multi-user beamforming are being tested in Manchester, UK. By combining MIMO with beam forming, Vodafone is better able to focus customers' mobile signals in specific directions to ensure the best user experience and minimize interference during peak times in highly populated areas. As a result, more signal reaches more subscribers particularly at the edge of the base station coverage, in order to provide higher average speeds across the network.

"...release the potential of TDD spectrum..."

Vodafone UK's chief technology officer, Jorge Fernandes, said, "We are working hard with our radio network equipment partners to ensure our network is future-proofed for the expected arrival of 5G in four to five years' time, whilst continually improving our 4G performance for customers throughout the UK."

Huawei LTE TDD President, Veni Shone, said, "This joint innovation with Vodafone has proved that 4.5G (TDD+) is a good solution to release the potential of TDD spectrum and will help Vodafone build the most advanced LTE network available. We are very proud of this collaboration, and are dedicated to providing optimal solutions to customers. The newly deployed LTE TDD network immediately serves the LTE TDD capable commercial smartphones and successfully carries significant live network traffic. This trial proves that LTE TDD with the most recent technologies can be naturally converged with LTE FDD and improve the overall experience enjoyed by all users on the network."

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Mobile and Computing Markets Catapult WiGig into the Mainstream

VIEW VIDEO

The 802.11ad (WiGig) chipset market is set to reach a critical juncture in 2017 when the technology hits higher adoption levels in the mobile and computing space. ABI Research forecasts 180 million WiGig chipsets will ship to the smartphone market in 2017, with smartphone chipsets accounting for almost half of the 1.5 billion total market shipments in 2021.

"Tri-band products that incorporate 2.4 GHz, 5 GHz and 60 GHz technologies will take Wi-Fi to the next level, providing a better balance between reliability and performance than ever before," says Andrew Zignani, industry analyst at ABI Research. "But Wi-Fi will still have one major market hurdle: it will not have an existing device ecosystem to build upon once it moves to the 60 GHz band."

As there are currently few products on the market that utilize 802.11ad, many OEMs have yet to find a compelling enough use case to justify the additional costs and complexities in adopting the standard. But the industry is making waves, with recent collaborations from Intel and Qualcomm fueling growth and a number of others, including Broadcom, MediaTek, Nitero, Peraso and SiBeam, already providing or planning to provide WiGig chipsets to the market.

> WiGig chipsets significantly enhance Wi-Fi throughput, improve efficiency and expand product use case potential.

The first WiGig-enabled smartphones are likely to arrive later this year, albeit in limited quantities, with 802.11ad support provided alongside Qualcomm's Snapdragon 820 platform. This marks the start of a larger push from Qualcomm and other IC suppliers to drive the technology forward. The new technology will allow OEMs to further differentiate their flagship products from the middle and lower tier devices, as well as maximize streaming performance from access points and push content between devices.

The technology will also find significant opportunities in the PC space as the push to wireless charging and cable free devices gains momentum. 802.11ad is additionally gaining traction in routers, with vendors such as TP-link relying on it to drive improvements in internet access and streaming capabilities.

"WiGig has a bright future across the mobile, PC, networking and accessory space, and beyond, with 2017 marking a critical juncture in its development and success," concludes Zignani. "We expect to see many IC suppliers in this space taking steps to promote and scale the technology this year to prepare."

Bluetooth 5 Will Lead to Widespread Deployments on IoT Landscape

VIEW VIDEO

With the new technical enhancements enabled by Bluetooth 5, in addition to the support of mesh networking, and Internet protocol, ABI Research forecasts Bluetooth-enabled device shipments will increase by an average of half a billion per year through 2021, reaching more than five billion. Bluetooth will extend beyond cable replacements and smartphones to branch out into the wider IoT landscape and result in the development of larger scale networks that no longer rely on the smartphone as a hub.

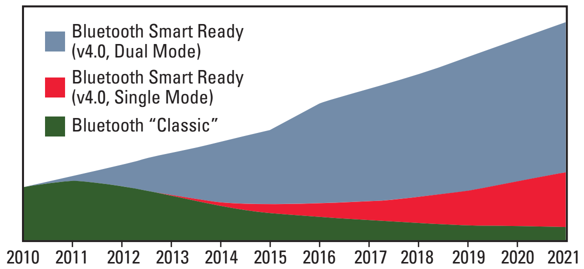
"Bluetooth is evolving from a smartphone and personal area network solution to a scalable, low-power wireless networking technology," says Andrew Zignani, industry analyst at ABI Research. "This development will unlock growth in beacons, home automation, building automation, lighting, and other smart city applications over the next decade and beyond."

Bluetooth Smart or Smart Ready devices, combined with market growth in the connected home for speakers, remote controls, smart televisions, and game consoles, has, and will continue to, help drive the market to much greater scale in the coming years.

By 2021, smartphones will still account for 40 percent of Bluetooth product shipments, but this will represent a 12 percent drop in volume share from 2015. This significant portion of the market will continue to drive the mobile accessory market, the second largest portion of devices at this time. And as mobile and computing devices rely less on physical ports, notably headphone jacks, Bluetooth accessories will further climb in volume share, expected to capture 13% of total Bluetooth product shipments by 2021.

But it is beacons that represent one of the largest opportunities for Bluetooth-enabled devices. By 2021, it will be the third largest market for Bluetooth devices, and the fastest growing of all segments. The smart home market will also see significant growth, though it will still take some time to mature. Its major advancement will stem from home automation devices, smart lighting and smart appliances.

Bluetooth-Enabled Device Market Split by Version
World Markets, Forecast: 2000 to 2021



Source: ABI Research

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"As we move forward, Bluetooth will gain market share at the expense of low data rate technologies, like Thread, ZigBee and Z-Wave, and power hungry technologies like Wi-Fi," concludes Zignani.

Sensors and Connected Peripherals Outpace Smartphones and PCs

ABI Research forecasts the installed base of active wireless connected devices will top 47 billion by 2021, more than double the current level. Smartphones, PCs and other "hub" devices historically commanded the leading share of total active connections, with accessories (including smartphone and PC peripherals, residential smart home lighting and wearable devices) and sensor nodes (like Bluetooth beacons, proximity sensors and other edge devices) rounding out the remainder. But moving forward, the latter will benefit most from continued improvements to underlying IoT infrastructure.

"A 24.1 percent CAGR through 2021 positions 2016 to be the first year that accessories and sensor nodes are in the majority, rising to more than 65 percent of total active connections by the end of the forecast period," says Ryan Martin, senior analyst at ABI Research. "Now the critical question for companies is how to create a strategic framework that optimizes IoT solution ROI in concert with connected endpoint growth. Growth will be driven by a massive uptick in contextually-aware IoT endpoints across retail, advertising and supply chain, smart home, and industrial IoT markets."

> Sensors and connected peripherals will top 65 percent of total active connections by 2021.

The recent convergence of low-power wide area, short-range wireless, and cellular networks represents a fertile battleground for the future of IoT enablement. While today about 55 percent of IoT connections can be attributed to the digital-first domain (the Internet of Digital), the emergence of low-power wide-area and short-range wireless network technologies purpose-built for the IoT puts the physical-first domain (IoT) on track to account for 65 percent of active wireless connections in the next five years.

The incipient IoT playing field includes everything from newly-minted specifications for Bluetooth 5 to the designation of Wi-Fi HaLow (802.11ah), LTE Cat M (followed by NB-IoT), and LPWAN technologies, such as those from Ingenu, LoRa, SIGFOX and Thread. Advances in mesh networking, location-aware ICs, and better utilization of unlicensed spectrum are among the key ingredients driving wireless sensor network deployments, and, in turn, the next generation of connected devices.

Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Dassault Systèmes, the 3DEXPERIENCE Co., world leader in 3D design software, 3D digital mock up and product lifecycle management (PLM) solutions, announced that it has entered into a definitive agreement to acquire **CST – Computer Simulation Technology AG**, the technology leader in electromagnetic (EM) and electronics simulation, for approximately €220 million. With the acquisition of CST, based near Frankfurt, Germany, Dassault Systèmes will complement its industry solution experiences for realistic multiphysics simulation on the 3DEXPERIENCE platform with full spectrum EM simulation.

Analog Devices Inc. and **Linear Technology Corp.** announced that they have entered into a definitive agreement under which Analog Devices will acquire Linear Technology in a cash and stock transaction that values the combined enterprise at approximately $30 billion. Upon completion of the acquisition, Analog Devices will be the premier global analog technology company with approximately $5 billion in anticipated annual revenues. Under the terms of the agreement, Linear Technology shareholders will receive $46.00 per share in cash and 0.2321 of a share of Analog Devices common stock for each share of Linear Technology common stock they hold at the closing of the transaction.

Infinite RF Holdings Inc., an urgent needs supplier of engineering-grade RF, microwave and millimeter wave components and cable assemblies through their Pasternack and Fairview Microwave branded lines, announced the acquisition of **L-com Inc.**, a manufacturer of wired and wireless connectivity solutions with significant custom manufacturing capabilities. Headquartered in North Andover, Mass. with global manufacturing, sales and distribution operations, L-com serves the wireless engineering community with short lead time design and product solutions. Its comprehensive offering includes wireless components, cable assemblies, antennas, specialized military/aeronautics connectivity solutions, electrical connectors and wireless sensors for IoT applications through the branded product lines L-com, HyperLink®, MilesTek®, Aiconics and Point Six Wireless.

Infineon Technologies AG and **Cree Inc.** announced that Infineon has entered into a definitive agreement to acquire the **Wolfspeed Power and RF division of Cree.** The deal also includes the related SiC wafer substrate business for power and RF power. The purchase price for this planned all-cash transaction is $850 million (approximately €740 million). This acquisition will enable Infineon to provide the broadest offering in compound semiconductors and will further strengthen Infineon as a leading supplier of power and RF power solutions in high-growth markets such as electro-mobility, renewables and next-generation cellular infrastructure relevant for IoT.

Gowanda Electronics, a business unit of **Gowanda Components Group (GCG)**, announced that its capabilities for the design and manufacture of inductors and other passive components are expanding in connection with its parent company's acquisition of **Butler Winding** in Butler, Pa. Terms of the deal were not disclosed but it is anticipated that the company will relocate from Butler, Pa. to GCG's facilities in Arcade, N.Y. in the near future. This is the fourth acquisition for GCG within the last five years.

Ams AG has signed an agreement to divest NFC and RFID reader IP, technologies and product lines to **STMicroelectronics** for an up-front cash consideration of $79.3 million (approx. €71.5 million) plus a substantial deferred earn-out consideration contingent on future results of up to $37 million. With this transaction, ST takes another step towards becoming a leading provider of sensor solutions worldwide. They will retain their sensor-related NFC/RFID tags business and relevant design capabilities to create wireless IoT sensor solutions and support upcoming sensor nodes. The transaction is part of ongoing efforts to actively manage their portfolio of technologies with a clear focus on implementing sensor solutions strategy.

COLLABORATIONS

HawkEye 360, a subsidiary of **Allied Minds** and **Lockheed Martin**, are collaborating to introduce the HawkEye 360's RF detection and mapping technology into new markets. HawkEye 360 plans to deploy a constellation of small satellites in the low-Earth orbit at less than 600 km (383 miles) from the Earth's surface, to identify, locate and analyze RF signals globally. Lockheed Martin has chosen Allied Minds to build one of the world's first privately funded global RF signal monitoring systems. Combining Lockheed Martin's expertise in satellite systems with HawkEye 360's approach to space-based radio frequency detection will enable them to develop an innovative solution to some of the big challenges being faced by their shared customer base.

Telit has announced a multi-faceted collaboration with **Tech Mahindra** on developing complete solutions for the Internet of Things (IoT). The relationship is centered on combining and integrating their leading portfolio of IoT products and services with Tech Mahindra's unmatched system integration expertise and strengths in developing end-to-end enterprise solutions. Both companies will also jointly pursue new business opportunities across many markets and industries, such as IoT horizontal and Industrial IoT around the world. Additionally, Telit has reached an

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agreement to outsource related engineering development and testing activities to Tech Mahindra.

NEW STARTS

Renesas Electronics has announced that they will withdraw from the microwave devices business to strengthen and focus more on optical devices (photo-couplers, laser diodes, photo diodes). Renesas has been selling low noise amplifiers, RF switches, mixers and transistors for the wireless segment based on GaAs and SiGe for some time now. The business was profitable, however with an increase in the number of manufacturers, specially in Taiwan developing these products, they expect the profitability to decline. At this point they have no development plans for the future of microwave devices.

ACHIEVEMENTS

LPKF, the laser specialist headquartered in Garbsen, Germany, unveiled a new high-end laser system for drilling and cutting flexible circuit boards. The first system has been sold to Sagami PCI, a client from Japan. The MicroLine 5000 uses a UV laser and tops off the LPKF MicroLine series. It is extremely rapid and precise. This makes it possible to process large numbers of flexible circuit boards and simultaneously reduce the per-unit costs.

Marvin Test Solutions Inc., a provider of globally-deployed innovative test solutions for military, aerospace, and manufacturing organizations, is marking the silver anniversary of ATEasy, its evolutionary test software suite, first released in 1991 and now in its ninth generation. Since its founding almost 30 years ago, Marvin Test Solutions' singular focus has been automated functional test, with the goal to make test easy for its customers by creating innovative solutions with unrivaled long-term support. ATEasy provides test engineers with all of the necessary tools to efficiently develop, debug, document, maintain and execute test applications.

CTT Inc. a technology leader in the design and production of solid-state microwave amplifiers for use in electronic defense, industrial and commercial communications, announced the receipt of the 4-Star Supplier Excellence Award from Raytheon's Integrated Defense Systems (IDS). The 4-Star Supplier Excellence award was presented to CTT at Raytheon's Operational Excellence Supplier Conference on June 7, 2016, in Danvers, Mass. The award recognizes suppliers that consistently deliver outstanding service and partnership in exceeding customer requirements. This year there were more than 3,000 candidates, and only 159 suppliers received an Operational Excellence Supplier Award, placing CTT in the top 5 percent of eligible nominees.

Integra Technologies Inc., a designer and manufacturer of high-power RF transistors, pallets and amplifiers, announced the completion of a 1 kW GaN high efficiency amplifier, IGNP0450M1000, for aerospace radar applications, funded by NASA/JPL through SBIR Phase I and II grant awards. An additional 200 W high efficiency GaN amplifier for shorter-term programs has also been completed through an SBIR Phase IIX grant award.

CONTRACTS

BAE Systems has received a $245 million contract from the **UK Ministry of Defence (MOD)** to provide the gun system, known as the Maritime Indirect Fires System (MIFS), for the Type 26 Global Combat Ship. This award follows the MOD's announcement of BAE Systems as the preferred bidder last year after a competitive process. Under the contract, the company will manufacture three MIFS Integrated Gunnery Systems (IGS) and one trainer system for the UK Royal Navy. The MIFS IGS includes the 5-inch, 62-caliber Mk 45 Mod 4 Naval Gun System, along with an automated ammunition handling system, gun fire control system and qualified ammunition.

L-3 Communications announced that its Electronic Systems group was awarded a seven-year contract to provide training solutions in support of the **U.S. Air Force's Warfighter Readiness & Training Program** following a recompetition process. L-3 initially won the Warfighter Program in 1997 and will continue its prime contractor role under an initial task order valued at $23.5 million with a maximum ceiling value of $200 million. The Warfighter Program provides the Air Force with a wide range of research into advanced technologies to improve training effectiveness. L-3's Link Simulation & Training division in Arlington, Texas, will serve as the prime contractor on the program.

Orbital ATK, a global leader in aerospace and defense technologies, announced that the company has received a $69 million contract that exercises a second option from the **U.S. Government** to produce artillery precision guidance kits (PGK) for the U.S. military. PGK-fuzed projectiles allow battlefield commanders to more safely employ artillery with greater accuracy and less risk of collateral damage. Orbital ATK produced 4,779 PGK fuzes under the low-rate initial production contract and has transitioned to full-rate production to support the current program needs.

Inmarsat Government has been issued modification P00001 to lift the stop-work order issued due to a bid protest filed on the initial award. Inmarsat Government remains the awardee on the single award indefinite-delivery/indefinite-quantity contract issued against solicitation HC1013-14-R-0004 announced Sept. 8, 2015. This contract supports the **U.S. Navy's Commercial Broadband Satellite Program** (CBSP) **Satellite Services Contract** (CSSC). Under the contract, Inmarsat Government will support the U.S. Navy's requirement to acquire worldwide commercial telecommunication services, to include satellite capacity for mobile and fixed satellite transceivers on maritime, airborne and ground platforms, as well as CT services, backhaul connectivity, monitoring and control and operations.

Norsat International, a provider of unique and customized communication solutions for remote and challenging applications, has announced that it has received an order for $3.8 million from **Harris Corp.** for its compact and efficient ATOM series solid-state power amplifiers (SSPA). Norsat has been working closely with Harris since 2013, in order

Around the **Circuit**

to develop and deliver custom SSPAs to meet the challenging RF performance requirements for linearity, gain flatness and phase matching that is required by the Harris system. This contract is for the second phase of the project that Norsat first announced in October 2013 and April 2014 after the successful implementation of the SSPAs.

Phoenix Nuclear Labs (PNL) announced that it has been awarded multiple contracts by the **U.S. Army** totaling $3.6 million. Under these contracts, PNL will build an advanced neutron radiography system to detect defective munitions and demonstrate the ability to use their neutron generators to detect and identify concealed explosive threats. The company will deliver an upgraded, pilot production neutron radiography system that will be the first such system to be installed in a munitions production facility. The new system is expected to produce 10 times higher neutron yield, enabling faster performance and higher resolution.

PEOPLE

▲ *Christopher C. Cambria*

Mercury Systems Inc. announced that **Christopher C. Cambria** has joined the company as its senior vice president, general counsel, and secretary, reporting to Mercury's president and chief executive officer, Mark Aslett. Mr. Cambria will lead the overall direction and management of legal and regulatory matters at Mercury, including support for mergers and acquisitions and corporate finance transactions. Cambria brings more than 30 years' experience providing strategic oversight of legal and regulatory matters, managing major acquisition transactions and serving as a key advisor in rapidly growing business environments.

Skyworks Solutions Inc., an innovator of high performance analog semiconductors connecting people, places and things, announced that **Mitchell J. Haws** has joined Skyworks as vice president of investor relations. Haws will serve as the primary interface to Skyworks' existing buy-side and sell-side analysts and is chartered to expand the company's shareholder base. Most recently, Haws served as vice president of investor relations for NXP Semiconductors, which merged with Freescale Semiconductor in December 2015. Prior to NXP, he managed investor relations for Equifax Inc., Reynolds & Reynolds and Geneva Steel. Haws earned a bachelor's degree in communications from Brigham Young University and an MBA from Westminster College.

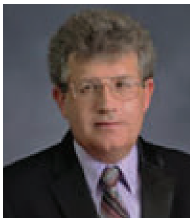
▲ *Eleanor Lukens*

AMETEK Inc. announced that the Board of Directors has elected **Eleanor Lukens** as vice president and general manager of the measurement and power systems division within AMETEK Aerospace & Defense. Lukens has nearly 30 years of experience with AMETEK businesses. She joined AMETEK in 1999 with the acquisition of Drexelbrook Engineering, where she held increasingly responsible positions, including director of engineering and director of op-

erations, since 1986. She was named vice president of the AMETEK test business unit in 2008 and promoted in 2012 to her most recent position as vice president and business unit manager of Hughes-Treitler within AMETEK Aerospace & Defense.


▲ *Takaki Murata*

Peregrine Semiconductor Corp., founder of RF SOI (silicon on insulator) and pioneer of advanced RF solutions, announced the promotion of **Takaki Murata** to vice president and general manager of the high performance analog (HPA) business unit. A long-time veteran of Murata, Takaki has a Ph.D. in electrical engineering and 12 years of experience at Murata, in a range of different assignments including: LTCC material development, SAW filter development, antenna sales engineering, RF front-end sales engineering, corporate accounting and inductor business strategic planning.


▲ *Dr. Alexander Chenakin*

Micro Lambda Wireless Inc. announced it has appointed **Dr. Alexander Chenakin** as vice president, Advanced Technologies. Dr. Chenakin is well recognized in the field of frequency synthesis and is referred to as the inventor of QuickSyn technology. In 2009, he received the ARMMS RF & Microwave Society's best contribution award for his work on fast-switching frequency synthesizers. His professional achievements have been widely presented in trade publications and international conferences. He is a senior member of the IEEE and holds a number of patents in frequency synthesis. Dr. Chenakin has held previous positions at Phase Matrix, National Instruments and Anritsu.


▲ *Carl Frank*

Anokiwave Inc., an innovative company providing highly integrated core IC solutions for mmW markets and AESA based solutions, announced the latest addition to its leadership team with the appointment of **Carl Frank** to the position of chief operating officer, a new position within Anokiwave, effective immediately. Frank will report directly to chief executive officer, Robert Donahue. As the Anokiwave COO, Frank will be responsible for the execution of Anokiwave's worldwide growth strategy, as well as assume responsibility for the worldwide marketing, sales, and operations organizations.

REP APPOINTMENTS

Custom MMIC, a developer of performance driven monolithic microwave integrated circuits (MMIC), has announced the appointment of **Repwave** as their new technical representative in Canada. Repwave was founded in 2003 and has an established team of high-tech profession-

Around the **Circuit**

als offering state-of-the-art components and related technologies of the RF/microwave and wireless markets.

Maury Microwave Corp., a global leader in calibration, interconnect, measurement and modeling device characterization solutions, announced it has signed an agreement with **Hi-Tech RF & Microwave Solutions** of Maarssen, the Netherlands, to act as Maury Microwave's Master European Reseller. Hi-Tech will support European sales and service for the company. Hi-Tech will work for Maury as a dedicated sales management arm and technical support system for Europe, working with the current Maury sales channel. Hi-Tech will be responsible for recruiting, managing, quoting, and supporting the Maury channel for pre- and post-sales.

PCTEL has entered into a product representation agreement with Antioch, Ill.-based **EPI Technologies**. EPI will be the exclusive representative for their SeeHawk Engage portfolio in the upper Midwest. The portfolio consists of User Equipment (UE)-based mobile network performance test and engineering tools.

RFMW Ltd. and **Akoustis Technologies Inc.** of Huntersville, N. C., have announced a distribution agreement effective immediately. Akoustis Technologies Inc. is a manufacturer of innovative BulkONE™ bulk acoustic wave (BAW) high band RF filters for mobile wireless and general purpose RF catalog components. RFMW Ltd. is a specialized distributor providing customers and suppliers with focused distribution of RF and microwave components as well as specialized component-engineering support. Under the agreement, RFMW is franchised worldwide for Akoustis' complete product offering.

Dynawave, a designer and manufacturer of RF & microwave connectors, adapters, bulk cable and cable assemblies, announced the appointment of **Ultra-RF Technical Sales**, as their new manufacturer's representative in the Southern California region. Ultra-RF will support the full range of Dynawave products and cover from San Louis Obispo County to San Diego County and to the east covering San Bernardino, Riverside and Imperial Counties.

PLACES

Imec, a leading nanoelectronics research center, announced the opening of Imec Florida, a new entity focusing on photonics and high-speed electronics IC design based in Osceola, Fla. Imec Florida kicked off with the signing of a collaboration agreement with the University of Central Florida (UCF), Osceola County and the International Consortium for Advanced Manufacturing Research (ICAMR), that is setting up fab facilities for the development and production of highly innovative III-V-on-silicon solutions for a broad range of applications including sensors, high-speed electronics and photonics. Imec Florida will be established as a design center facilitating the collaboration between Imec's headquarters, based in Leuven, Belgium, and U.S.-based semiconductor and system companies, universities and research institutes.

Welcome to European Microwave Week 2016

Andrew Gibson
General Chairman of EuMW 2016
Ivar Bazzy
President, Horizon House Publications

For complete coverage of the EuMW conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at www.mwjournal.com/eumw2016.

Welcome to ExCeL London for the 19th European Microwave Week (EuMW) from 3 to 7 October, when Europe's premier microwave event returns to the UK capital after an absence of 15 years. A generous venue rich in facilities, ExCeL London now has the means to provide the interaction, flow and intimacy that EuMW demands. During the week it will be home to three conferences: the 46th European Microwave Conference (EuMC), the 11th European Microwave Integrated Circuits Conference (EuMIC) and the 13th European Radar Conference (EuRAD), together with the European Microwave Exhibition and affiliated workshops and short courses.

London has been home to Newton, Faraday, Maxwell, Franklin, Babbage and Fleming who were all Fellows of the Royal Society. In a similar vein, EuMW 2016 welcomes the current and future generations of RF and microwave engineers/scientists, be they speakers, delegates, exhibitors or visitors. Such inclusivity is reflected in this year's motto—Microwaves Everywhere—which recognizes the way microwave technology is fully integrated into our lifestyles, continuously opening up new frontiers that will govern how individuals and objects communicate, sense and move.

Whether these frontiers are technological or geographical they will be crossed and addressed at EuMW 2016. There are four special and three focused sessions drawing attention to interesting technical topics and links with other microwave communities. There are sessions updating advances in THz imaging and multipactor effects as well as the new topic of surface waves, together with selected papers

from the Asia Pacific Conference, the European EMC Conference, the UK ARMMS RF & Microwave Measurement Society (www.armms.org) and a special group of papers highlighting activities from countries in South, Central and North America.

The invited speakers for the opening and closing sessions of EuMC, EuMIC and EuRAD are leaders in their respective fields who will consider cutting edge concepts. Details can be found in Attending EuMW 2016 on page 78 where the content of all three conferences is outlined. Complementary to the conferences are the workshops and short courses, which will cover key themes including: 5G communications; GaN, CMOS and SiGe technologies and their applications in the mmWave and THz bands; additive manufacturing; power amplifiers; developments in space based technologies; and automotive, multistatic and space based radar.

London can definitely be classified as a complex urban environment, so could be used as a practical example during the 2016 Defence, Security and Space Forum, which this year focuses on defence and security in Complex Urban Environments. The Forum will take place on Wednesday 5 October and more information can be found on page 94.

EuMW 2016 also aims to create the right environment for students and young engineers looking for a career in the RF and microwave sector to meet companies and network via the Career Platform. They will also be able to impress in a competitive environment through the Student Challenge poster competition where groups of students develop new ideas based on papers presented at the conference. Similarly, the Student Design Competition is a design and measurement contest where the students present the performance of their prototypes in a special event held during the week.

The well-established Women in Engineering event, co-sponsored by the IEEE MTT-Society, will feature a panel session focused on "Inspiring Women in Engineering," where those aiming for the stars will be inspired by a visit to the Greenwich Royal Observatory at the end of the session.

Those who want to observe the latest products and services from the leading RF and microwave companies across the globe can get close-up and personal at the European Microwave Exhibition that spans the middle of the week from 4 to 6 October. Accessed adjacent to the registration area on the Boulevard via entrance S11 Halls 20 to 23 will be filled to capacity with over 300 exhibiting com-

panies taking up around 7800 square metres of gross space.

The invaluable European Microwave Week Microwave Application Seminars (MicroApps) offer engineers the practical solutions that can make a difference. They will take place in the MicroApps Auditorium on the show floor for the entire three days of the exhibition and provide a platform for education and discussion. The Exhibition Halls will also be the home of the conference Poster Sessions and Copper Mountain sponsored coffee breaks, feature the Publisher's Corner and the ever popular CST sponsored Cyber Café.

There will be more than coffee available at the welcome reception on Tuesday evening, which provides networking opportunities and a convivial atmosphere that actively encourages delegates and industry to interact and socialize. On Wednesday evening socializing will move from ExCeL London to the River Thames for a cruise, including a cocktail reception on board a river boat as it tours London's famous landmarks after dark. Mixing business and pleasure can be enjoyed throughout the week through the strong calendar of social events.

To bring EuMW 2016 to London and to fruition, from paper submission and review to the on-site organization at the venue, has been a major undertaking. So, on behalf of the Local Organising Committee we would like to thank the Technical Programme Committees of the three conferences along with the reviewers who worked tirelessly to shape the conference programmes. We would like to acknowledge the EuMA Board for its continued advice and guidance and thank the Horizon House personnel assigned to EuMW for their indispensable expertise and support in organising this major event. Recognition should also go to the organisers of workshops, special sessions and student events and we also acknowledge the significant financial and in-kind sponsorship of many industrial companies and organisations.

Microwaves may be everywhere but in the first week of October the focus of the microwave community will be trained on ExCeL London and we look forward to seeing you there.■

Andrew Gibson

Ivar Bazzy

Attending European Microwave Week 2016

Richard Mumford, Microwave Journal *International Editor*

London may be steeped in history but it is also a vibrant, modern cosmopolitan city. Architecturally, the centuries

Photo Courtesy of ExCeL London.

old St Paul's Cathedral, Houses of Parliament and the Tower of London share the city's skyline with this century's London Eye and The Shard. Ancient artifacts take centre stage at the Victoria and Albert and the Natural History Museums, while the more contemporary works can be seen at the Design Museum and Tate Modern.

Similarly, the likes of Newton, Faraday and Maxwell pioneered technological evolution, while today's RF and microwave engineers and scientists have the opportunity to shape the development of the interactive, information age by meeting the challenges of 5G, the Internet of Things, satellite communications, defence/military systems and the development of autonomous cars, to name a few. Such cutting edge technology will be the topics of conversation, conference sessions and the product offerings of exhibiting companies.

Illustrating the intellectual and geographical reach of the week's programme around

European Microwave Week

EuMW 2016
Microwaves Everywhere

Photo Courtesy of ExCeL London.

Photo Courtesy of ExCeL London.

1000 papers were submitted for review to the three conferences from more than 50 countries. The technical programme includes 92 technical sessions, 450 oral papers and 136 posters, four special sessions and three focused sessions.

Firmly established as the premier RF and microwave event in Europe, EuMW 2016 is expected to attract in excess of 1500 unique conference delegates, around 4500 attendees, with the exhibition featuring more than 300 exhibiting companies, spread over about 7800 square metres (gross).

Not just numbers, the attendees are individuals that should be encouraged to network, interact and enjoy each other's company, and where better to start than at the ever popular EuMW Welcome Reception, sponsored by Keysight Technologies. On Tuesday 4 October the reception will be held in the Platinum Suite. The evening will begin with a cocktail reception at 18:30, when guests will be addressed by the 2016 EuMW Chairman, Andrew Gibson, who will hand over to the 2017 EuMW Chairman for Nuremberg, Arne Jacob, followed by Keysight Technologies, after which a three course seated buffet for 1000 people will be served.

From the conference programme, through poster sessions, to new products on display, the main aim is to ensure a productive and informative week for all. To help visitors achieve these aims the following quick reference guide is designed to complement the Conference Programme and Exhibition Show Guide, where you will find more detailed information.

There is virtual access for the first time too via the EuMW app, which is designed to be a digital companion leading up to, and during the week. For the exhibition it will enable users to navigate the show floor with the interactive map, filter and search for selected exhibitors and contact exhibitors directly to book a meeting. For the conferences, users can follow and build their own personal agenda, access abstracts, post questions and leave feedback.

THE CONFERENCES

Each with their own dedicated time slots throughout the week there are three focused conferences:

- **The European Microwave Integrated Circuits Conference** (EuMIC) – 3 to 4 October
- **The European Microwave Conference** (EuMC) – 4 to 6 October
- **The European Radar Conference** (EuRAD) – 5 to 7 October
- Plus **Workshops and Short Courses** – 3 to 7 October
- In addition, the **Defence, Security and Space Forum** will take place on Wednesday 5 October

Rohde & Schwarz sponsored online registration opened on 1 June 2016 and remains open up to and during the event until 7 October 2016. There will be onsite registration from Sunday 2 October from 16:00-19:00 and at 08:00 each morning from Monday 3 to Friday 7 October 2016.

Those who have pre-registered should bring their badge barcode and confirmation with them to the registration area where they can print out their badge by scanning their barcode at the Fast Track desk.

Those who have not pre-registered can do so on site. There will be onsite registration terminals located within the registration area, located on the Boulevard, where delegates can enter their details and either pay immediately by swiping their credit or debit cards through the card readers attached to the terminals. Alternatively, there is a cashier desk for those who require a printed receipt.

Once in possession of a badge, delegates can collect their delegate bags, sponsored by Infineon Technologies and Leonardo-Finmeccanica, from collection points in the registration area. The bags will include a USB stick containing the conference proceedings.

THE EUROPEAN MICROWAVE CONFERENCE

EuMC is Europe's leading forum for presenting microwave and related technologies. 630 papers were submitted, which enabled the TPC to produce a wide programme that includes 49 EuMC and 12 joint technical sessions, 15 workshops, five short courses and three special sessions alongside a special event, and the student challenge. One of the special sessions is devoted to the Asia Pacific Microwave Conference.

The technical sessions cover the latest microwave techniques including filters, power amplifiers, antennas, biological applications and many other areas. The opening session includes a presentation by Glyn Thomas, Payload Director of Airbus entitled, "Quantum Flexible Payloads for Telecoms Satellites." At the closing session, fascinating insights into the worlds of microwave instrumentation and measurements will be given by Mark Pierpoint of Keysight Technologies, and Nick Ridler of NPL. The conference prizes will also be presented.

EUROPEAN MICROWAVE INTEGRATED CIRCUITS CONFERENCE

Jointly organised by the GAAS® Association and EuMA, the aim of the conference is to promote the discussion of recent developments and trends, and to encourage the exchange of scientific and technical information covering a broad range of high frequency related topics, from materials and technologies to integrated circuits and applications, that will be addressed in all of their aspects: theory, simulation, design and measurement.

The EuMIC opening plenary session will feature two keynotes that balance a futuristic research-oriented agenda with the more practical perspectives of industrial designers. Dylan Williams of NIST, USA will speak on "THz Transistors and Calibration Challenge," while Liam Devlin from Plextek Ltd., UK will deliver a talk entitled, "MMICs – Custom or COTS."

The closing session will include the traditional foundry session gathering several key representatives of RF and microwave semiconductor foundries, as well as a keynote talk by a world renowned expert on power amplifiers, Steve C. Cripps of Cardiff Univer-

sity, UK, who will consider "Balanced Microwaves," stressing the need for access to a mature and reliable multilayer integrated process for microwave designers.

During the closing ceremony, the prize for the best contributed paper to EuMIC 2016 will be awarded and the EuMIC Young Engineer Award will be presented to a young engineer or researcher who authored an outstanding paper presented at the EuMIC Conference. Three GAAS® Ph.D. student fellowships will also be celebrated.

Photo Courtesy of ExCeL London.

THE EUROPEAN RADAR CONFERENCE

This conference is the major European event covering the present status and future trends in the field of radar technology, system design, and applications that covers a wide variety of topics, ranging from radar components and systems, radar echo modeling, advanced signal processing techniques, up to the most innovative radar architectures and concepts and the latest applications.

This year, 171 papers were submitted from which the 100 accepted papers were organised into 13 oral sessions and one poster session. EuRAD delegates can also attend five sessions shared with EuMC, related to millimetre-wave antenna arrays and millimetre and THz radar applications as well as antennas and propagation and electronic scanned array design.

During the opening session Dr. Paul Holbourn of Selex ES, will present, "Captor for Typhoon: Past, Present and Future," that focuses on the development of the Captor radar for Typhoon, which is the most significant European airborne radar. Three focused short courses will be presented by renowned experts on very innovative and interesting fields, dealing with electronic scanned array design and multibeam antennas and beamforming networks.

Expert workshops covering a range of topics and led by renowned experts in the field include: Automotive Radar chaired by Holger Meinel, Radar Imaging chaired by Professor Motoyuki Sato, Radar Performance in Clutter chaired by Professor Simon Watts, Bistatic and Multistatic Radar chaired by Professor Mike Cherniakov and Digital Beamforming Space Borne Synthetic Aperture Radar chaired by Professor Steven Gao.

During the closing session Professor Hugh Griffiths will talk on "Early History of Bistatic Radar," which will describe Appleton's 1924 experiments to measure the height of the ionosphere (also the first FM radar), Watson Watt's celebrated Daventry Experiment in 1935, and the German WWII Klein Heidelberg system, which used the British Chain Home radars as its illumination source and which was the first proper operational bistatic radar.

The Exhibition

The European Microwave Exhibition will be housed in halls 20 to 23, which is accessed from the registration area on the Boulevard via Entrance S11. Taking place from 4 – 6 October, and larger than in 2015, it will be the hub of activity generated by the multitude of companies eager to display and demonstrate their latest introductions.

See us at EuMW Stand 148

European Microwave Week

Photo Courtesy of ExCeL London.

The FREE to attend exhibition will feature companies large and small, established and emerging. Of course, European companies are to the fore and UK companies are making their presence felt on home soil. The U.S. and Asia are well represented with the Chinese Pavilion expanding in 2016, demonstrating the country's continued emergence as a force in the RF and microwave sector and its desire to reach overseas markets.

Significant this year is the participation, for the first time, of the Centre national de la recherche scientifique (CNRS), which is the largest fundamental research organization in France. Conducting research in a wide range of scientific and technological sectors the organisation will feature eight of its research institutes.

With its focused international audience EuMW has established itself as an event that leading manufacturers often choose to launch new products onto the European and global market. To find out which companies will be exhibiting at ExCeL London see the latest exhibitor list, starting on page 172.

By nature engineers are practical so the popular exhibitor workshops offered by leaders in their respective fields, including Keysight Technologies, Rohde & Schwarz and National Instruments offer attendees the opportunity to see live demonstrations and gain hands-on experience.

The educational/instructional theme will continue on the show floor with the sixth European Microwave Week Microwave Application Seminars (MicroApps). The National Instruments, Rohde & Schwarz and Horizon House sponsored, free-to-attend seminars will take place in the MicroApps Auditorium for the entire three days of the exhibition. Designed to provide engineers with insight into products and techniques that will aid them in their everyday work EuMW exhibitors will present technical presentations describing state-of-the-art applications, products, design techniques and processes of interest to the RF and microwave community. Continuing the educational theme, the show floor will also be home for both the Student Challenge and the Stu-

dent Design Competition, while the Career Platform will be on the Mezzanine floor of the Conference Centre.

The exhibition space will also be the home of the conference poster sessions, coffee breaks, sponsored by Copper Mountain, and the publisher's corner. Once again CST is sponsoring a cyber café located on the show floor for all delegates, exhibitors and visitors to use, as well as free Wi-Fi access to emails for delegates in all conference areas.

See us at EuMW Stand 24

Exhibition Opening Hours

Tuesday 4 October: 9:30 to 18:00 (followed by the Welcome Reception)

Wednesday 5 October: 9:30 to 17:30

Thursday 6 October: 9:30 to 16:30

GETTING TO THE ExCeL LONDON

London can easily be reached by plane and is served by six international airports and a very convenient railway system. Details of how to reach ExCeL London can be found at http://excel.london/visitor/getting-here.

By Plane

London has six international airports. London City Airport is recommended as it is less than a mile from ExCeL London. It takes just 5 minutes by taxi or 15 minutes by the Docklands Light Railway (DLR). The airport has 350 flights per day, from over 40 international destinations including Amsterdam, Dublin, Madrid, Nice, Frankfurt, Rome and Zurich.

London City Airport

Average journey time by public transport: 15 mins.

Depart London City Airport, taking the DLR west towards Canning Town. Change at Canning Town, heading east on the DLR towards Beckton. Arrive at Prince Regent for ExCeL London (East).

Gatwick Airport

Average journey time by public transport: 1 hour.

Depart Gatwick train station, heading towards London Victoria on the Gatwick Express or Southern Trains. From London Victoria take the London Underground and head east on the Circle (yellow) or District (green) line. Change at Westminster, heading east on the Jubilee line (grey). Change at Canning Town, heading east on the DLR towards Beckton to arrive at Prince Regent.

Heathrow Airport

Average journey time by public transport: 1 hour, 30 minutes.

When using the Heathrow Express, you can pre-book tickets at a discounted price. Take the Heathrow Express, heading to London Paddington. From Paddington take the London Underground and head east on the Bakerloo line (brown). Change at Baker Street, heading south on the Jubilee Line (grey). Change at Canning Town, heading east on the DLR towards Beckton to arrive at Prince Regent.

Stansted Airport

Average journey time by public transport: 1 hour, 10 minutes.

Depart Stansted, heading to London Liverpool Street on the Stansted Express then head west on the London Underground on the Central Line (red). Change at Bank for the DLR towards Beckton to arrive at Prince Regent.

Luton Airport

Average journey time by public transport: 1 hour, 40 minutes.

Depart Luton or Luton Parkway, heading south towards London Blackfriars on the Thameslink Service. From Blackfriars take the London Underground and head west on the Circle (yellow) or District (green) line. Change at Westminster, heading east on the Jubilee line (grey). Change at Canning Town, heading east on the DLR towards Beckton to arrive at Prince Regent.

Southend Airport

Average journey time by public transport: 1 hour, 34 minutes.

Depart Southend Airport, heading towards London Liverpool Street on the Abellio Greater Anglia service. From Liverpool Street take the London Underground and head west on the Central Line (red). Change at Bank for the DLR towards Beckton to arrive at Prince Regent.

Parking

If you are using satellite navigation to drive to the venue, we recommend using postcode, E16 1DR. For more information and to see a map of the route, please visit tfl.gov.uk/. All onsite parking is pay and display, with the exception of the Royal Victoria multi-storey car park where payment can be made at three pay points at the end of your visit. All machines accept cash and credit card.

Public Transport

Train

Rail services in the UK are run by a set of private train operating companies. London's main railway stations are: Charing Cross (27 minutes from ExCeL London), Euston (32 min.), King's Cross/St Pancras International (32 mins), Liverpool Street (26 min.), London Bridge (16 mins), Maryle-

bone (31 mins), Moorgate (26 min.), Paddington (32 min.), Victoria (40 mins) and Waterloo (17 min.).

Train tickets can be booked via: www.thetrainline.com or www.nationalrail.co.uk or www.eurostar.com/uk-en.

London Underground

The Jubilee Line and the DLR are the quickest routes to ExCeL London. Alight at Canning Town on the Jubilee Line and change onto a Beckton-bound DLR train, getting off at Prince Regent for ExCeL London (east entrance) Visit tfl.gov.uk for information on routes and timetables.

River & Cable Car

The river route is serviced by MBNA Thames Clippers with departures from major London piers every 20 minutes. When travelling to ExCeL London alight at North Greenwich Pier for the O2, where you can use the Emirates Air Line Cable Car for a quick journey to the venue campus. See full list of fares at www.thamesclippers.com.

HOTEL RESERVATIONS

Horizon House has teamed up with Connex Hotels and Events to offer the ability to book accommodations for this exhibition at the most competitive rates. Simply visit the booking page at www.connexhotelsandevents.com/eumw2016-london.html or email sally@connexhotelsandevents.com.

SHOPPING & SIGHTSEEING

London is the city that has everything. There are so many places to shop, tour, eat, drink, etc. Top attractions include The British Museum, The Coca-Cola London Eye, St Paul's Cathedral, The National Gallery, The Natural History Museum, The Science Museum, The Tate Modern, Tower of London, Victoria & Albert Museum and Westminster Abbey.

For information on other top attractions, visit www.visitlondon.com.

Finally, ExCeL London has put together a number of guides that will help you to plan your time away from European Microwave Week: ExCeL.london/exhibitor/after-hours.■

For complete coverage of the EuMW conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at

www.mwjournal.com/eumw2016

Photo Courtesy of Shmuel Auster

The 2016 EuMW Defence, Security and Space Forum

Richard Mumford
Microwave Journal ***International Editor***

A forum on Wednesday, 5 October focused on defence and security in complex urban environments.
Rooms 8 to 11, ExCeL London

In the 21st century the scope of the defence, security and space sector goes beyond conventional combat zones and border control. Today technology has to address cyber security, secure communications, tracking and sensing of targets in different environments and adapt to operation in varied terrain and densely populated areas.

To reflect the activity of industry, academia and government addressing these issues and driving technology forward, the emphasis of this year's Forum is on Complex Urban environments, encompassing the challenges and opportunities for indoor/enclosed and urban communications and sensing technologies. The Forum has the scope to cover topics including: Smart City initiatives; 3D tracking technologies in complex and indoor environments; sensing complex targets in dense target environments; congested spectrum and network issues, including brown out issues in mmWave sensing; integrated mmWave sensing and universal RFID technologies.

The Forum will feature executives from industry, academia, the military and space agencies. It will be held in combination with the opening of EuRAD and will conclude with a round-table discussion and cocktail reception.

THE FORUM FORMAT

Below is a brief outline of each session. A full listing of the presentations at the time of going to press can be found on pages 98 & 99.

For the fifth year, the EuMW Defence, Security and Space Forum will incorporate the EuRAD Opening Session, which begins the day's proceedings from 09:00 to 10:40. After a coffee break the theme of this year's Forum will be dealt with comprehensively during the Complex Urban Sensing and Communication Session (11:20 to 13:00) where speakers from industry and academia will present RF solutions and systems that address the challenges imposed by operation in complex urban environments. This session will be presented by the

key technical leaders in the various fields, providing a real world perspective into developing technologies and systems for urban sensing and communication.

Providing sustenance for the mind as well as the body, the Strategy Analytics Lunch & Learn Session (13:10 to 14:10) will add a further dimension by offering a market analysis perspective, illustrating the status, development and potential of the market.

The afternoon *Microwave Journal* Industry Panel Session (14:20 to 16:00) offers an industrial perspective on the key issues facing the defence, security and space sector. In accordance with the theme for 2016, the panel will address: Complex Urban Environments, encompassing the challenges and opportunities for indoor/enclosed and urban communications and sensing technologies.

Completing the technical sessions the EuMW Defence & Security Executive Forum (16:40 to 18:20) will provide a platform for high level speakers from leading defence and security companies to present their views and experiences on RF microwave technology trends and its use in urban environments. The presenters are complemented by speakers from government agencies and research organisations who will offer their perspective of military, security and industry needs, programmes, budgets and research into next generation systems.

The event will conclude with a cocktail reception (18:20 to 19:00) that will afford delegates the opportunity to network and discuss the issues raised throughout the Forum in an informal setting.

REGISTRATION AND UPDATES

Registration fees are £10 for those who have registered for a conference and £40 for those not registered for a conference. Register online at www.eumweek.com. As information is formalized, the Conference Special Events section of the EuMW website will give further details and will be updated on a regular basis.■

The 2016 Defence, Security and Space Forum

At European Microwave Week

Wednesday, 5 October

A focused Forum addressing the application of RF and microwave technology to Complex Urban Environments.

The emphasis will be on complex urban environments, encompassing the challenges and opportunities for indoor/enclosed and urban communications and sensing technologies. The Forum has the scope to cover topics including: Smart City initiatives; 3D tracking technologies in complex and indoor environments; sensing complex targets in dense target environments; congested spectrum and network issues.

Programme:

09:00 – 10:40 EuRAD Opening Session

11:20 – 13:00 Complex Urban Sensing and Communication

Speakers from industry and academia will present RF solutions and systems that address the challenges imposed by operation in complex urban environments. Confirmed speakers include:

- New Transceiver Technology Applied to Standoff Submillimetre-Wave Imaging Radar – *Ken Cooper, JPL*
- Indoor and Urban Environment Location of Moving People and Vehicles Using Signals of Opportunity – *Pierfrancesco Lombardo, University of Rome*
- Communication Satellite Impact on TV and Data Broadcasting Through Urban Environments – *Erdem Demircioğlu, Turksat International*
- Analyzing Doppler Spectrum Using WiFi for Trained-Once Device-Free Crowd Counting and Occupancy Estimation – *Alfonso Farina, Leonardo Company*

13:10 – 14:10 Strategy Analytics Lunch & Learn Session

This session will add a further dimension by offering a market analysis perspective, illustrating the status, development and potential of the market.

14:20 – 16:00 *Microwave Journal* Industry Panel Session

The session offers an industrial perspective on the key issues facing the defence, security and space sector. In accordance with the theme for 2016, the Panel will address: *Complex Urban environments, encompassing the challenges and opportunities for indoor/enclosed and urban communications and sensing technologies*. Confirmed speakers include:

- Spectral Detection and Visualisation with Distributed RF Receivers – *Raymond Shen, Keysight Technologies*
- Addressing Communications in Urban Environments with UltraCMOS and Intelligent Integration – *Andrew Christie, Peregrine Semiconductor*
- GaN Integration in Defense and Security Applications – *Dean White, Qorvo*
- How do Mobiles Develop the 6th Sense? – An Introduction to LTE-based Device-to-Device (D2D) Communication Principles – *Meik Kottkamp, Rohde & Schwarz*

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Photos Courtesy of Shmuel Auster

16:40 – 18:20 EuMW Defence & Security Executive Forum

High-level speakers from leading defence and security companies present their views and experiences on RF microwave technology trends and its use in urban environments. Confirmed presentations include:

- Challenges for Maritime Border Surveillance Radar
  –Tony Brown, EASAT
- Challenges in the 'Future Borders' Concept - Combining Technology, People and Processes
  – Roger Cumming, Fenley-Martel (ex UK Home Office)
- Challenges in Urban Sensing and Communications
  –Ian Beresford, QinetiQ

18:20 – 19:00 Cocktail Reception

Registration and Programme Updates

Registration fees are £10 for those who have registered for a conference and £40 for those not registered for a conference.

As information is formalized, the Conference Special Events section of the EuMW website will be updated on a regular basis.

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EuMA

Microwaves in Europe: Leaving Unanswered Questions

Richard Mumford
Microwave Journal ***International Editor***

As the UK waits in the departure lounge for the final flight of Brexit Airways, both the UK and the remaining 27 Member States of the European Union are fastening their seatbelts for a journey into the unknown. Just what is on the Horizon (2020) for Europe as a whole and the RF and microwave industry in particular? This report aims to set the scene, evaluate current activities and initiatives, and proffer possible scenarios.

On 23 June 2016 the Union of Europe took on a different landscape as the United Kingdom decided not to remain united with the other 27 Member States and voted to leave the EU. The big question is what happens next and what the impact will be regarding economy, trade, research and industry. Indeed, the only certainty is the unpredictability of the unknown. The UK's leap of faith is also a leap in the dark—no Member State has left the European Union before and the UK has to negotiate the terms and conditions for packing its bags, the responsibilities it will continue to undertake and the "maintenance" it is prepared to pay for doing so. Ultimately and inevitably, it will be the politicians and lawyers who decide who gets custody of the proverbial dog and CD collection and who pays for further education!

"The UK's leap of faith is also a leap in the dark..."

Even the staunchest "Brexiteers" recognise that the UK will need to continue to trade and cooperate with the rest of the EU, especially if it wants to have a voice on global issues. In so many areas, the UK has led and helped shape the world we live in. RF and microwave technology has been no exception, with the pioneering work of Newton, Faraday, Maxwell and others woven into the fabric of our technological history. That rich tapestry of innovation continues today with the UK hosting centres of excellence and technology hubs, allied to the endeavour of scientists and engineers working to develop state-of-the-art technology, a fair proportion of which is in collaboration with European colleagues, either under commercial agreements or as part of Horizon 2020.

The European Commission has committed its intent, finances and organisational structure to enable Europe to play a significant role and strive to take the lead in technology that will shape the global future such as 5G, the Internet of Things (IoT), materials technology and the automated car, all of which are key areas of development for our industry. The UK cannot afford to divorce itself from cooperative programmes and agreements that already exist or risk being secluded from future partnerships or initiatives. So, following the UK's decision, what is the likely scenario regarding technology development in Europe, in general, and the impact on the RF and microwave industry, in particular?

EU law continues to apply in the UK until the country leaves the union. To start the process, the UK government must invoke Article 50 (the exit clause) of the Lisbon Treaty. At the time of going to press, the latest indication from the UK government is that the withdrawal process will not be triggered until the end of 2016 at the earliest. After that, negotiating the terms of departure and untangling financial ties with Brussels is expected to take approximately two years.

One issue that was a key argument for those proposing that the UK leave the European Union was that it contributes more to the EU than it receives. However, one exception is in the field of science and innovation, where the seven year Horizon 2020 Programme that began in 2014 and which has just entered the 2016 to 2017 Work Programme (outlined later in this article) has a total budget of around €80 billion to fund, support and take to market the results of collaborative science and innovation, with specific emphasis on the involvement of small and medium-sized enterprises (SME) and industry. As the name suggests, the programme extends until 2020 when it will be succeeded by Framework Programme 9.

It is believed that the UK's existing Horizon 2020 commitments will be honoured and that valid funding/agreements between the EU and the UK will continue. However, there may be a question mark over future plans being considered in Horizon 2020, where they involve bids for multi-year funding from the UK. To address this issue, the UK government is being urged to continue participation in Horizon 2020, which it can do by becoming an "associate country" and paying a share of the programme's costs in proportion to gross domestic product. Non-EU Member States such as Norway and Turkey currently take part in Horizon 2020 as associate countries.

Significant for the RF and microwave industry, membership of organizations such as the European Space Agency (ESA) is unaffected, as it is not an EU institution, but an intergovernmental one that negotiates directly with Member States about projects and funding at annual ministerial conferences. Some EU countries are only "cooperating members," while some non-EU countries like Switzerland and Norway have full membership.

While the UK's exit from the EU has been the headline grabbing focus of attention since the decision was taken, life, collaboration, investment, research and technological development go on. So, what significant initiatives are being taken and what are the prospects for the future?

HORIZON 2020

As previously highlighted, Horizon 2020 is the EU's largest research and innovation funding programme. It has now entered its next phase with the Horizon 2020 Work Programme for 2016-2017, which provides a budget of almost €16 billion.

In line with the agenda of the European Commission President Jean-Claude Juncker, the two-year programme is designed to contribute to the jobs, growth and investment package to strengthen Europe's global competitiveness. Research and innovation investments will cover both the immediate requirement to stimulate the re-industrialisation of Europe as well as the objective of building a solid knowledge base that will be vital for being in a position to take a lead in next-generation innovation.

> "…take a lead in next generation innovation."

Through the European Research Council (ERC), researchers will be able to investigate the best ideas that could lead to innovative growth-enhancing breakthroughs. In 2016 alone, almost €1.7 billion—worth around 1000 grants—will be made available through ERC calls.

Importantly for industries such as RF and microwave, around €2 billion of the Work Programme 2016-17 funding will go to SMEs, including €740 million through a dedicated instrument which should benefit over 2000 highly innovative SMEs. On top of that, financial instruments, targeted in particular at SMEs, will increase the opportunities for funding to support research and innovation. These investments will be intensified with the support of the European Fund for Strategic Investments (EFSI).

The programme will support a range of cross-cutting initiatives, many

of which directly and indirectly impact the RF and microwave industry: technologies and standards for automatic driving (over €100 million), to improve safety and energy efficiency while reducing congestion and emissions; the IoT (€139 million), to address digitalisation of EU industries: and the modernisation of Europe's manufacturing industry (€1 billion); and Smart and Sustainable Cities (€232 million), to better integrate environmental, transport, energy and digital networks in urban environments.

LEADING INITIATIVES & OVERVIEWS

Horizon 2020 is designed to generate an environment that encourages research and innovation. In an industry so diverse as RF and microwave, it is impossible to cover every activity. There are areas where the industry is particularly proactive and specific key technologies where Europe is leading the way, together with smaller scale efforts of engineers and designers endeavouring to make a difference and push the boundaries.

The following offers a snapshot of pioneering activity in key projects, together with overviews from the three 2016 European Microwave Week (EuMW) Conference chairmen who are well placed to offer matchless insight into key areas of development and identify future trends.

"...meeting the needs of tomorrow's connected society..."

5G

This month's cover story is titled "The 5G mmWave Radio Revolution" (see page 22). Such a potent word as "revolution" is used all too frequently, but to see 5G reach the goals it is aiming for and to achieve its full potential will be worthy of any plaudits. In his cover story, Amitava Ghosh of Nokia Bell Labs illustrates the technical challenges that are being addressed and mentions some of the research and development work being carried out.

5G will be a critical factor in formulating a "digital society," and Europe has demonstrated its determination to lead global development of this vital technology. Showing its intent, in December 2013, the European Commission signed an agreement with the 5G Infrastructure Association to establish a Public Private Partnership on 5G (5G PPP), which is the EU flagship initiative to accelerate research in 5G technology.

The European Commission has identified 5G standards as one of the five priority areas under the Digitising European Industry initiative and has earmarked public funding of €700 million through Horizon 2020 to support this activity, which EU industry is set to match by up to five times, to more than €3 billion.

At the Mobile World Congress (MWC) 2015, the European Commission and Europe's tech industry presented the EU's vision of 5G technologies and infrastructure. Earlier this year at MWC 2016, the European Commissioner for the Digital Economy and Society, Günther H. Oettinger, announced that Europe has started work on a 5G Action Plan that aims to put Europe at the forefront of deployment of standardised 5G networks from 2020.

Industry has responded with the 5G Manifesto, which was signed by the CEOs of 17 European telcos, equipment vendors and satellite operators, illustrating that 5G will involve mobile, fixed and satellite network technologies. Five non-telecom companies will also participate in the next phase, including Airbus Defence & Space and Thales Alenia Space.

The manifesto commits to delivering a roadmap of trials and demonstrators by January 2017, to achieve interoperability of networks and use cases for the period 2018 to 2020, prior to full deployment. It also outlines that commercial 5G services will require a large amount of harmonised spectrum and calls on the EU to foster standardisation of 5G spectrum and to ensure that sufficient spectrum is licensed in time and at reasonable prices.

Although the 5G Manifesto was published after the UK voted to leave the EU, it is signed by all four of the UK's mobile operators (or their parent companies) and specifies 28 EU Member States. Funding is likely to be an issue for the UK once it leaves the EU. Spectrum allocation is be-

ing coordinated at a global level, so it appears inevitable for the departed UK to harmonise its regulations with those agreed to by the EU if it wants to be a major player.

Those drawing up the 5G Action Plan, which is expected to be presented in September 2016, will consider the recommendations in the 5G Manifesto as well as feedback from a public consultation that closed in July.

In the meantime, 5G development in Europe cannot afford to delay or lose momentum with crucial research and testing underway across Europe. For example, the 5G Innovation Centre (5GIC) at the University of Surrey, UK, aims to drive the delivery of mobile communications and wireless connectivity capable of meeting the needs of tomorrow's connected society and digital economy. Research is conducted in close collaboration with 5GIC's members, who represent all aspects of the wireless communications and future internet domains and include the major telecom service providers, infrastructure vendors, device and car manufacturers.

Similarly, in Finland, the 5G Test Network Finland (5GTNF) test environment, which is a joint venture between industry, academia and the Finnish government, is promoting research and technology development by interconnecting 5G test networks belonging to the 5th Gear Programme funded by Tekes. The 5GTN is a scalable test environment enabling future business model piloting and service development in real life use cases that provide a platform for testing and developing the 5G system's technology components.

RF and Microwaves

Sector Overview by Ian Hunter, EuMC 2016 Chair, with contributions from EuMC 2016 TPC Chairs: Steve Nightingale, Ian Robertson and Al Abunjaileh

We who work in the RF and microwave industries may sometimes forget how essential these technologies have become to society. Imagine turning the clock back to a world without wireless communications, radar, GPS or satellite communications.

The development and maturity of RF and microwave technologies has led to increased system capability becoming available to both the civilian and defence business sectors. In the defence sector, for example, a mobile ground platform may include a number of RF and microwave systems, including communications radios, high capacity data radios, ECM equipment to counter radio controlled threats, as well as other sensor systems that can detect what is in the air, in the vicinity on the ground and buried in the ground. This complexity has introduced a higher probability of interference between the different systems. This in turn has led to an increase in the requirement for interference mitigation technologies, such as fixed and electronically tuneable filters, signal cancellation techniques and use of time division multiplexing methods.

The mobile communications industry continues to drive filter and power amplifier technology, especially for base stations. Antenna sharing drives demand for filter-combiners, both single and multi-band. More flexible architectures and 5G are driving the need for tuneable and adaptive filters. Miniaturisation remains a main objective, with many variations of ceramic filters being developed. Highly linear power amplifiers, which will operate with maximum efficiency, even with signals with high peak-to-average ratio, remain of critical importance to the industry.

Higher demands on data for SatComm systems require higher flexibility in terms of coverage, frequency bands and connectivity. This derives the need for advanced antenna and payload systems. While a traditional transparent payload system would cover Europe using a single beam, for example, there is now a demand for regenerative payloads with multibeam antennas. These are now progressively used commercially to allow for frequency reuse (i.e., higher bandwidth) and ultimately could focus the capacity on desired markets, reducing the cost per bit. It is expected that the market will drive the satellite systems to be more complex with the development of flexible payloads and active antennas to increase the operational revenue of the satellite system.

In the area of RFICs and MMICs, it is very clear that the trend continues towards high power with GaN technology and high levels of integration and higher frequencies with silicon technology. For very high power applica-

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600 W L-Band GaN HEMT

- P_{3dB} = 610 W
- 1200 – 1400 MHz
- 70% Efficiency
- 18 dB Gain
- Evaluation board – 1200 – 1400 MHz

GTVA126001FC

Radar and commercial avionics LDMOS product line

Product	Operating frequency (MHz)	Matching	@P_{1dB}			@P_{3dB}			Pulse	V_{DD} (V)	Package type
			P_{OUT} (W)	Gain (dB)	Eff (%)	P_{OUT} (W)	Gain (dB)	Eff (%)			
PTVA030121EA	390 – 450	Unmatched	12	25.0	69	14	22.0	73	12 µs, 10% DC	50	H-36265-2
PTVA035002EV	390 – 450	Unmatched	400	19.5	65	500	17.5	67	12 µs, 10% DC	50	H-36275-4
PTVA102001EA	1030 / 1090	I/O	200	18.0	57	230	16.0	58	128 µs, 10% DC	50	H-36265-2
PTVA104501EH	960 – 1215	I/O	450	17.0	57	490	15.0	55	128 µs, 10% DC	50	H-36288-2
PTVA101K02EV	1030 / 1090	I	920	18.0	56	1090	16.0	57	128 µs, 10% DC	50	H-36275-4
PTVA120251EA	500 – 1400	Unmatched	30	16.0	56	40	14.0	59	300 µs, 10% DC	50	H-36265-2
PTVA120501EA	1200 – 1400	I	54	16.5	55	63	14.5	57	300 µs, 10% DC	50	H-36265-2
PTVA123501EC/FC	1200 – 1400	I/O	375	16.0	56	415	14.0	57	300 µs, 12% DC	50	H-36248-2/ H-37248-2
PTVA127002EV	1200 – 1400	I/O	700	16.0	55	800	14.0	58	300 µs, 10% DC	50	H-36275-4

Radar and commercial avionics GaN product line

Product	Operating frequency (MHz)	Matching	@P_{3dB}			Pulse	V_{DD} (V)	Package type
			P_{OUT} (W)	Gain (dB)	Eff (%)			
GTVA104001FA	960 – 1215	I	410	18.5	70	128 µs, 10% DC	50	H-37265J-2
GTVA107001FC	960 – 1215	I	750	17	70	128 µs, 10% DC	50	H-37248-2
GTVA126001FC	1200 – 1400	I	610	18	70	300 µs, 10% DC	50	H-37248-2
GTVA123501FA	1200 – 1400	I	370	18	72	300 µs, 10% DC	50	H-37265J-2

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- P_{3dB} = 750 W
- 960 – 1215 MHz
- 70% Efficiency
- 17 dB Gain

H-37248-2

350 W L-Band GaN HEMT

- GTVA123501FA
- P_{3dB} = 370 W
- 1200 – 1400 MHz
- 72% Efficiency
- 18 dB Gain

H-37265J-2

180 W S-Band GaN HEMT

- GTVA311801FA
- P_{3dB} = 180 W
- 2700 – 3100 MHz
- 50% Efficiency
- 12 dB Gain

H-37265J-2

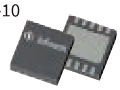
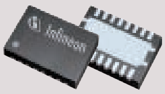
New GaN solutions for cellular applications

Product	Operating frequency (MHz)	P_{1dB} typ (W)	Gain typ (dB)	Eff typ (%)	Test signal	Supply voltage typ (V)	Package type
GTVA261701FA	2620 – 2690	170	18	47	WCDMA	48	H-37265J-2
GTVA262601FA	2620 – 2690	260	18	40	WCDMA	48	H-37265J-2
GTVA263202FC	2620 – 2690	160 + 160	18	40	WCDMA	48	H-37248-4
GTVA220701FA	1800 – 2200	70	20	70	WCDMA	48	H-37265J-2

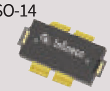
ISM (2.4 GHz) product line

Product	Operating frequency (MHz)	Matching	@P_{1dB}			@P_{3dB}			Test signal	V_{DD} (V)
			P_{OUT} (W)	Gain (dB)	Eff (%)	P_{OUT} (W)	Gain (dB)	Eff (%)		
PXFD252207NF	2400 – 2500	I/O	210	16.7	57	250	14.7	57.5	CW	28

General purpose transistors (700 MHz – 2200 MHz)

Product	Operating frequency (MHz)	Matching	P_{1dB} typ (W)	Gain typ (dB)	Eff typ (%)	Test signal	Supply voltage typ (V)	$R_{\theta J=C}$ (°C/W)	Package type
PTFC270051M	900 – 2700	Unmatched	7.3	20.3	60	CW @ 2170	28	3.84	SON-10 
PTFC270101M	900 – 2700	Unmatched	12	20.0	60	CW @ 2140	28	4.04	
PTVA120121M	500 – 1400	Unmatched	12	21.0	65	CW @ 821	50	4.97	
PTVA120252MT	500 – 1400	Unmatched	25	19.8	64	CW @ 960	48	2.6	SON-16 

LDMOS integrated RF power amplifiers (700 MHz – 2200 MHz)

Product	Operating frequency (MHz)	P_{1dB} Typ (W)	Gain typ (dB)	Eff typ (%)	P_{OUT} avg (W)	Test signal	Supply voltage typ (V)	$R_{\theta JC}$ (°C/W)	Package type
PTMC210204MD	1800 – 2200	10+10	30.5	19	2.5	WCDMA	28	9.7/3.1	HB1DSO-14 

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tions, power-combined GaN modules are becoming an attractive potential replacement for vacuum devices, whilst at the high frequency end devices are pushing into E-Band. In silicon, a number of centres of excellence are now demonstrating outstanding single-chip radar sensors well beyond 100 GHz and with integrated antenna arrays. Also, the EU DOTSEVEN project is addressing how to progress towards 0.7 THz SiGe HBT technology.

Recent developments in transceiver design at millimetre wave frequencies and above are being focused on, particularly with regards to packaging and interconnects. Significantly too, as device developments to address the "THz gap" such as the THz Quantum Cascade Laser are reported associated measurement challenges remain.

MATERIALS TECHNOLOGY

When Professors Andre Geim and Konstantin Novoselov of the University of Manchester, UK, discovered graphene in 2004, they unleashed a material with almost limitless potential across a multitude of applications, including semiconductor, electronics and composites, many of which impact RF and microwave industries.

> "...bring a new dimension to future technology..."

With its roots in Europe, it was considered paramount for the continent to remain at the forefront of its development, so as part of its Future and Emerging Technologies (FET) scheme, the European Commission launched the Graphene Flagship in October 2013. The ramp-up phase began with 76 academic and industrial partners in 17 countries and finished at the end of March 2016 with 152 partners in 23 countries, one third being industrial partners.

The next stage, which aims to move the project forward in its mission to transfer graphene and related materials from the laboratory into society, has begun with the Core One phase under the Horizon 2020 phase of the Flagship. With €45 million per year of EU funding, the Core One phase runs from 1 April 2016 to 31 March 2018.

The Flagship's overriding goal is to take graphene, related layered materials and hybrid systems from a state of raw potential to a point where they can revolutionize multiple industries. This may bring a new dimension to future technology and put Europe at the heart of the process.

ICs & Semiconductors

Sector Overview by Thomas Brazil, EuMIC 2016 Chair

The 11th European Microwave Integrated Circuits (EuMIC) conference provides the opportunity to assess and reflect on developments in the essential material, device and circuit technologies that underpin the full spectrum of high frequency electronics.

The application drivers are clear, primarily arising from the continuing global explosion in data exchanged using radio-based technologies, with the next phase (5G) of mobile communications now coming firmly into view. This evolution will address not only a need for exceptionally high local rates of data transfer but also the requirements for highly distributed, generally low data rate nodes often associated with the deployment of the IoT. The trend towards mass market exploitation of millimetre wave bands to achieve these goals is especially apparent.

Of course, many other markets are also critically dependent on high frequency electronic components and circuits, ranging from the automotive sector, which is of high strategic importance to Europe, through space/defence and photonics to personal/wearable devices.

In terms of technologies to address these markets, there are at least three major groups. The well established GaAs-based technologies now offer a mature, commercially attractive option with good design support and rapid turn-around from foundries. In recent years, there has also been intense interest in wide bandgap GaN-based technologies.

A critical subsystem in RF or microwave-based communications links is the transmitter power amplifier, and GaN-based designs show particular promise in this application. For example, within the past year, a 2 W GaN-based power amplifier using a travel-

ling wave concept has been demonstrated over a full 25 GHz bandwidth, from 75 to 100 GHz.

The need to manage linearity while maintaining high efficiency and dealing with demanding thermal issues means that circuit design is not straightforward in amplifier applications. GaN-based devices and MMICs, in particular, are still maturing, and this is reflected in continuing challenges in areas such as characterisation and modelling. Indeed, there is an entire session at this year's EuMIC devoted to the modelling of thermal and trapping effects in GaN-based and GaAs-based HEMTs.

A third strong area of technology is provided by devices and circuits based on Si and SiGe. LDMOS devices have been around for many years at lower frequencies, but the most remarkable growth has been driven by the excellent RF and microwave performance attainable at low cost by aggressively scaled MOS devices. Achieving efficient power amplifiers in MOS technology remains a challenge, although concepts based on stacking devices are under active investigation.

Also significant is the recently-completed DOTSEVEN project, part-funded by the 7th Framework Programme of the EU, which was an ambitious effort to achieve room temperature operation of SiGe HBTs up to 0.7 THz. A further dimension to the use of Si technology is the increasing trend to complement traditional RF and microwave circuit design with CMOS-based digital and mixed-signal functionality in areas such as digital baseband predistortion and RF digital-to-analog converters (DAC). In conclusion, ICs and semiconductors continue to show rapid progress, providing key enabling capability for vast new and existing markets.

AUTOMOTIVE

Europe has a strong and influential automotive industry that has always been at the forefront of technology and innovation. The automotive industry is the largest private investor of R&D in Europe with four out of the top five companies investing most in R&D in Europe being automotive companies.

Cars and trucks are so much more than just a mode of transport. They have the potential to be the vehicle for technological development from infotainment to connectivity and automated driving. And it is the RF and microwave industry that is in the driving seat when it comes to providing that technology, from chips to sensors and the means of connecting the vehicle to outside communications. Europe has leading chip and radar sensor developers, test companies and others working independently and with the automotive manufacturers to put the technology on the road at a competitive cost.

With initiatives such as the Advanced Radar Tracking and Classification for Enhanced Road Safety (ARTRAC), the EU has endeavoured to move development from the 24 GHz radar band sensor and use €1.12 million of EU funding to establish the worldwide harmonized frequency allocation for automotive radar systems in the 77 to 81 GHz (79 GHz) frequency range.

Of course the "buzz" is being created by "automated driving" and the "autonomous car." A study commissioned by the German Federal Ministry of Economics estimates that the German market for driver assistance systems and automated vehicles will be worth €8.8 billion and create nearly 130,000 jobs by 2025. As part of the IoT, intelligent transport systems and connected vehicles will not only increase road safety, but can also help reduce congestion, raise fuel efficiency and improve social inclusion and accessibility.

Keen to avoid the all too familiar "developed in Europe but produced outside" scenario the European Road Transport Research Advisory Council (ERTRAC) is promoting a pan European approach, acknowledging its role in ensuring a harmonised approach towards implementation of higher levels of automated driving functionalities. Version 5 of the "ERTRAC Automated Driving Roadmap" was published last year. Its objective is to identify challenges to implementing higher levels of automated driving functions. To do

> **"Europe has leading chip and radar sensor developers..."**

so, the whole industrial sector needs to evolve and adapt at a fast pace to stay ahead of global competitors.

Radar Sector

Overview by David Daniels, EuRAD 2016 Chair

(Thanks to many distinguished colleagues who contributed their views and insights)

The 13th European Radar Conference highlights the advancing scientific and technical capability of the European radar industry. In the space sector, the European Space Agency has an active programme of earth observation by means of the Sentinel mission, comprising a fleet of satellites, some carrying the C-SAR sensor, which offers medium and high resolution imaging in all weather conditions. ESA has also developed ground radar for the detection of space debris.

Active electronically scanned array (AESA) radar technology is now relatively mature, with numerous systems in service on air, land, sea and space, examples being the Captor-E radar for the Typhoon fighter and the Searchmaster, an airborne surveillance radar.

There is an increasing drive to expand the multi-functionality of systems, both within traditional radar frequency bands and by the adoption of wideband or multi-band technologies. These developments present major technical and engineering challenges in implementing optimised solutions within cost and installation constraints. Major enablers are a modular, scalable approach, which limits non-recurring expenditure, and a drive to reuse technologies in as many applications as possible.

The development of lightweight antennas and faster processors, along with the need to equip smaller platforms, underlines the growing indispensability of synthetic aperture radar (SAR) technology. The developing use of UAVs in the defence portfolio is an area where innovation and cost reduction will assist the growth of suitable radar systems.

> **"...multi-tasking still challenges radar resource management..."**

For the commercial market, automotive radars are growing in importance and volume of manufacture. Europe is at the forefront of development and implementation of 24 GHz and 77 GHz radar chips for cars. Companies in niche markets such as security, sensing and measurement are also active, and radars for drone detection, IED detection, airport security scanning and pedestrian detection are either in development, trials or production.

The technology of active array radar systems is well established, but few operational systems exploit all the possibilities of adaptivity and space time adaptive processing (STAP), and the workload associated with multi-tasking still challenges radar resource management. Future engineering challenges relate to improving the capability of cognitive radar in complex and rapidly changing environments.

The increasing use of advanced DSP leads to the exploitation of waveform diversity opportunities to accurately control waveform spectral characteristics and optimise target identification. Improvements in low noise amplifiers and high dynamic range fast analog-to-digital converters (ADC) aid receiver performance, while GaN technology for high power transmitter modules impacts the market for solid-state transmitters by significantly increasing reliability.

Much academic research is being carried out into multiple input, multiple output (MIMO) radar in order to overcome the issues of fading and obscuration and the low target RCS associated with monostatic radars. This and passive bistatic radar (PBR) are receiving much attention, and PBR has demonstrated detection and tracking of air targets at ranges in excess of 100 km, as well as the detection of missile launches.

Extremely high spatial resolutions are now being obtained from SAR and ISAR imaging on airborne and satellite platforms and enable ground target monitoring. Polarimetry, interferometry and coherent change detection (CCD) techniques enable the detection of vehicle movement, ground and vegetation changes.

In summary, the European radar industry and scientific community make a major international contribution to the field of radar and continue to harness and develop new technology and concepts for implementation in both defence and consumer applications.

CONCLUSION

This special report could not ignore the elephant in the room that is the UK's decision to leave the European Union, which has cast a large shadow of uncertainty and raised questions concerning the consequences of that decision.

The UK may be leaving the EU, but it is not leaving Europe, and for its prosperity and growth it needs to trade and cooperate with its close neighbours to achieve common goals. It is a significant player that can continue to contribute its expertise and resources. That is particularly true for industrial development and the advancement of research and innovation.

Europe is playing a major role in leading edge technologies such as 5G, IoT, materials technology and automated driving. Under Horizon 2020, the mechanisms, both financial and technical, are in place to encourage and support development and, more importantly, bring these technologies to market. Those initiatives will continue, as will the contribution of UK partners to the projects currently being collaborated on. Hopefully, negotiations will ensure that such vital cooperation can be maintained for future programmes.

Whether breaking up is hard to do remains to be seen, but at this early stage, all parties appear to be committed to an amicable separation. Uncertainty and the subsequent difficulty in planning the next step and beyond is the main concern. Hopefully, the options will become clearer in the coming months and years, leading to greater confidence and stability.■

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

1. Convert your standard Assembly into a Push-On Assembly using the Nf to Nm Push-On Adapter.

2. Put your fingers firmly onto the knurls of the “Lock Nut”.

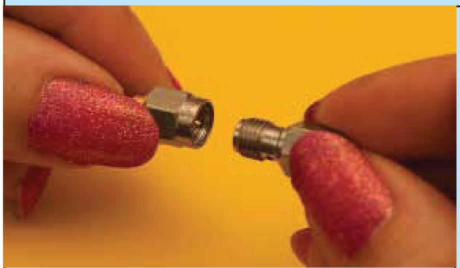
3. Push “Lock Nut” forward and engage the Push-On end of the Adapter with the mating female. Back nut must be released.

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

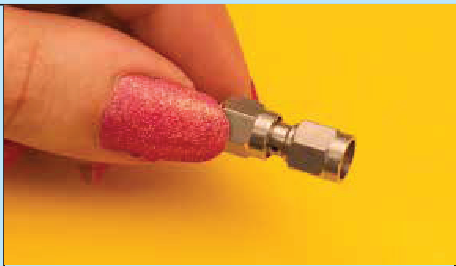
5 . To unlock (when “Back Nut” is in unlocked mode) push the “Lock Nut” forward and stop reverse movement by setting your fingers onto the “Back Nut”.

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

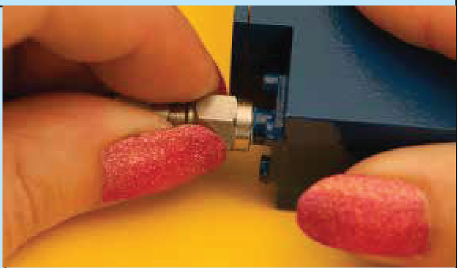
Procedure for how to use the SMA male and SMA female Push-On connectors. SMA Push-On Connectors mate with any standard connector of the same but opposite connector style.



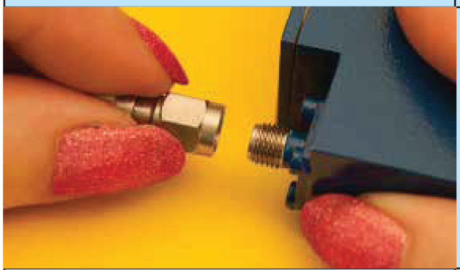
1. Convert your standard cable assembly into a Push-On Assembly by threadening the standard female side of the adapter onto the male connector of the assembly.



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



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



4. To disconnect, just pull the connector off.

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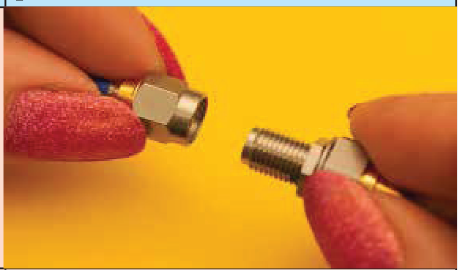
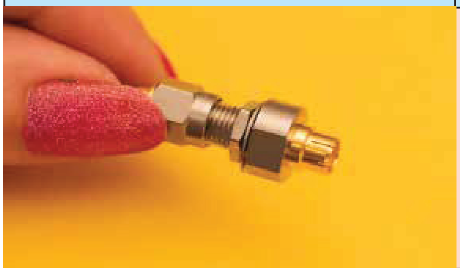
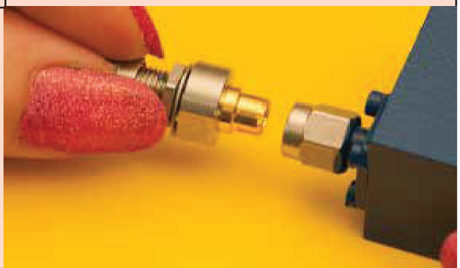


1. Convert your standard cable assembly into a Push-On Assembly by threadening the standard female side of the adapter onto the male connector of the assembly.



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

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



4. To disconnect, just pull the connector off.

INVITED PAPER

LDS Molded Interconnect Devices Fit For mmWave

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Leibniz Universität Hannover, Hannover, Germany
Malte Fengler
LPKF Laser & Electronics AG, Garbsen, Germany

Molded interconnect devices (MID) are the three-dimensional (3D) response to the increasing market demand for components to be smaller and allied to efficient and flexible circuit carrier manufacturing. For several years, different methods have been developed to allow integration of circuit patterns as well as radiating and shielding elements on nearly arbitrary shaped plastic parts, providing the full 3D design scope for the developer. 3D flexibility is becoming more and more important—indispensible—to address the challenges facing the design of modern radio frequency systems. Decreasing space for installation, increasing functionality, together with higher frequency coverage are contradicted by the uncompromising limitations of production costs.

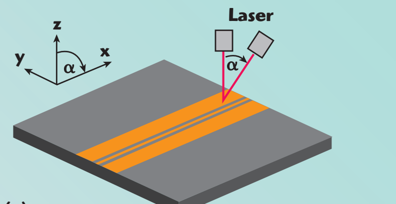
The available manufacturing methods for 3D MIDs can facilitate optimal manufacturing processes depending on the specific application. For instance, when using these methods for RF device fabrication, the 3D plastic parts replace the RF laminates that are typically used. This means that the established requirements on the RF properties of the substrate material, as well as the applied metallization, have to be met by the 3D manufactured parts. This is especially significant for future applications in the millimeter wave (mmWave) frequency range. One manufacturing method for MIDs that is already common for large scale production of antennas in consumer devices (e.g., smartphones, tablets, laptops), is the laser direct structuring (LDS) method.[1] Injection molded plastic parts combined with laser activated surfaces that allow selective metallization open up almost unlimited design scope. Because present LDS fabricated applications mainly cover frequencies up to 6 GHz, this article evaluates the suitability of the LDS method for RF applications up to the mmWave range.

LDS MANUFACTURING FOR 3D MIDS

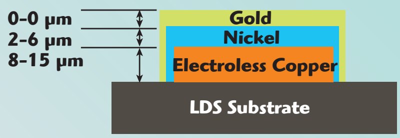
The LDS process with its laser based selective metallization processes provides great flexibility for developing electronic devices. This includes the 3D design scope in the development process, as well as the adaptability of a design during ongoing manufacturing. The substrate to be metallized by the LDS method is typically fabricated in an injection molding process using thermoplastic or thermoset materials that are doped with a special filler of mixed metal oxides. Using conventional injection molding, high volume production of the desired 3D substrate is possible. Additionally, there are LDS capable materials available that can be processed with additive manufacturing processes such as fused deposition modeling

(FDM) for development prototypes. Another method of making a substrate suitable for the LDS process is using an LDS varnish called LPKF ProtoPaint. With this varnish nearly arbitrary substrate materials can be metallized by the LDS method.[2]

Based on a CAD dataset including the mechanical and the electrical designs of the part, the circuit pattern is transferred to the molded part by laser structuring and forms the structures to be metallized. High speed 3D LDS laser systems can structure nearly arbitrary 3D shapes while achieving fine pitches down to 150 μm, as well as large circuit patterns for radiation, heat and current transportation. With the structuring parameters like laser beam width, overlap of the structured lines, pulse repetition rate, laser inclination angle (α) and laser power, the mechanical characteristics of the plastic surface, such as adhesion and roughness, as well as the electrical properties of the metal layer can be influenced (see ***Figure 1a***). In that way, the specific requirements of an application can be considered in the structuring process, within certain limits. The laser beam causes a micro rough surface and activates the mixed metal oxide that serves as a catalyst for a subsequent metallization. In an electroless plating process, a first layer of copper is deposited only on these activated areas. The copper layer has a conductivity of about 30 MS/m. Due to the laser ablation, micro cavities are formed on the surface and ensure a strong bond between the copper and the substrates, with adhesion strengths of 0.8 N/mm or higher. In additional plating processes, the surface is typically finished using electroless nickel and immersion gold (ENIG). The resulting layer configuration is depicted in ***Figure 1b***, showing its typical layer thicknesses. The different available metallization compounds (see ***Figure 1c***) enable the metallization best suited for a specific application to be chosen.



(a)



(b)

Metallization	Typical Layer Thickness
Electroless Copper	8-15 μm
Copper/Nickel/Gold	8-15/2-6/0-0.15 μm
Copper/Nickel	8-15/2-6 μm
Copper/Silver	8-15/0.15-0.3 μm
Copper/Galvanized Copper	8-15/2-35 μm

(c)

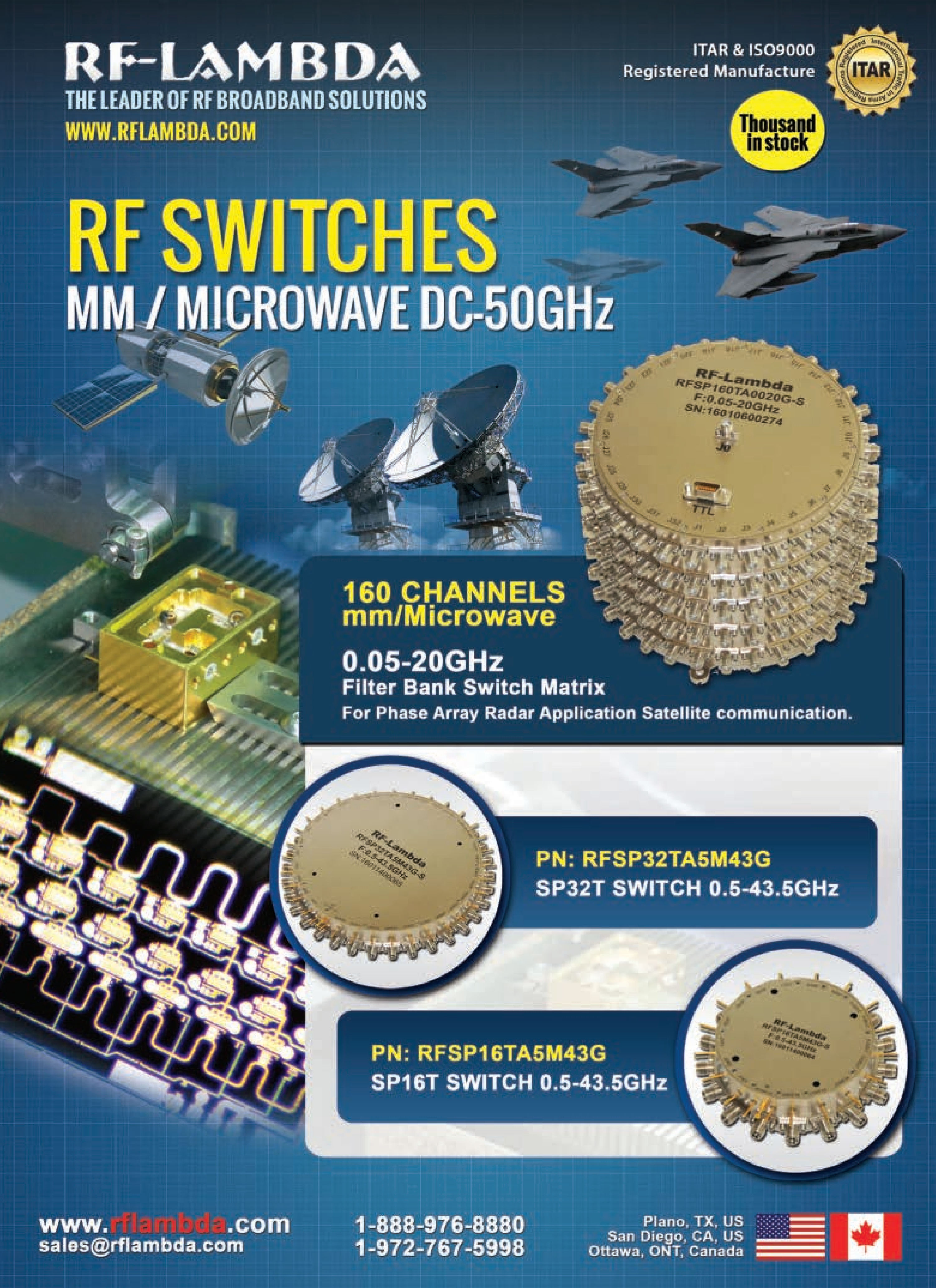
(d)

▲ *Fig. 1 LDS process laser-substrate geometry (a) typical ENIG metallization (b) metallization compounds and thicknesses (c) and sample part at various steps (d).*

Depending on the plastic resin used, an LDS MID can be used for state-of-the-art SMT processes by applying various low or high temperature soldering methods, such as reflow. ***Figure 1d*** shows an LDS part in different fabrication steps: injection molded plastic, laser structured, metallized with standard LDS ENIG and the final assembly (left to right). The recommended minimal line width is 150 μm with a minimal gap width down to 150 μm. Depending on the geometric shape of the substrate part and the laser focus size, smaller line and gap widths can also be achieved. Due to a 3D laser-based digital process, the laser beam can travel along nearly free formed shapes within an xyz scan volume of 200 mm × 200 mm × 80 mm. An optical z-axis allows the structuring of steep areas with high accuracy to an inclination angle of up to 70°.

RF PROPERTIES

The typical LDS process is based on a thermoplastic material and a metallization of the laser structured surfaces. When developing RF devices, field simulation software is typically used to optimize the required characteristics. Since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the exactness of this modeling increases the accuracy of the simulated results, the efficiency of the development process can be significantly influenced by knowledge of the RF properties. To provide this information for the user of the LDS method, a detailed evaluation of the RF properties is carried out: first, the dielectric properties of the available LDS substrate polymers are assessed. Second, the RF conductor characteristics for the different LDS metallization compounds are evaluated based on measurement and simulation.

Dielectric Properties

The complex permittivity is the main influencing factor of typical dielectric materials in an RF application. Besides the frequency related geometric dimensions, the losses induced in the substrate material can be derived from the complex permittivity. Because the dielectric properties are frequency related, the evaluation has to reflect the frequency range covered by the specific application. ***Figure 2*** shows the permittivity values (Dk) for five different LDS materials with their associated dielectric losses (DF). The measurements used an open resonator method.[3] The permittivity values

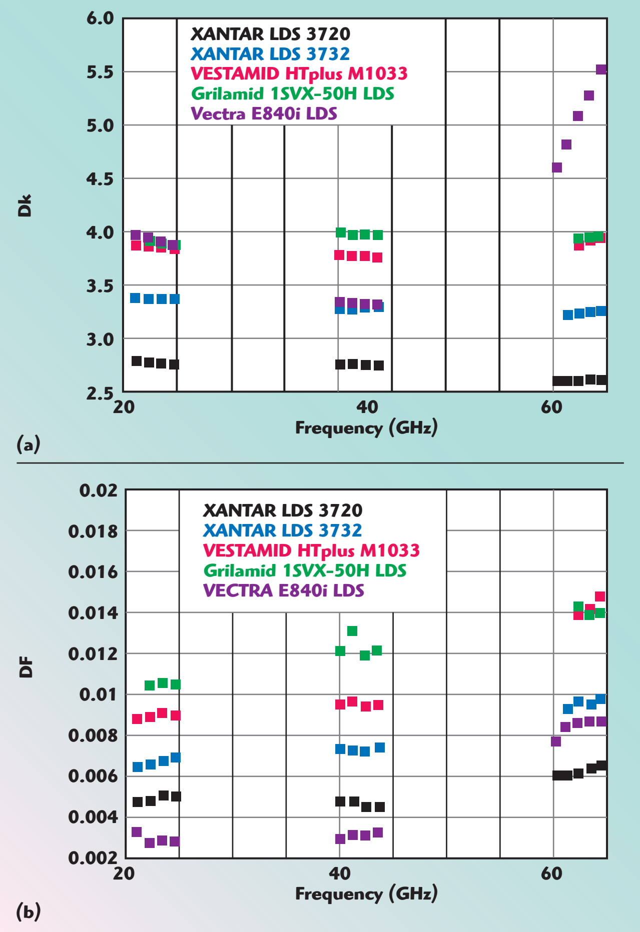

Fig. 2 Dielectric constant and dissipation factor of different LDS materials.

TABLE 1

MEASURED SURFACE ROUGHNESS FOR LDS COPPER AND ROLLED COPPER

Test Sample	S_a	S_z
Xantar LDS 3730: 8 to 12 µm Electroless Copper	6.4 µm	66.3 µm
Rogers 4003C: 17.7 µm Rolled Copper Foil	1.7 µm	22.3 µm

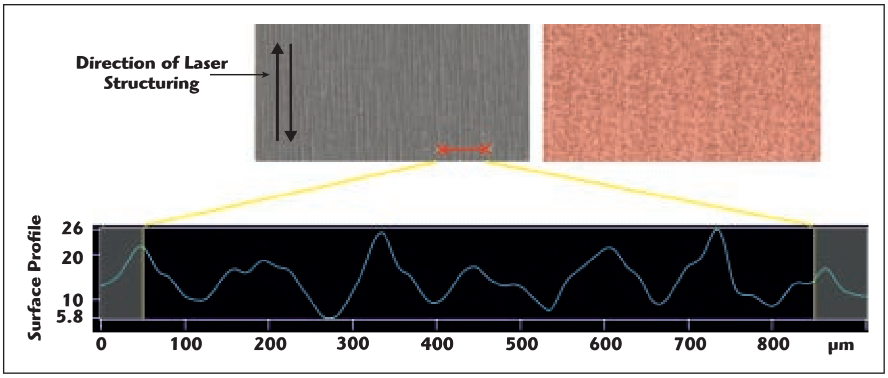

Fig. 3 Laser structured test sample with surface profile.

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- Aging: ±1E-7 per Year
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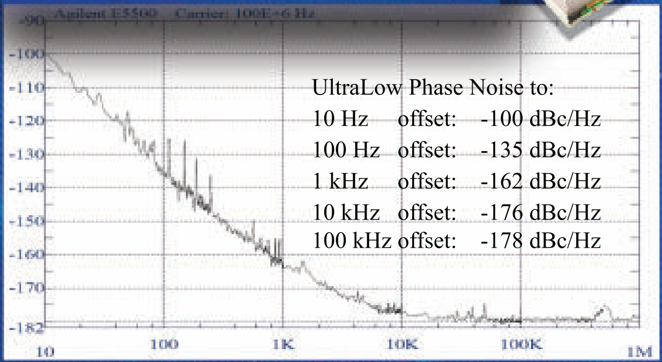


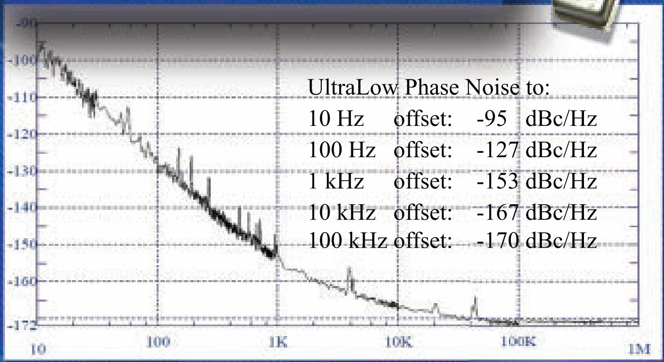
UltraLow Phase Noise to:

10 Hz	offset:	-100 dBc/Hz
100 Hz	offset:	-135 dBc/Hz
1 kHz	offset:	-162 dBc/Hz
10 kHz	offset:	-176 dBc/Hz
100 kHz	offset:	-178 dBc/Hz

MV269 +3.3 / +5V

New

- Temperature Stability: 2.5E-8
- Aging: ±1E-7 per Year
- Package: 20.3x12.7x9.5 mm (DIL14)



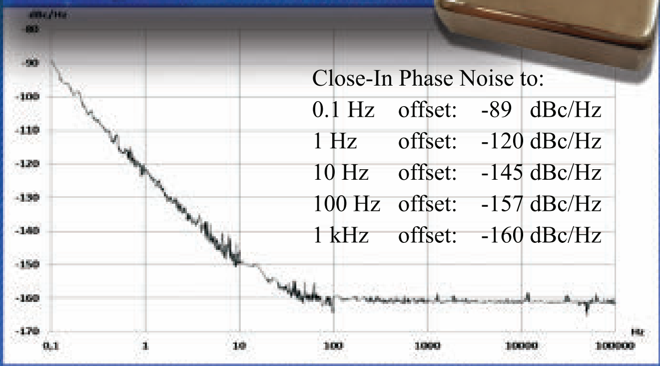
UltraLow Phase Noise to:

10 Hz	offset:	-95 dBc/Hz
100 Hz	offset:	-127 dBc/Hz
1 kHz	offset:	-153 dBc/Hz
10 kHz	offset:	-167 dBc/Hz
100 kHz	offset:	-170 dBc/Hz

Ultra-Low Close-In Phase Noise OCXOs 10 MHz

MV341

- Temperature Stability: 1E-9
- Allan Deviation: <2E-13 per Sec.
- Package: 50.8 x 50.8 x 12.7 mm



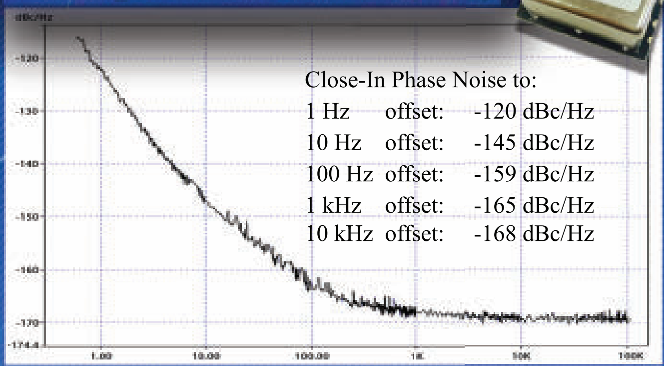
Close-In Phase Noise to:

0.1 Hz	offset:	-89 dBc/Hz
1 Hz	offset:	-120 dBc/Hz
10 Hz	offset:	-145 dBc/Hz
100 Hz	offset:	-157 dBc/Hz
1 kHz	offset:	-160 dBc/Hz

MV272M

New

- Temperature Stability: 1E-9
- Allan Deviation: <4E-13 per Sec.
- Package: 41.0 x 30.0 x 17.0 mm (SMD)



Close-In Phase Noise to:

1 Hz	offset:	-120 dBc/Hz
10 Hz	offset:	-145 dBc/Hz
100 Hz	offset:	-159 dBc/Hz
1 kHz	offset:	-165 dBc/Hz
10 kHz	offset:	-168 dBc/Hz

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are in a range of about 3 to 5.5 for frequencies from 1 to 67 GHz. These values are in the same range as for the basis polymer and do not differ significantly from that of typical RF substrate materials. The measured dissipation factor ranges from 0.003 to 0.014. The dissipation factor of some LDS materials is slightly higher than for typical RF materials.

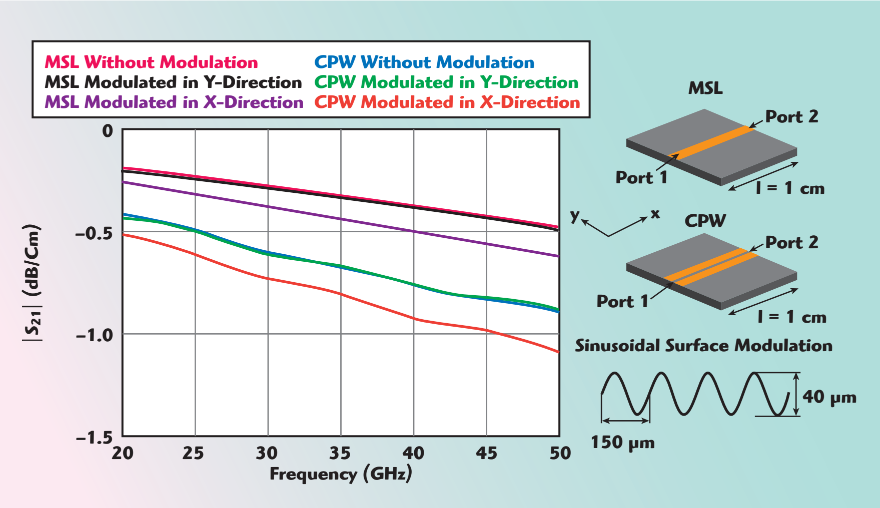
With materials like Vectra E840i LDS, a liquid crystal polymer (LCP); polyetheretherketon (PEEK), Cyclic Olefine Copolymer (COP); and also polycarbonate (PC) based materials such as Xantar LDS 3720/3732/3730, the induced material losses are comparable to those of typical RF laminates. LDS materials are generally suitable for RF applications and similar to a typical RF laminate, the choice of a LDS substrate material must be made by considering the specific application, taking into account both the RF and mechanical requirements.

Conductor Properties

Another important aspect for a circuit carrier in RF applications is the applied metallization. In addition to the electrical properties, the mechanical properties and the geometrical shape have to be considered. These characteristics influence each other. The metallization of an RF device is typically used to guide the electromagnetic waves. The condition of the metal structure influences the losses induced in the conductor. The main influencing aspects are the electric conductivity of the metal material, the geometric dimensions and the geometric surface condition. Since LDS metallization typically consists of more than one layer (e.g., Cu and ENIG), the effective conductivity is influenced by the specific surface current distribution. Especially for higher frequencies, the main surface currents will be in the outer cross section of the metal structure due to the skin effect. However, this is not automatically the outer surface of the metalized structure. The main current distribution can also be displaced to the cross section connected to the substrate material.

Evaluating the condition of a surface, roughness parameters like the arithmetic mean roughness, R_a or S_a, and the maximum height, R_z or S_z, are usually used. Typical values of these surface roughness values for LDS metallized surfaces are shown in ***Table 1***. For comparison, the same parameters for a Rogers 4003C substrate with a 17.5 µm rolled copper layer are included. The measurements were made using the Keyence One-Shot-3D-Measurement Macroscope VR-3000. As shown, the S_a and S_z values of the LDS fabricated metal layer are considerably higher than for the RF substrate. When evaluating the surface properties of the LDS metallization, these higher values defined by R_z/S_z and R_a/S_a are not complete because the exact shape of the surface will influence the losses. This fact has already been evaluated for other rough metal surfaces,[4, 5] where parameters other than the surface roughness values are defined to model the conductor losses. In the case of LDS manufacturing, the laser causes grooves where the laser beam activates the surfaces to be metallized. This leads to a waviness that depends on the laser beam width, the overlap, the pulse repetition rate and the laser power used for the structuring. ***Figure 3*** depicts one example of a laser structured plastic part where the grooved surface from the laser is analyzed. A 3D profile view of the surface shows this slight surface modulation. This modulation has a high impact on the resulting surface roughness values, while the influences on the RF losses may be lower due to the specific shape of the surface.

Therefore, the RF losses are evaluated based on a field simulation carried out with the ANSYS Electromagnetics Suite 16.2.0. The grooved surface structure is modeled with a sinusoidal surface curvature for a coplanar waveguide (CPW) and a microstrip line (MSL). The modulation is evaluated for a laser structuring parallel (x-direction) and across (y-direction) the transmission line. The transmission lines are evaluated without this surface modulation for comparison. All metal surfaces are defined as sheets with a finite conductivity boundary condition and the conductivity of LDS copper (30 MS/m). The substrate material used is an LDS polycarbonate MEP Xantar LDS 3730 with a dielectric constant of about Dk = 3 and a dissipation



▲ *Fig. 4 Simulated insertion loss for the laser induced surface modulated CPW and MSL.*

factor of about DF = 0.005 at 25 GHz. The resulting simulated insertion loss in dB/cm and the corresponding simulation models are shown in ***Figure 4***. For a surface modulation with a periodicity of 150 µm and a peak-to-peak amplitude of 40 µm, the conductor losses are increased to about 0.11 dB for the MSL and 0.18 dB for the CPW for structuring in the y-direction at 50 GHz. In case of structuring parallel to the transmission line (x-direction), no apparent difference can be observed compared to the simulated flat conductor. This shows that this part of the LDS surface roughness does not have the high impact expected. To reduce the losses, structuring in parallel to the direction of propagation (x-direction) is recommended.

Conductor Losses of a Coplanar Waveguide

Measurements on a CPW prove the results evaluated by simulation. Different laser angles (α) are used to structure the test samples metallized with different metallization compounds afterwards. Each metallization compound is based on a layer of electroless LDS copper. With the different laser angles, the three dimensional fabrication process can be evaluated, although a planar transmission line has to be used due to the limitations in the measurement setup. Each test sample consists of four transmission lines with different lengths, a short and an open line to allow for multiline TRL calibration.[6] The test structures are metallized on a plate made of MEP Xantar LDS 3730 with a height of about 1 mm. Five samples are fabricated for each configuration. The measurements are carried out on a wafer prober using GSG measurement probes with a pitch of 400 µm. The frequency range evaluated is from 1 to 67 GHz. ***Figure 5*** depicts

the measurement setup with a test sample as described.

Considering the skin depth ($\delta_{1\,GHz}$ = 2.9 µm for LDS copper) and the electromagnetic fields of a coplanar waveguide, it becomes obvious that the main surface currents will be concentrated in the outer cross section of the structure. The current distribution is dependent on the specific RF structure. ***Figure 6*** shows the insertion loss in dB/cm for all evaluated test samples, with the metallization compound and laser parameter depicted in the legend. The laser structuring is done in parallel to the direction of propagation (x-direction) with a laser angle of 45° and 0°. For comparison, a CPW fabricated in a photolithographic process out of a single rolled copper layer on Rogers 4003C is shown. The LDS substrate material used has a loss tangent (DF) of approximately 0.005 at 20 GHz, compared to approximately 0.0027 at 10 GHz for the Rogers 4003C. Consequently, the higher losses are also due to the dielectric losses as well as conductor losses. At 60 GHz, the CPW test samples with copper show a loss of about 0.9 dB/cm, while the nickel surface finish causes a loss of about 1.7 dB/cm. The sample on Rogers 4003 with the rolled copper foil induces a loss of about 0.75 dB/cm. The results show that there is only a slight difference between the losses of the typical RF substrate and the LDS sample with the copper metallization. The LDS samples with the nickel and nickel/gold layer induce higher losses due to the poor conductivity of nickel.

The investigations of the different metallization compounds of LDS fabricated RF test samples show that the surface roughness of LDS copper does not have the high impact on the losses as may have been expected. This is due to the specific shape of the laser structured surface, with its laser induced grooves, leads to a kind of surface modulation that only slightly influences conductor loss. Because the coplanar samples are manufactured with different laser inclination angles (α = 0° and α = 45°), this applies to 3D fabricated structures.

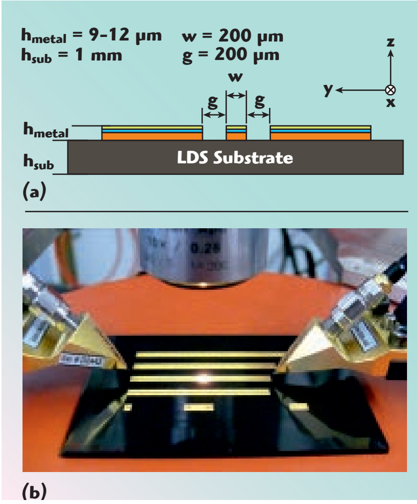
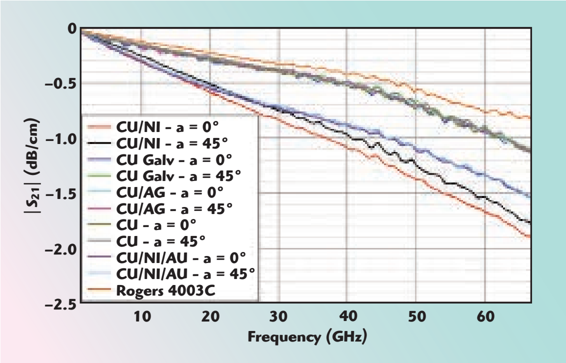


Fig. 5 CPW structure (a) and measurement setup (b).

CONCLUSION

3D manufacturing methods are becoming more important for the fabrication of RF devices. The flexibility of an arbitrarily shaped and selective metallized injection molded part can be used to meet often contradictory re-



◀ *Fig. 6 Measured CPW insertion loss on Xantar LDS 3730 compared to Rogers 4003 with a rolled copper layer.*

quirements. When replacing the typical RF substrate with a 3D manufactured plastic part, it becomes clear that the RF properties of the 3D fabricated components have to be evaluated to guarantee proper functionality, an efficient development process and a long lifetime. As these properties are frequency dependant, evaluation depends on the specific frequency of application. In this article, the 3D LDS process was evaluated for RF applications up to 67 GHz. The results show that the complex permittivity of the LDS polymer materials is only slightly changed due to the LDS additive. There are materials available that have comparable properties to those of typical RF substrate materials.

The conductor losses in different metallization compounds were evaluated. The surface roughness values of the LDS metallization may lead to the assumption that the roughness will cause high conductor losses. A detailed mechanical surface evaluation together with different field simulations showed that the laser structuring causes a grooved surface that has only a slight impact on the resulting RF losses. Measurement of the insertion loss of LDS manufactured CPW structures compared to typical rolled copper metallization on an RF laminate verified these results. The metallized surfaces were evaluated for structuring with different laser angles. In that way, the results are adaptable to 3D fabrication, even though the test samples were planar, due to limitations in the measurement setup.

LDS fabrication is suitable for RF applications in the mmWave range. The evaluated data of the frequency related losses and the available design scope show that 3D LDS technology is a good solution for fabricating RF devices, helping to meet future challenges. ■

References

1. N. Heininger, "3D LDS Components for New Production Opportunities," *Microwave Journal*, Vol. 55, No. 2, February 2012.
2. LPKF Laser & Electronics AG, "A Shortcut to 3D-MID Prototypes," *Microwave Journal*, Vol. 56, No. 11, November 2013.
3. www.damaskosinc.com/cavitiy.htm, 2016.
4. P. G. Huray, "The Foundations of Signal Integrity," New York, NY, USA: Wiley, 2009, Ch. 6, pp. 216–277.
5. S. Hall, S. G. Pytel, P. G. Huray, D. Hua, A. Moonshiram, G. A. Brist and E. Sijercic, "Multigigahertz Causal Transmission Line Modeling Methodology Using a 3-D Hemispherical Surface Roughness Approach," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 55, No. 12, pp. 2614–2624, December 2007.
6. R. B. Marks, "A Multiline Method of Network Analyzer Calibration," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 39, pp. 1205–1215, July 1991.

Design of Waveguide Windows for mmWave Components

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Hai Zhang
Nanchang Institute of Technology, China

A millimeter wave (mmWave) waveguide window employs a direct coupled filter network, which includes LC resonators and J inverters. ABCD matrix theory and full-wave simulation are used in the design. It is wideband and low-cost. Back-to-back waveguide sealed windows are built and measured. In the frequency range of 75 to 100 GHz, return loss is greater than 15 dB, insertion loss is less than 0.7 dB and the leakage rate is lower than 8×10^{-8} Pa.m^3/s.

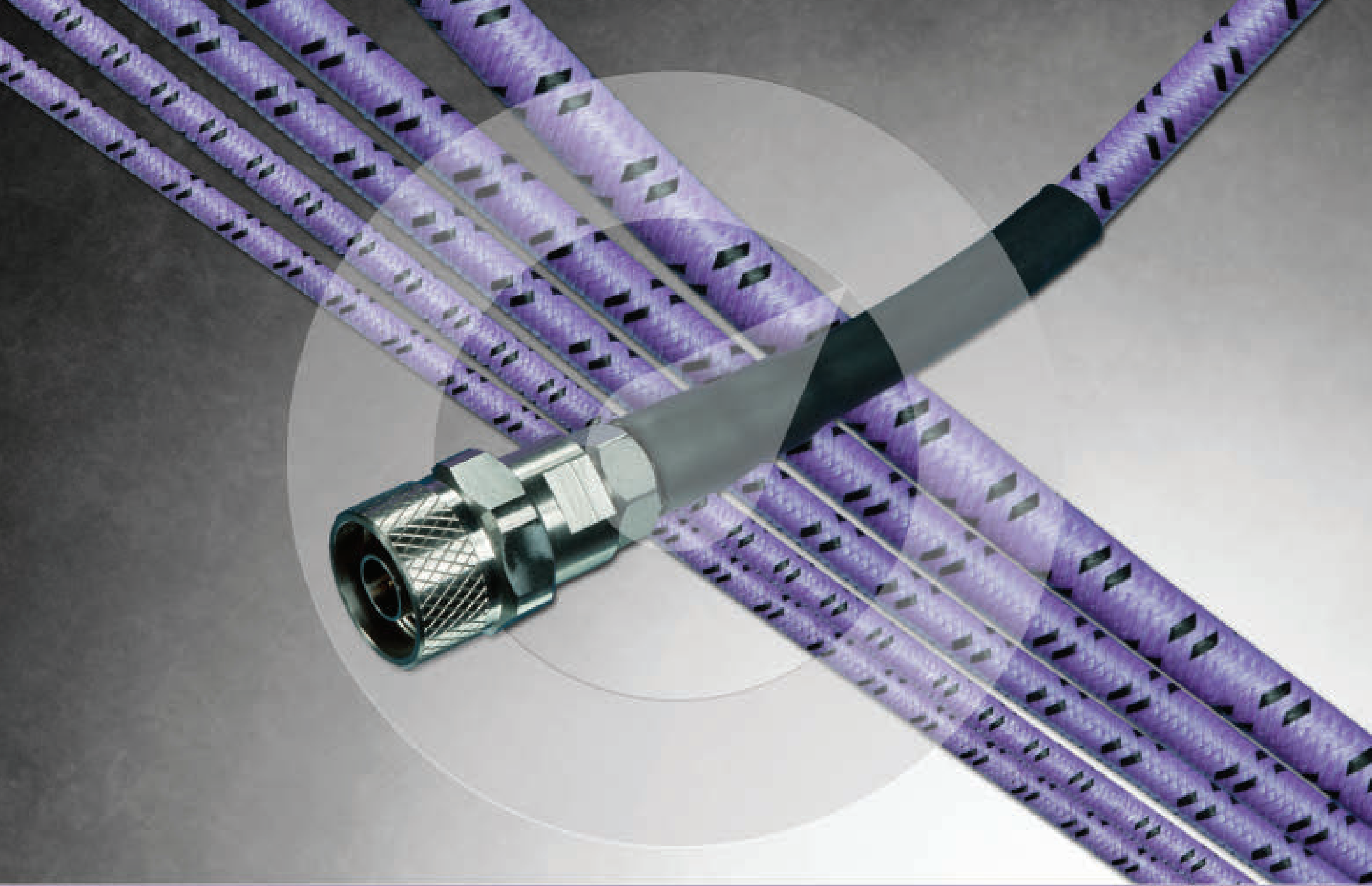
Millimeter wave components, usually constructed with waveguide interfaces, are widely used in millimeter wave systems. In order to improve reliability, the waveguide interfaces are sealed. There are several types of waveguide sealed windows frequently in use. One is a pillbox;[1-5] however, detailed synthesis methods are not provided.[1,2,4] Liu[3] employs an ABCD matrix method for design, but the pillbox requires a complex welding process. Another is a resonance type,[6,7] but its bandwidth is limited. Further approaches, such as multilayer waveguide windows,[8] need different dielectric windows with different thicknesses that increase insertion loss.

In this article, a new double-layer waveguide window (DLWW) for mmWave components is designed to improve reliability while reducing cost. In addition, the bandwidth of the sealed window is increased relative to other designs. This design is carried out for W-Band back-to-back waveguide sealed windows by employing a direct coupled filter network design method using ABCD matrices and full-wave simulation.

SYNTHESIS AND FULL-WAVE SIMULATION

DLWW Circuit Description

The back-to-back waveguide sealed windows (see ***Figure 1***) are designed using a broadband direct coupled filter synthesis method.[9-11] Each DLWW is composed of two RT/Duroid 5880 substrates (thickness = 0.127 mm, ε_r = 2.2) and one quarter-wavelength waveguide (between the two substrates). The direct coupled filter model (see ***Figure 1b***) is used for this design. The substrate is equivalent to a dielectric resonator (composed of C_1 and L_1), whose resonant frequency is determined by the parameters of substrate. The quarter-wavelength waveguides, which determine the



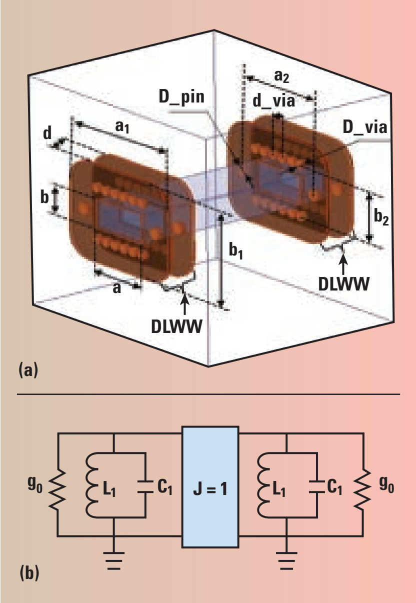


Fig. 1 Back-to-back DLWW structure (a) and equivalent model (b).

coupling coefficient are equivalent to an admittance inverter of value J = 1.

DLWW Synthesis

The ABCD matrix and scattering parameters are used to determine the DLWW parameters. According to Figure 1, the two-port matrix of the dielectric resonator is

$$\begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ j\left(\omega C_1 - \frac{1}{\omega L_1}\right) & 1 \end{bmatrix} \quad (1)$$

and the two-port matrix of the quarter-wavelength waveguide is

$$\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} = \begin{bmatrix} \cos(\beta l) & jZ_0 \sin(\beta l) \\ jY_0 \sin(\beta l) & \cos(\beta l) \end{bmatrix} \quad (2)$$

where ι is the length of quarter-wavelength waveguide, and ß is the propagation constant.

The cascaded dual-port ABCD matrix of the DLWWs is

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \cdot \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \quad (3)$$

The input return loss (S_{11}) of the DLWW is expressed as

$$S_{11} = \frac{A + B/Z_0 - CZ_0 - D}{A + B/Z_0 + CZ_0 + D} \quad (4)$$

Therefore, the transmission power ratio is

$$P_L/P_I = 1 - |S_{11}|^2 \quad (5)$$

where P_L is the power delivered to the load and P_I is the available power from the source.

As shown in Figure 1b, this model provides the parameters of the network, namely, the resonant frequency (f_0) and the loaded quality factors (Q_L) of each dielectric resonator.

$$f_0 = 1/2\pi\sqrt{L_1 C_1} \quad (6)$$

$$Q_L = 2\pi f_0 C_1 \quad (7)$$

The dielectric resonator's f_0 and Q_L can also be deduced from its scattering parameters through full-wave simulation.[11]

$$f_0 = \text{frequency at which } S_{11} \approx 0 \quad (8)$$

$$Q_L = \frac{f_0}{2} \frac{\partial \operatorname{Im}(Y_{11})}{\partial f} \quad (9)$$

where Y_{11} is the input admittance of the dielectric resonator.

The synthesis procedure for the DLWW is shown in ***Figure 2***. First,

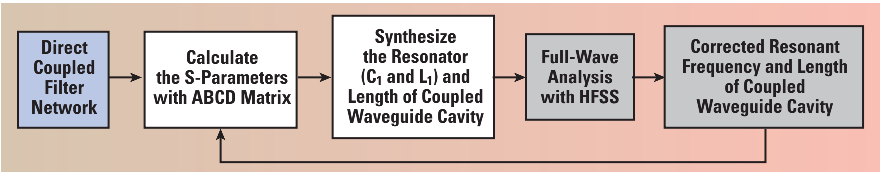


Fig. 2 Waveguide window synthesis procedure.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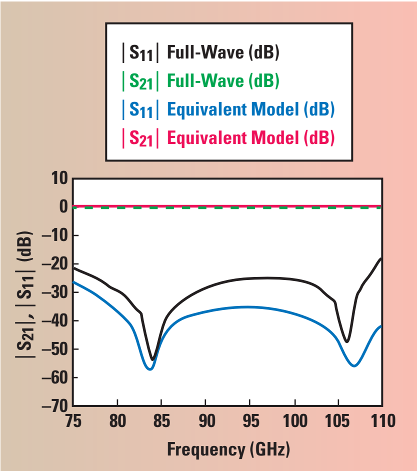
the direct coupled filter model is used to synthesize the DLWW. Then, the scattering parameters are derived using its ABCD matrix. Third, the dielectric resonator's (f_0,Q_L) and the length of coupled waveguide cavity are determined when S11 reaches a minimum. The full-wave model is then established and simulated. Finally, the direct coupled filter network parameters are corrected through full-wave simulation.

DLWW Full-Wave Simulation

The Ansoft HFSS full-wave simulator is used to accurately calculate the size of the dielectric resonator and the coupling cavity. The design parameters are defined in Figure 1a and their numerical values are: a = 2.54 mm, b = 1.27 mm, a_1 = 5.54 mm, b_1 = 4.27 mm, a_2 = 4 mm, b_2 = 2.26 mm, d = 0.86 mm, d_via = 0.508 mm, D_via = 0.4 mm and D_pin = 0.5 mm. ***Figure 3*** shows predictions from the equivalent model and the full-wave simulation. The full-wave simulation takes into account the loss of the transmission medium, so the curves are not exactly the same. From 75 to 108 GHz, the return loss is greater than 20 dB for the full-wave simulation curves.



▲ *Fig. 3 DLWW model vs. simulation.*

FABRICATION AND TEST

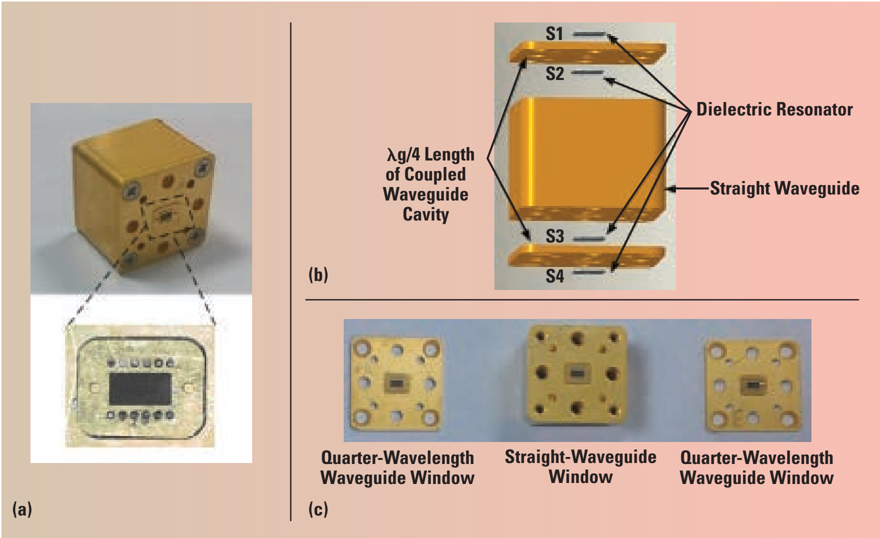
Window Fabrication

The fabricated waveguide windows are composed of two DLWWs and one 15 mm length of straight waveguide (see ***Figure 4a***). The dielectric resonators are fabricated using a PCB process with RT/Duroid 5880, giving the DLWWs the advantages of low complexity and low-cost in manufacturing. The waveguide is gold-plated aluminum alloy. The flange of the waveguide is WR10.

As shown in ***Figures 4b*** and ***4c***, dielectric resonators S_2 and S_3 are welded onto the straight waveguide, and dielectric resonators S_1 and S_4 are welded onto the quarter-wavelength waveguides for the sealing. The solder is Au-Sn with a thickness of 0.025 mm. The welding temperature is 280°C. Two quarter-wavelength waveguide windows and one straight waveguide window are assembled with screws to form the back-to-back waveguide window (see ***Figure 5***).

Test Results

To accurately test performance, a straight waveguide (length of 15 mm) is designed. ***Figure 6*** shows measured scattering parameters compared with



▲ *Fig. 4 Photo (a) and exploded view (b) of back-to-back waveguide windows. Exploded view of welded quarter-wavelength waveguides and straight waveguide (c).*

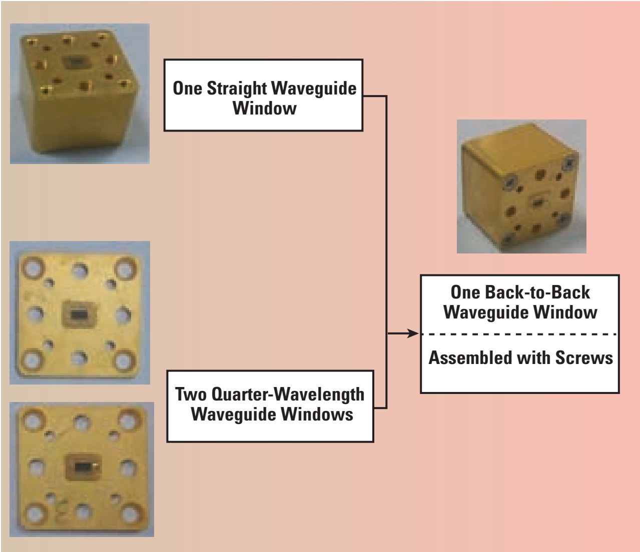


Fig. 5 Back-to-back waveguide assembly.

simulated results using Ansoft HFSS. Simulated return loss is higher than 20 dB and insertion loss lower than 0.2 dB in the frequency range of 75 to 100 GHz. Measured return loss is higher than 15 dB and measured insertion loss (after deducting the straight waveguide insertion loss) is better than 0.7 dB from 75 to 105 GHz. The leakage rate measured on several back-to-back devices, using a helium spectrometer leak tester, is less than 8×10^{-8} Pa.m^3/s.

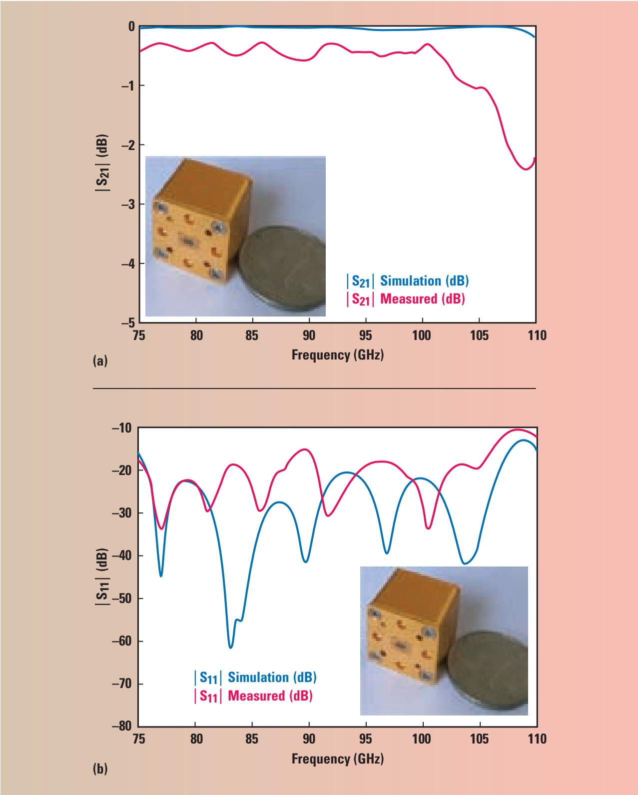


Fig. 6 Simulated and measured S-parameters of back-to-back waveguide windows, $|S_{21}|$ (a) and $|S_{11}|$ (b).

CONCLUSION

A novel waveguide window for millimeter-wave module sealing is demonstrated. Its development was motivated by the desire for low complexity and low-cost in manufacturing. The structure is wideband compared with the resonance type windows. Measured results show that its return loss is greater than 15 dB and its insertion loss is less than 0.7 dB from 75 to 100 GHz for the back-to-back windows. The leakage rate is less than 8×10^{-8} Pa.m^3/s. ■

ACKNOWLEDGMENTS

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References

1. A. Srivastava, O. J. Kwon , M. Sattorov, A. Sharma, A. Tanwar and G. S. Park, "Broadband THz Vacuum Window Using Impedance Matching Approach," *35th International Conference on Infrared Millimeter and Terahertz Waves*, September 2010, pp. 1.
2. I. Freidovich, B. Prokofiev, A. Balabanov, A. Yegorov, A. Zakirov and A. Grigoriev, "Waveguide Window for a Broadband Multibeam Ka-Band Klystron," *IEEE 14th International Vacuum Electronics Conference*, May 2013, pp. 1–2.
3. S. Liu, "A RF Window for Broadband Millimeter Wave Tubes," *International Journal of Infrared and Millimeter Waves*, Vol. 17, No. 1, January 1996, pp. 121–126.
4. L. Earley, E. Smirnova and P. Ferguson, "Experimental Measurements and Field Modeling for a W-Band Window," *IEEE 5th International Vacuum Electronics Conference*, April 2004, pp. 244–245.
5. A. M. Cook, C. D. Joye, T. Kimura, E. L. Wright and J. P. Calame, "Broadband 220-GHz Vacuum Window for a Traveling-Wave Tube Amplifier," *IEEE Transactions on Electron Devices*, Vol. 60, No. 3, February 2013, pp. 1257–1259.
6. M. E. Hill, R. S. Callin and D. H. Whittum, "High-Power Vacuum Window in WR10," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 49, No. 5, May 2001, pp. 994–995.
7. S. Bashaiah, P. K. Sharma and K. C. J. Raju, "Fabrication of High Dielectric Constant and Low Loss X-Band Ceramic Waveguide Window for High Power Applications," *5th International Conference on Computers and Devices for Communication*, December 2012, pp. 1–4.
8. M. C. Lin, "A Multilayer Waveguide Window for Wide-Bandwidth Millimeter Wave Tubes," *International Journal of Infrared and Millimeter Waves*, Vol. 28, No. 5, May 2007, pp. 355–362.
9. S. B. Cohn, "*Direct Coupled Resonator Filters*," *Proceedings of the IRE*, Vol. 45, No. 2, February 1957, pp. 187–196.
10. R. Levy, "Theory of Direct-Coupled-Cavity Filters," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 15, No. 6, June 1967, pp. 34–348.
11. R. M. Barrio-Garrido, S. LIorente-Romano, A. Garcia-Lamperez and M. Salazar-Palma, "Design of Broadband Directly Coupled Non-Centred Resonant Irises Filters," *33rd European Microwave Conference*, October 2003, pp. 219–222.

INVITED PAPER

Achieving Metrology-Level Accuracy When Making THz Measurements

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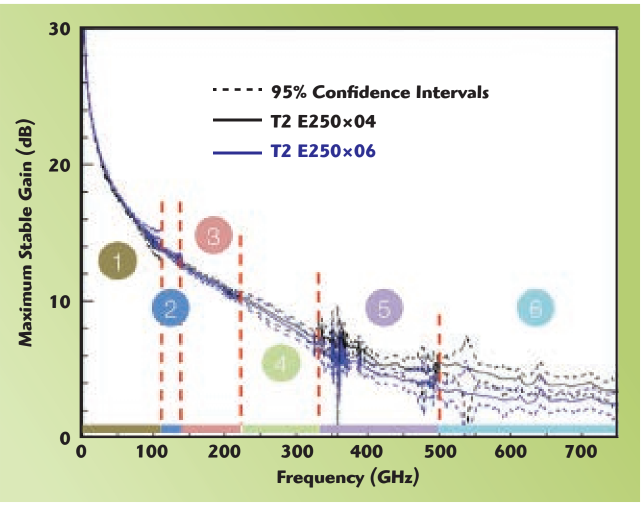
Rohde & Schwarz, Munich, Germany

With significant expansion of emerging terahertz (THz) applications such as noninvasive spectroscopy, security and surveillance, short range automotive radar and 5G communications, the need for accurate, reliable and repeatable measurement data is crucial. This is especially true for the research and technology development of the devices, integrated circuits and new product building blocks serving the needs of THz applications.

This article discusses solutions to address the challenges of wafer-level calibration and measurements at THz frequencies. Solutions for measurement instrumentation, frequent system reconfiguration, operator skill affecting the accuracy and repeatability of calibration, and the need for metrology-level analysis of the measured data are described.

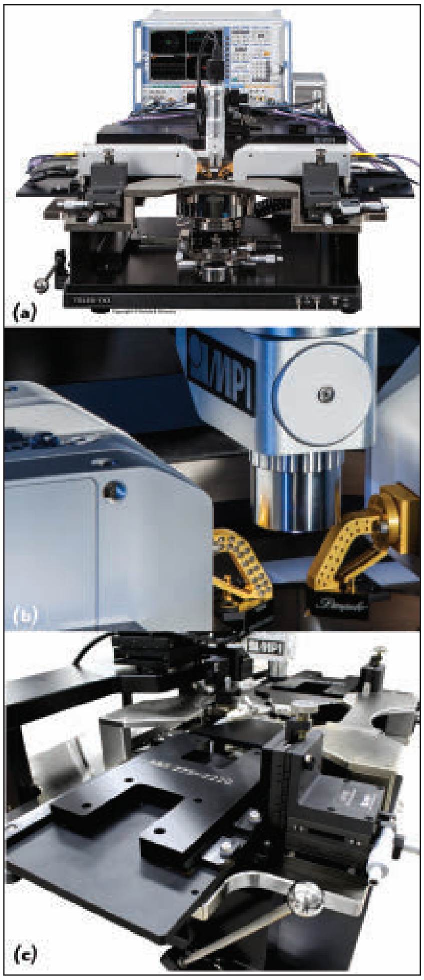


▲ *Fig. 1 MSG measurements of THz transistors with 95% confidence intervals; measuring to 750 GHz requires six system reconfigurations. Data courtesy of Dylan Williams, NIST.*

TEST INTEGRATION

Measurements at sub-THz frequencies usually require repeated and tedious system reconfiguration to switch between frequency bands. For example, the probe system and the vector network analyzer (VNA) have to be reconfigured and recalibrated six times to reach 750 GHz (see ***Figure 1***). Characterizing a device under test (DUT) across frequency bands is becoming an extremely time consuming exercise. The conventional approach of mounting the sub-THz VNA frequency extenders on the probe system requires elevation of the chuck and microscope, which reduces the system's mechanical stability. At the same time, increasing the measurement frequency demands extremely accurate positioning of the RF probes on the DUT contact pads and calibration standards. As a result, the accuracy and repeatability of the system calibration decrease exponentially with increasing frequency, and characterization of the DUT becomes a very challenging task.

A manual system such as the MPI TS150-THZ incorporates many features that address the challenges of wafer-level measurements at THz frequencies. These include seamless integration of any type of VNA frequency extender



▲ *Fig. 2 The MPI TS150-THZ integrated probe system configured for measurements to 330 GHz with the R&S ZVA VNA (a). GGB waveguide probes directly mounted at the output of the mmWave ZVA converters (b). Dovetail interface of R&S®ZVA-Z75 to R&S®ZVA-Z220 frequency converters (c). Photos courtesy of Rohde & Schwarz.*

at any frequency band, to provide the maximum measurement dynamic range and reproducibility (see ***Figure 2a***). This trade-off was resolved by combining the low profile and stable chuck Z-stage with the ridged probe platen resting below its surface. This allows direct mounting of THz RF wafer probes on the output waveguide port of the VNA frequency extenders (see ***Figure 2b***), which maximizes measurement dynamic range. A dedicated dovetail interface of the VNA extenders holding plates makes swapping them easy (see ***Figure 2c***). There is no need to unmount the interface plate from the extender. Due to its flat bottom, the interface and the VNA extender can be handled as one unit, located on the laboratory shelf or in a cabinet for later use.

WHY MULTILINE TRL?

The multiline thru-reflect-line (TRL) RF calibration method developed at the U.S. National Institute of Standards and Technology (NIST) has become the benchmark for metrology and industry laboratories focused on wafer-level RF measurements. Its key advantage over other calibration methods is the calculation of the calibration reference impedance, Z_{REF}, based on measurement of the traveling waves propagating through the calibration planar line standard. Traveling waves are purely physical phenomena defined by the type and design of the transmission lines and are independent of the geometry and design of the RF probes. The multiline TRL algorithm enables accurate extraction of the propagation constant γ of the calibration lines. Therefore, the multiline TRL can set the measurement reference plane precisely and at an arbitrary position. The multiline TRL calibration kit can be designed and fabricated using the same semiconductor process as the DUT. Customized, on-wafer, multiline TRL calibration kits eliminate the need for de-embedding the DUT measurement results from the parasitic impedances of the device contact pads. With all these advantages, the multiline TRL is the only method that delivers trustable calibration results at frequencies above 110 GHz.

Three or more lines with different physical lengths should be used in the calibration to cover a wide frequency range. Together with the thru and reflection standards, the multiline calibration kit can include more than five elements. Measuring such a kit involves repeated readjustment of the micro-positioners and realignment of the probes to the contact pads to achieve repeatable measurements. It is often difficult to obtain accurate and repeatable multiline TRL calibration at millimeter wave (mmWave) frequencies on a manual probe system, especially if it is operated by several users with various levels of expertise. A system such as the TS150-THZ offers the option of an integrated digital

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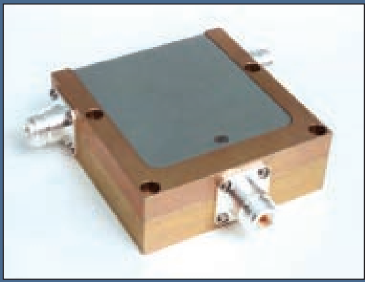

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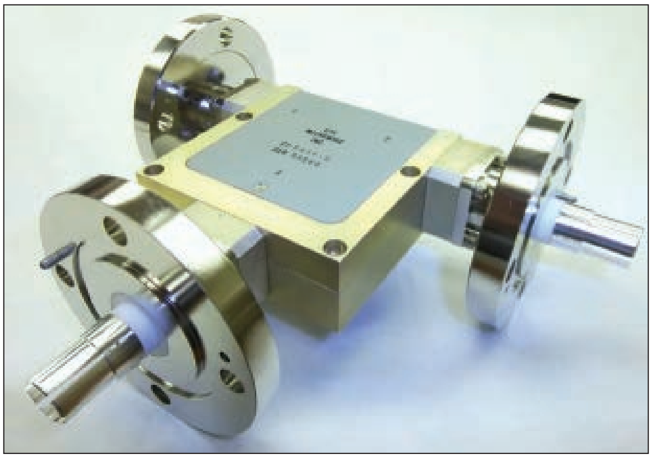

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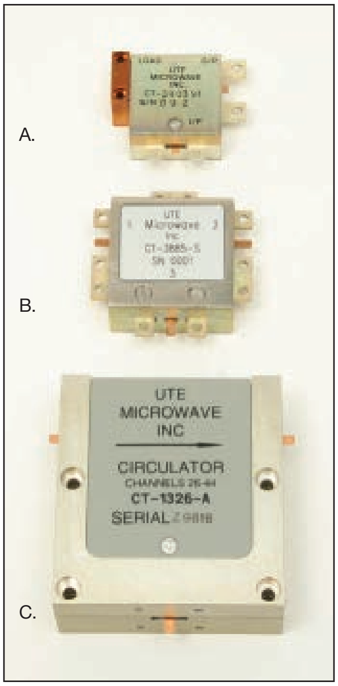

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CT-3838-N	5 Kw Pk 500 W Av	N Conn.	2.7–3.1 GHz
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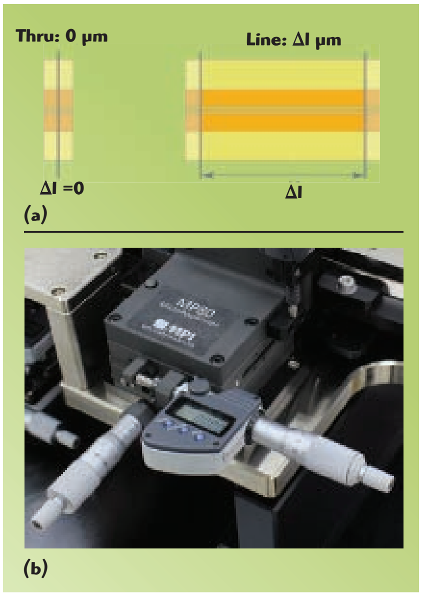


▲ *Fig. 3 TRL definition of Δl for line standards (a). MP80-DX micro positioner with the digital micrometer on the X axis (b).*

micrometer that simplifies the calibration process. The TRL algorithm always treats the thru standard as a zero-length line. The effective length of each subsequent line standard, Δl, is defined with respect to the length of the thru (see ***Figure 3a***). The operator simply zeros out the digital micrometer after the initial adjustment of the probes, i.e., on the thru standard (see ***Figure 3b***). Next, the distance between RF probes can be readjusted to the required value of Δl (see ***Table 1***) with a precision better than 1 µm. As a result, the system improves the accuracy and repeatability of calibration—even for inexperienced operators—while reducing setup times.

TABLE 1

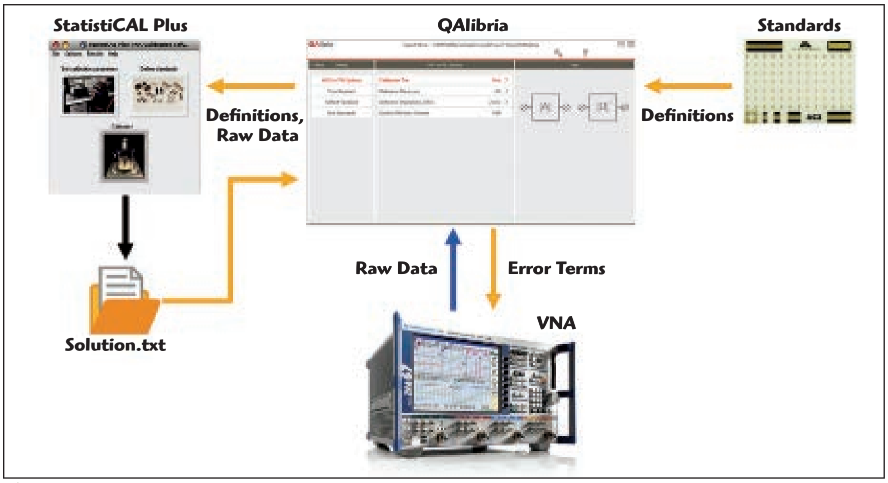
CS15 ALUMINA CALIBRATION SUBSTRATE COPLANAR WAVEGUIDE LINES

Standard Type	Physical Length (µm)	Effective Length, l (µm)	Δl (µm)
Thru	175	150	0
Line 1 (L2)	250	225	75
Line 2 (L3)	355	330	180
Line 3 (L4)	575	550	400
Line 4 (L5)	1025	1000	850
Line 5 (#10)	6600	6575	6425

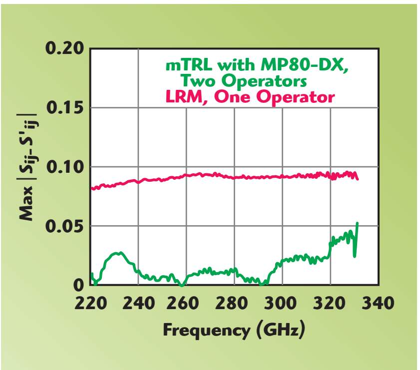
NIST UNCERTAINTY FRAMEWORK

StatistiCAL™ Plus is a software package developed at NIST that realizes both conventional multiline TRL and calibration solutions based on the orthogonal distance regression. The algorithms were developed at NIST and the Physikalisch-Technische Bundesanstalt (PTB) of Germany. The unique feature of this algorithm is the ability to estimate the uncertainty of its own results due to random errors. The StatistiCAL Plus algorithm features a high degree of robustness, as it is able to find solutions even with poor initial estimates. The NIST Microwave Uncertainty Framework extends StatistiCAL Plus, adding data post-processing related to calculating and propagating uncertainties through different models. The framework includes post processors that allow the uncertainties in measured S-parameters to be propagated to transistor gain, power, material parameters and other derived measurements and metrics. Both software packages were developed for metrologists and microwave measurement experts with the intention of post-processing already measured data offline, i.e., without a link to the VNA, probe system and device characterization software. Their application in a typical industry or university measurement laboratory and the integration into a common automated measurement workflow requires enormous programming and extensive experience in microwave metrology.

Now, NIST multiline TRL metrology-level VNA calibration from StatistiCAL Plus can be accessed through integration with MPI's QAlibria® software. Both software packages work hand-in-hand in the system calibration and data analysis workflow (see ***Figure 4***): QAlibria takes responsibility for interaction with the VNA, probe system and operator, while



▲ *Fig. 4 System calibration data flow.*



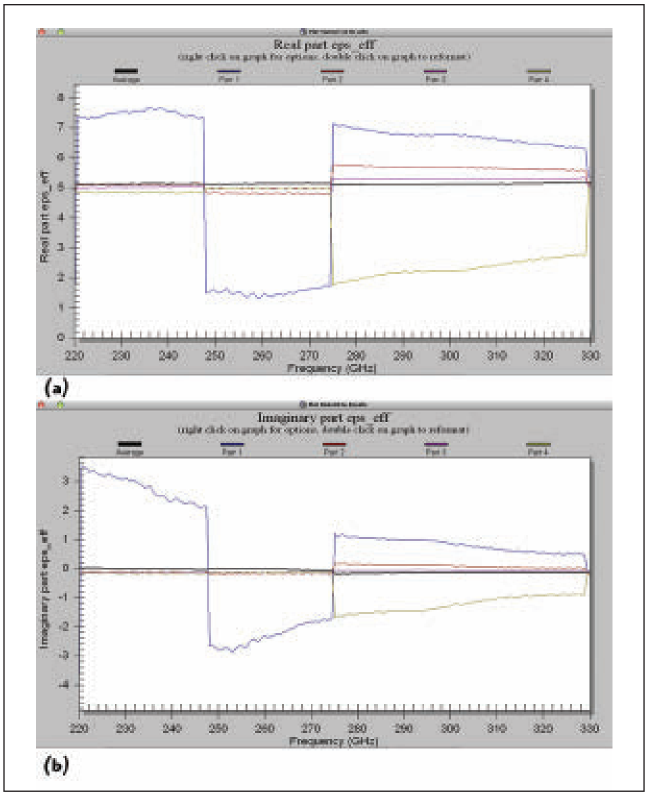
▲ *Fig. 5 Repeatability of a lumped LRM calibration vs. operator error for the multiple TRL calibrations performed on the TS150-THZ with the MP80-DX option.*

StatistiCAL Plus calculates calibration error terms and uncertainties, running in the background. With QAlibria's multi-touch and multi-language graphical user interface, configuration mistakes are minimized, and accurate calibration results can be obtained, even by inexperienced users.

Calculating the multiline TRL error terms requires initial information about calibration standards, such as the type of the reflection standard (i.e., open, short or high reflection), physical length of the line standards and an initial estimate of the effective dielectric constant. The StatistiCAL algorithm requests the initial estimate for error terms as well as some specific settings for the NIST ODRPACK calculation engine. These definitions are automatically prepared by QAlibria and saved locally as the StatistiCAL Plus calibration menu file QAlibriaMenuNIST.scm in the local folder: \MPI\QAlibria\Data\StatistiCAL\. This folder also contains the raw data of the calibration standards measured by QAlibria (in the _input\ directory) and the calibration results calculated by StatistiCAL, which are automatically saved as the solution vector Solution.txt in the _output\ directory. Once the StatistiCAL Plus calculations are completed, QAlibria loads the solution vector and sends the error terms to the VNA. The system is fully calibrated without any interaction from the operator.

REPEATABILITY AND REPRODUCIBILITY

The common features of MPI manual systems currently in the market include an air bearing stage, a highly repeatable platen lift with three discrete positions and the auto-contact feature. This latter feature is particularly important for improving contact repeatability and reproducibility of the DUT measured data, independent of the operator's expertise. ***Figure 5*** shows the experimental results for the calibration repeatability of the lumped line-reflect-match (LRM) and the multiline TRL methods with the CS15 commercial alumina calibration substrates and waveguide RF probes from GGB Industries, Inc. The LRM was executed twice sequentially and by the same experienced operator. The difference between these two calibrations was calculated using the calibration comparison method. Because the calibrations were performed sequentially, system drift was minimized, and the outcome of the calibration compari-



▲ *Fig. 6 Real (a) and imaginary (b) parts of the effective dielectric constant ε_{eff} calculated and displayed by StatistiCAL Plus (debug case).*

son method primarily presents the repeatability error of the LRM calibration. Next, four multiline TRL calibrations were performed, two by an experienced operator and two by an inexperienced operator. Each time, the digital micrometer was used to define the Δl of each calibration line, per Table 1. The difference in the maximum repeatability error of the multiline TRL calibration performed by the two operators is significantly smaller than the single operator repeatability error of the LRM.

The multiline TRL enables accurate extraction of the propagation constant, γ, of the calibration lines and easy calculation of the effective dielectric constant, ε_{eff}. NIST StatistiCAL Plus can plot both the real and the imaginary parts of ε_{eff} for each line pair, together with the average values (see ***Figure 6***). This is a handy feature for quick verification and debugging of calibration results. If required, the data can be exported as graphs or data files for further analysis. Another quick check of calibration success is to verify the corrected S-parameters of the line and reflection standards used for the calibration (see ***Figures 7*** and ***8***).

When detailed analysis of the DUT data, including calibration and measurement uncertainties, is required, the StatistiCAL Plus solution vector can be directly loaded into the Calibrate DUT Plus tool from the NIST Uncertainty Framework (see ***Figure 9***). The DUT parameters can be calculated, including the standard uncertainties with 95 percent confidence intervals. The covariance matrix of the calibration uncertainties should also be exported from the StatistiCAL Plus menu (see ***Figure 10***).

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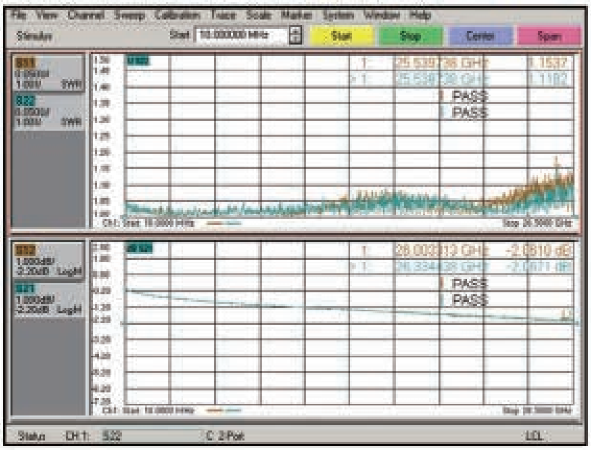
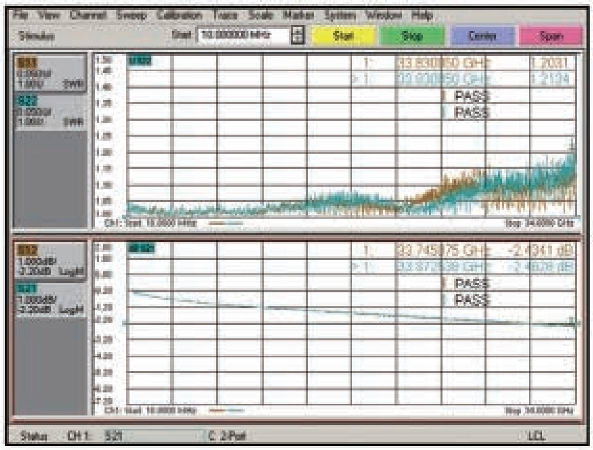
T26 Series DC~26.5GHz

Test Plot of T26 Assembly(3.5mm M - 3.5mm M, 1 Meter)



T34 Series DC~34GHz

Test Plot of T34 Assembly(3.5mm M - 3.5mm M, 1 Meter)



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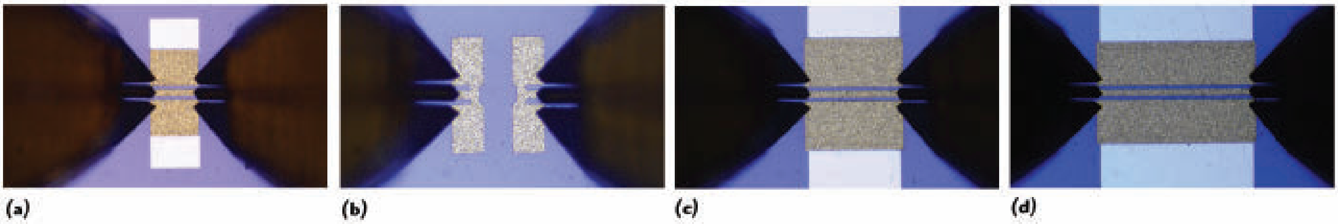
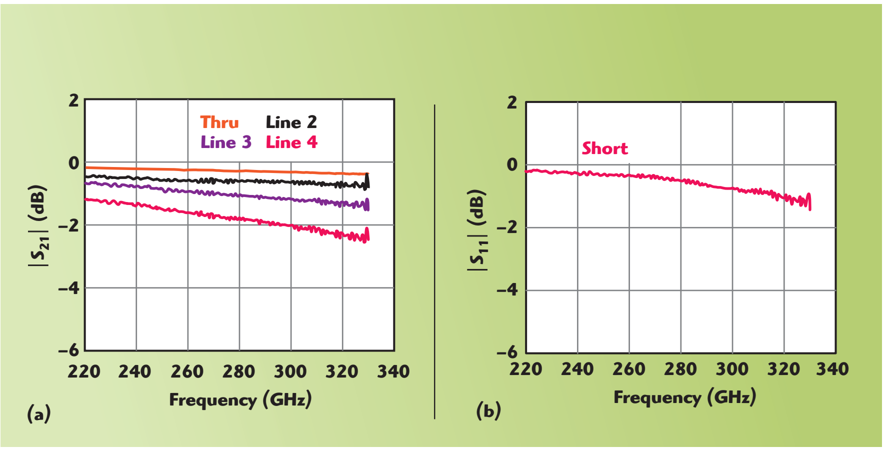


▲ *Fig. 7 Coplanar standards from the CS15 calibration substrate and probes from GGB Industries, Inc.: thru (a), short (b), line 2 (c) and line 3 (d).*



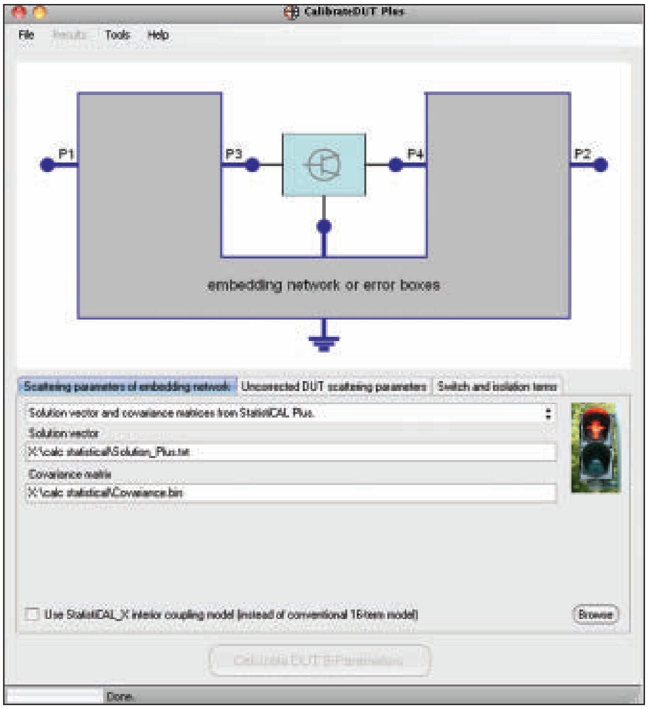
▲ *Fig. 8 Corrected results of the CS15 CPW line (a) and short (b) standards.*

CONCLUSION

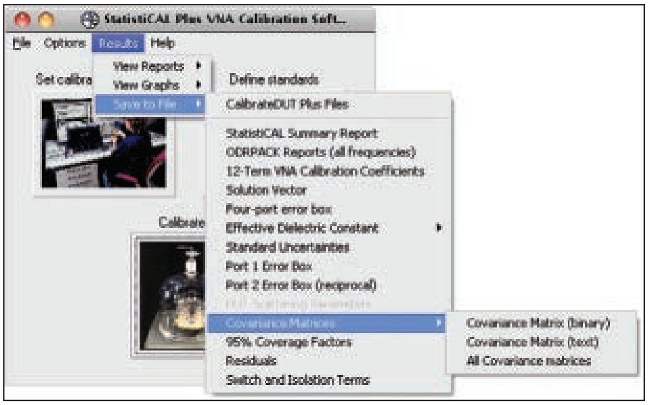
To demonstrate the system's capabilities, a four stage, 325 GHz MMIC low noise amplifier (LNA) developed by the Fraunhofer Institute for Applied Solid State Physics IAF was measured (see ***Figure 11***). $|S_{21}|$ is shown with the ±95 percent confidence intervals.

The expansion to THz frequencies of wafer-level measurements demands new approaches for system integration, calibration, operation and data analysis. Wafer probe systems designed from the ground up can incorporate many innovative features to simplify system operation and reconfiguration and provide the maximum measurement dynamic range and reproducibility. For the first time, it is possible to simplify the system calibration, device measurement and data analysis at the metrology level, by integrating the NIST StatistiCAL Plus and the NIST Uncertainty Framework software packages. Modular

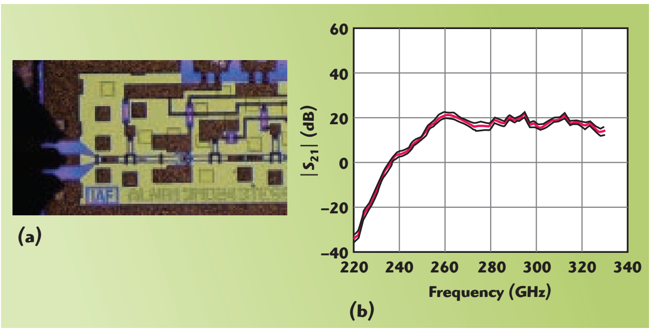
thermal and non-thermal chucks, advanced RF accessories (such as RF micro-positioners, RF cables, calibration substrates and RF probes), new calibration techniques and the integration of the VNA closer to the probe system yield a complete measurement solution that addresses the complexities and accuracy requirements of THz probing. ■



▲ *Fig. 9 The CalibrateDUT Plus tool from the NIST Uncertainty Framework package.*



▲ *Fig. 10 Exporting the calibration residual errors covariance matrix from StatistiCAL Plus.*



▲ *Fig. 11 Fraunhofer Institute four stage, 325 GHz MMIC LNA (a) and measured S_{21} with the ±95% confidence intervals (b).*

Power Analyzer Reaches 70 GHz with >100 dB Dynamic Range

Anritsu
Morgan Hill, Calif.

The MA24507A Power Master™ frequency selectable millimeter wave (mmWave) power analyzer from Anritsu is the world's first frequency selectable RF power sensor. By utilizing Anritsu's patented Shockline nonlinear transmission line (NLTL) technology, Power Master combines the industry's widest power measurement range, fast measurement speeds and the ability for the user to define the frequency of the signal to measure—all with the convenience of a USB-powered instrument. With measurement capability to 70 GHz, the MA24507A opens up new test capabilities for growing mmWave applications, like 802.11ad, WirelessHD™ and 5G wireless backhaul.

THE SHOCKLINE ADVANTAGE

Anritsu's state-of-the-art Shockline-based receiver uses a patented NLTL technique to sample RF signals. This gives Anritsu instruments the ability to sample high frequency signals that would normally require expensive fundamental mixers or leaky step recovery diode samplers. NLTL technology has made Anritsu the leader in high frequency VNAs, with products like VectorStar® and ShockLine™ VNAs. With Power Master, NLTL enables accurate measurement of mmWave power in an instrument just slightly bigger than a smartphone.

Anritsu's Shockline receiver has a dynamic range greater than 100 dB at all frequencies. Most power sensors use a diode or thermal-based element to detect changes in RF power. While these methods provide highly accurate power readings, they have limited power measurement range. Diode sensors typically do not measure signals below -60 dBm; even at that level, they require high measurement averaging to provide stable readings. Thermal sensors are even worse, generally tapping out around -30 dBm. Using the Shockline receiver to detect power, Power Master accurately reads many signals as low as -100 dBm. This is especially advantageous for over-the-air (OTA) testing of mmWave signals, which suffer high propagation losses through the air. Many mmWave receivers, like 802.11ad access points and automotive radar, may see signals below -90 dBm. With Power Master, users can read signals at those levels necessary for important tests like calibrating mmWave systems at both the transmitter and receiver, or measuring signal strength across various distances and through objects. This measurement flexibility creates a more robust test system by expanding the number of verification tests, which results in better designs and more reliable products.

COMPELLING FEATURES

PowerMaster allows the user to define the frequency band for measuring power. Thermal and diode-based sensors are inherently broadband, meaning they aggregate the power of all signals—regardless of the frequency—while making a measurement. That is not a concern for many controlled applications; however, in the field or when troubleshooting in the lab, it can hinder characterizing system behavior correctly. For example, when field testing signal strength for wireless backhaul networks, a diode or thermal power sensor will not differentiate between the intended RF signal from the other signals within the sensor's frequency range, which may

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- **Cutting-edge Technology** - exhibitors showcase the latest product innovations, offer hands-on demonstrations and provide the opportunity to talk technical with the experts
- **Technical Workshops** - get first hand technical advice and guidance from some of the industry's leading innovators

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Wednesday 5th October	09:30 - 17:30
Thursday 6th October	09:30 - 16:30

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- **European Microwave Conference (EuMC) 4th – 6th October 2016**
- **European Radar Conference (EuRAD) 5th – 7th October 2016**
- **Plus Workshops and Short Courses (From 3rd October 2016)**
- **In addition, EuMW 2016 will include the 'Defence, Security and Space Forum' on 5th October 2016**

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  - Sunday 2nd October (16:00 - 19:00)
  - Monday 3rd October (08:00 – 17.00)
  - Tuesday 4th October (08:00 – 18.00)
  - Wednesday 5th October (08:00 – 17.00)
  - Thursday 6th October (08:00 – 17.00)
  - Friday 7th October (08:00 – 10.00)

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Eu*M*A membership fees: Professional £19/year, Student £11/year.

If you register for membership through the EuMW registration system, you will automatically be entitled to discounted member rates.

Reduced Rates for the conferences are also offered if you are a Student/Senior (Full-time students 30 years or younger and Seniors 65 or older as of 1st August 2016).

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CONFERENCE FEES	ADVANCE DISCOUNTED RATE			
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1 Conference	Standard	Student/Sr.	Standard	Student/Sr.
EuMC	£355	£100	£500	£140
EuMIC	£270	£90	£380	£130
EuRAD	£240	£80	£340	£120
2 Conferences				
EuMC + EuMIC	£500	£190	£710	£270
EuMC + EuRAD	£480	£180	£680	£260
EuMIC + EuRAD	£410	£170	£580	£250
3 Conferences				
EuMC + EuMIC + EuRAD	£610	£270	£860	£390

STANDARD REGISTRATION CONFERENCE FEES (FROM 4TH SEPT. AND ONSITE)

CONFERENCE FEES	STANDARD RATE			
	Society Member (*any of above)		Non Member	
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.
EuMC	£500	£140	£700	£200
EuMIC	£380	£130	£540	£190
EuRAD	£340	£120	£480	£170
2 Conferences				
EuMC + EuMIC	£710	£270	£1,000	£390
EuMC + EuRAD	£680	£260	£950	£370
EuMIC + EuRAD	£580	£250	£820	£360
3 Conferences				
EuMC + EuMIC + EuRAD	£860	£390	£1,210	£560

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	Standard	Student/Sr.	Standard	Student/Sr.
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Half day WITHOUT Conference registration	£100	£75	£130	£100
Full day WITH Conference registration	£105	£80	£135	£100
Full day WITHOUT Conference registration	£135	£105	£180	£130

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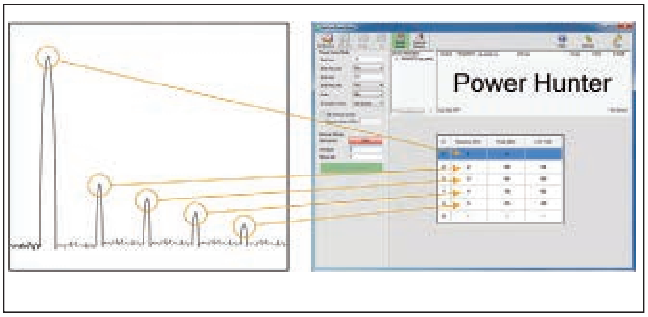
Date	**Time**	**Title**	**Location**	**No. of Days**	**Fee**	
Wednesday 5th October	11:20 - 19:00	Defence, Security & Space Forum	Rooms 8 to 11	1	£10 for delegates (those registered for EuMC, EuMIC or EuRAD)	£40 for all others (those not registered for a conference)



▲ *Fig. 1 The PowerXpert PC application enables users to search for CW peaks within any defined frequency channel up to 70 GHz.*

make the measurement useless. With Power Master, a field technician can define the frequency channel in which to measure power, focusing on the signals of interest or identifying specific interference in nearby channels. In the lab, an engineer verifying RF circuit designs can use Power Master for troubleshooting unexpected signal behavior caused by a dirty LO, bad components or outside signal interference.

Perhaps the most amazing benefit of the Shockline technology is its ability to fit all these features into a portable, USB-powered instrument that is convenient to use in the lab or field. Power Master is only slightly bigger than a smartphone, at approximately 6" × 3" × 1" and weighs less than 15 oz. For field testing, it is equipped with a standard ¼" mounting port that is compatible with a variety of extenders, perfect for raising the sensor close to access points or above crowds. In the lab or EMI chamber, it can connect the sensor to a tripod to position it for OTA testing. The sensor is also equipped with mounting holes for on-wafer testing. Instead of purchasing expensive low loss cables to connect to the power meter, Power Master connects directly to a probe, improving measurement accuracy and reliability.

Power Master comes with the standard benefits of a USB power meter. Because no reference calibration is required, the sensor can stay connected to a test system at all times, eliminating the need to disconnect and reconnect the sensor between test procedures. The sensor can be controlled by remote commands via the USB interface or through PowerXpert™, Anritsu's free PC application for USB power measurement tools. PowerXpert has been updated with new features to search for up to six power peaks across user-defined frequency bands or simultaneously monitor the RF power of up to six separate frequency channels (see ***Figure 1***).

Whether in the lab or the field, Power Master provides revolutionary power measurement capabilities. With the industry's best low power performance, frequency selectability and the convenience of a USB-powered instrument, Power Master is a "must have" for anyone testing WiGig, WirelessHD, auto radar or other mmWave applications.

VENDORVIEW

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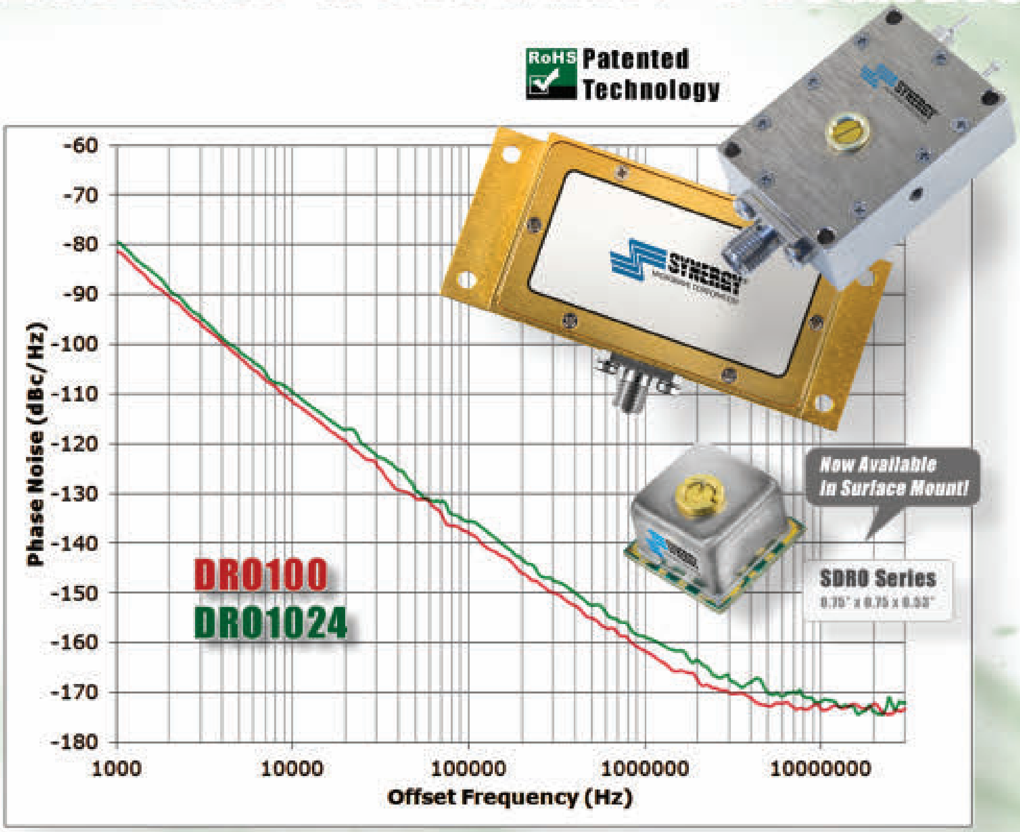

Model	Frequency (GHz)	Tuning Voltage (VDC)	DC Bias (VDC)	Typical Phase Noise @ 10 kHz (dBc/Hz)
Surface Mount Models				
SDRO1000-8	10	1 - 15	+8 @ 25 mA	-107
SDRO1024-8	10.24	1 - 15	+8 @ 25 mA	-111
SDRO1250-8	12.50	1 - 15	+8 @ 25 mA	-105
Connectorized Models				
DRO100	10	1 - 15	+7 - 10 @ 70 mA	-111
DRO1024	10.24	1 - 15	+7 - 10 @ 70 mA	-109

Model	Center Frequency (GHz)	Mechanical Tuning (MHz)	Supply Voltage (VDC / Current)	Typical Phase Noise @ 10 kHz (dBc/Hz)
Mechanical Tuning Connectorized Model				
KDRO145-15-411M	14.5	±4 MHz	7.5 V / 90 mA (Max.)	-88

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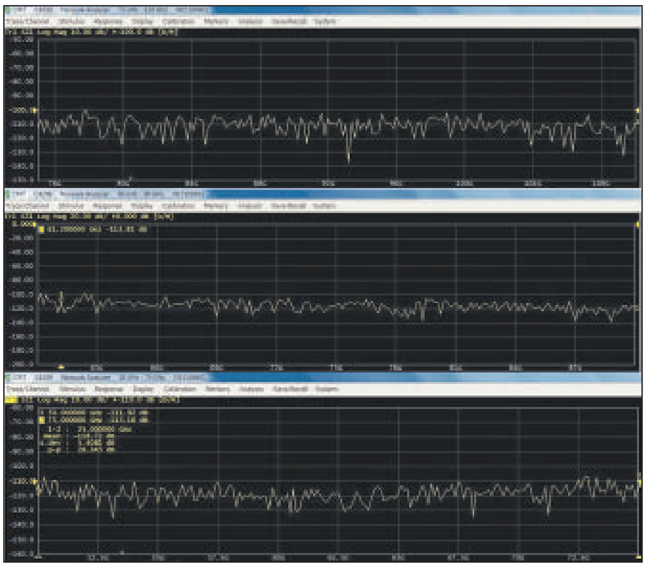
Affordable, mmWave VNA Solutions

Farran Technology
Cork, Ireland
Copper Mountain Technologies
Indianapolis, Ind.

With the advent of the Internet of Things (IoT), WiGig and 5G technologies moving to higher frequencies and backhaul at 60, 70 and 80 GHz, the need for S-parameter testing at higher frequencies is increasing. Traditional solutions also have to change to meet the requirements of today's applications: material characterization, on-wafer benchtop measurements, near and far field antenna and radar cross-section measurements, as well as automotive and non-automotive radar sensors.



▲ *Fig. 1 Dynamic range of the CobaltFx.*

To address these issues, Farran Technology and Copper Mountain Technologies have partnered to create CobaltFx—a new mmWave frequency extension solution, which the companies say is the first mmWave frequency extension solution that utilizes a 9 GHz VNA. CobaltFx's high dynamic range (see ***Figure 1***) and directivity allows for highly accurate and stable mmWave S-parameter measurements in three dedicated waveguide bands; 50 to 75 GHz, 60 to 90 GHz and 75 to 110 GHz.

The C4209 VNA used in this system is from Copper Mountain Technologies' Cobalt series. It features fast sweep speeds down to 10 µs per point and a dynamic range of up to 162 dB, all contained in a compact, USB form factor.

The C4209 works seamlessly with Farran Technology's mmWave FEV frequency extenders (see ***Figure 2***) that are packaged in small,

▲ *Fig. 2 Farran Technology's mmWave FEV frequency extenders are packaged in small and versatile enclosures.*

versatile enclosures that allow for flexible port arrangements with respect to the waveguide. Waveguide ports are manufactured in accordance to the new IEEE 1785-2a standard and ensure alignment and repeatability of connection, allowing for long interval times between calibration. The system comes with a precision calibration kit containing flush short, offset piece and broadband load.

MEASUREMENT CAPABILITIES

The CobaltFx will perform full S-parameter measurements with full 12-term port calibration. Time domain measurements are also possible. Mounting feet can be removed or orientated on different faces, giving the maximum flexibility in waveguide positioning.

The CobaltFx incorporates various sweep features with up to 16 independent logical channels: each logical channel is represented on the screen as an individual channel window. Extensive trace functions are available, including the ability to view data trace, memory trace or both. Data trace modifications by math operations, autoscaling, electrical delay and phase offset are also standard functions. The system software is COM/DCOM compatible, which allows the system to be used as part of an ATE station. The system and software are also fully compatible with LabView applications, enabling flexibility in user-generated programming and automation.

Other features and specifications include: Test port output power is 0 to +5 dBm minimum and typically +5 to +8 dBm, while the test port input power is typically +10 to +15 dBm. The system dynamic range, shown in Figure 2, is typically 110 to 120 dB, and the trace stability is ±0.2 dB. The RF/LO port damage level is +10 dBm minimum.

Calibration kits (FEK-15/12/10-0006) are also supplied, which ensure accurate and repeatable measurements. They are compatible with TRL and SOLT calibration techniques and contain full characterization data for the components required by the CobaltFx system for calibration.

APPLICATIONS

The potential applications for the CobaltFx system are extensive. It can easily perform antenna range measurements requiring high dynamic range and a fast sweeping test system. During the measurement, antenna gain, pattern, efficiency and directivity can be verified as well as parameters of the radome, while directivity and reflectivity measurements are fundamental for evaluating the backscatter parameters of the target.

5G technology is considered to be a fundamental medium for the IoT, and unlocking the high frequency part of the frequency spectrum (>50 GHz) is key to this concept. CobaltFx is a cost effective solution to enable the integration of various devices, materials, antenna beam forming and channel propagation concepts for indoor and outdoor 5G communication.

Multi-Gigabit Wi-Fi technology operating at 60 GHz will expand the capacity for indoor Wi-Fi data transmission. With 3D and 4K video streaming within the wireless network and devices there is a need for chipset and antenna technology to offer bandwidth and range that will reliably replace cable connectivity. High levels of integration of various technologies operating from single MHz to the 60 GHz range requires very accurate and thorough characterization of consumer electronics equipment. The CobaltFx system can address this application very cost-effectively.

With adaptive cruise control, collision mitigation and pedestrian detection systems already available; autonomous driving under development; and various non-automotive radar sensor applications for foreign object detection, perimeter and security detection, collision avoidance and moving object detection; the need for thorough characterization of devices and materials at 77 and 79 GHz has never been greater. CobaltFx offers a cost effective and flexible test and measurement solution for radar applications.

Every test laboratory in a commercial or industry orientated organization involved in production and testing of various components must have the means to evaluate their products. CobaltFx can carry out all these measurements and, with its flexibility and compactness, it easily fits on the lab bench.

On-wafer, S-parameter measurements provide for model generation of discrete semiconductor devices (diodes, transistors, MMICs). For accurate models, the data obtained during measurement must be accurate, and the system must allow for long time intervals between calibrations for development cost reduction. Such tasks require that mmWave test equipment is stable and accurate while being compact and flexible.

The increase in usage of mmWaves for high speed digital radio communications and radar sensors is driving the need for high frequency characterization of various materials: PCB laminates, antenna radomes and lenses, vehicle windscreens and various other dielectric composites. Accurate characterization is fundamental to understanding frequency dependent dielectric constant and loss tangents that allow for better modeling of structures, shorter development time and ultimately lower cost of the product. For material characterization, the CobaltFx system offers an accurate, compact and cost effective way of understanding the impact of various materials on the high frequency performance in today's and future mmWave components and systems.

Farran Technology
Cork, Ireland
www.farran.com

Copper Mountain Technologies
Indianapolis, Ind.
www.coppermountaintech.com

10 mm Diameter Circulators and Isolators for Wireless Infrastructure

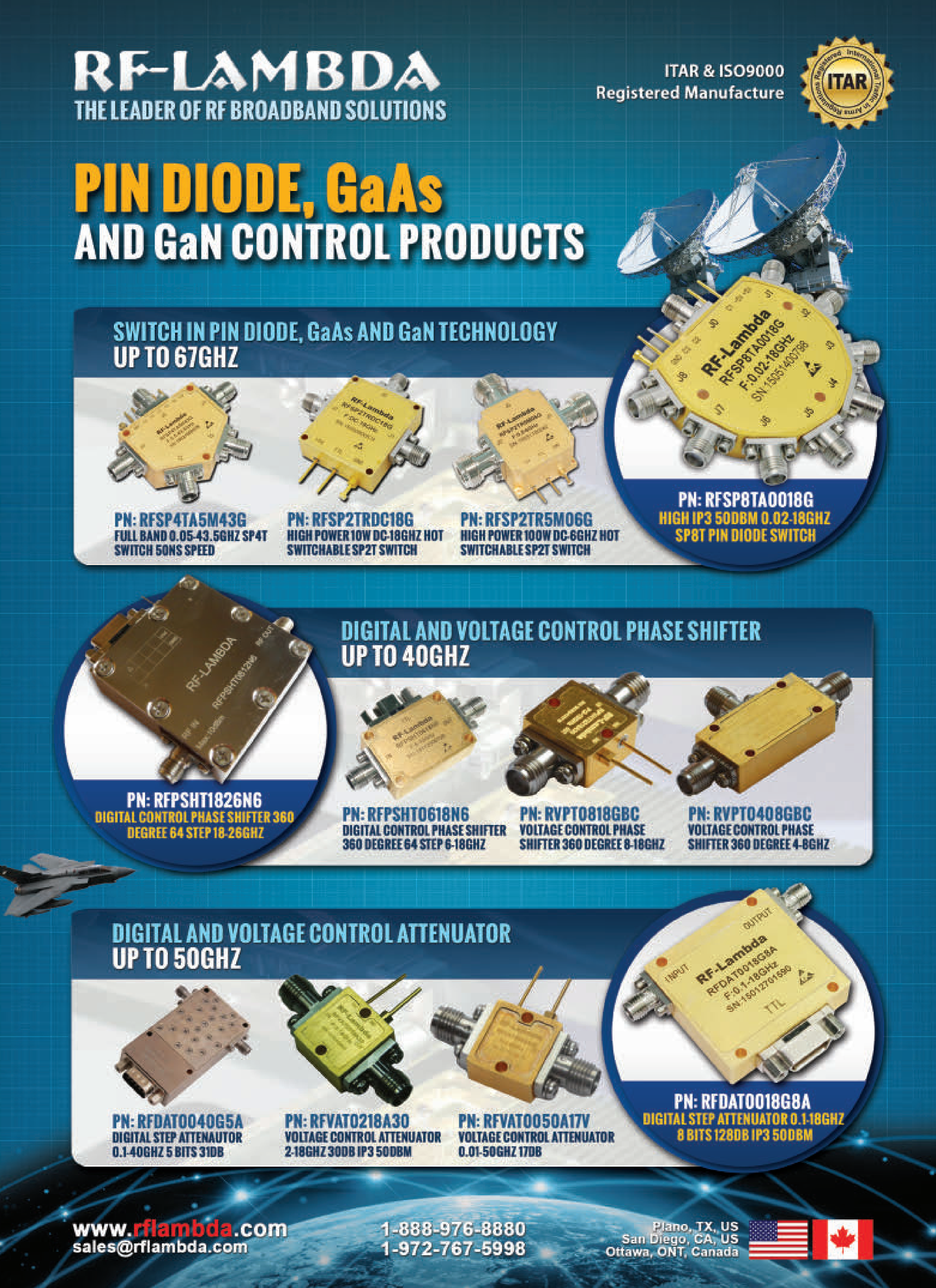
Skyworks Solutions, Inc.
Woburn, Mass.

Targeting wireless infrastructure, Skyworks Solutions has developed the world's smallest stripline junction circulators and isolators. The junction of this new product family is only 8.5 mm in diameter, with the contact pins on a 10.2 mm diameter circle. Both circulators and isolators are available for all standard wireless bands between 1.8 and 3.6 GHz (see ***Table 1***). These devices are all housed in a surface-mount package with robust leads and shipped in tape and reel packaging.

NEW HIGH K FERRITE MATERIAL

The key to the extremely small junction size is a new, high dielectric ferrite material developed by Skyworks. Manipulating the garnet structure yielded much higher dielectric constants than previously available, which enabled the size reduction. Garnets are crystalline materials with ferrimagnetic properties. Yttrium iron garnet (YIG) is a synthetic form of garnet widely used in ferrite devices because of its favorable magnetic properties, such as narrow line absorption at its ferromagnetic resonance frequency. YIG is generally composed of yttrium, iron and oxygen and is doped with one or more other rare earth metals such as the lanthanides or scandium. Substituting ions of higher polarizability into the structure, while simultaneously keeping magnetocrystalline anisotropy low, achieves low magnetic and dielectric losses without compromising temperature, linearity and power stability. Magnetization up to 1950 G is possible with this new range of materials, with dielectric constants up to 31.

New nano-level powder processing techniques are integral to manufacturing these materials. Various aspects of the design, manu-



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PN: RFSP2TR5M06G
HIGH POWER 100W DC-6GHZ HOT SWITCHABLE SP2T SWITCH
RF-Lambda
RFSP8TA0018G
F:0.02-18GHz
PN: RFSP8TA0018G
HIGH IP3 50DBM 0.02-18GHZ
SP8T PIN DIODE SWITCH
DIGITAL AND VOLTAGE CONTROL PHASE SHIFTER
UP TO 40GHZ
RF-LAMBDA
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DIGITAL CONTROL PHASE SHIFTER 360 DEGREE 64 STEP 18-26GHZ
PN: RFPSHT0618N6
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PN: RVPT0818GBC
VOLTAGE CONTROL PHASE SHIFTER 360 DEGREE 8-18GHZ
PN: RVPT0408GBC
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PN: RFDAT0040G5A
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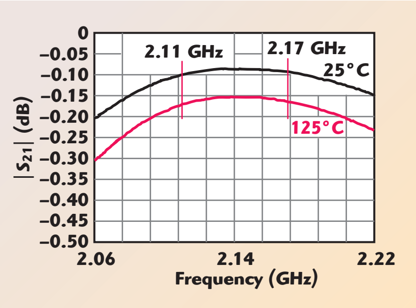
DIGITAL STEP ATTENUATOR 0.1-18GHZ 8 BITS 128DB IP3 50DBM
www.rflambda.com
sales@rflambda.com
1-888-976-8880
1-972-767-5998
Plano, TX, US
San Diego, CA, US
Ottawa, ONT, Canada

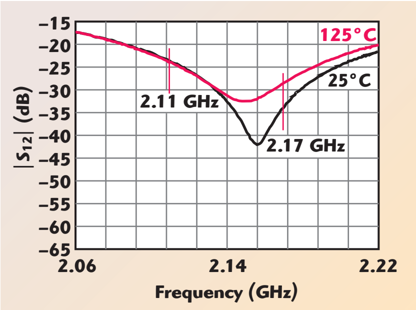
TABLE 1

WIRELESS INFRASTRUCTURE CIRCULATOR AND ISOLATOR PRODUCTS

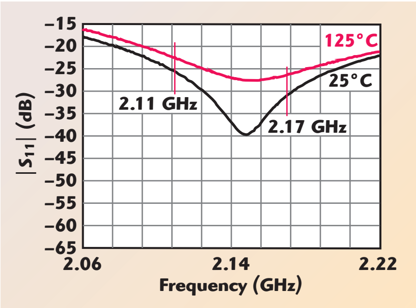
Part Number	Type	Cellular Band	Start Frequency (MHz)	Stop Frequency (MHz)	Insertion Loss, Max (dB)	Return Loss, Min (dB)	Isolation, Min (dB)
SKYFR-001387	Circulator	3	1805	1880	0.25	20	20
SKYFR-001436	Isolator	3	1805	1880	0.25	20	20
SKYFR-001388	Circulator	2	1930	1990	0.25	20	20
SKYFR-001437	Isolator	2	1930	1990	0.25	20	20
SKYFR-001389	Circulator	1	2110	2170	0.25	20	20
SKYFR-001438	Isolator	1	2110	2170	0.25	20	20
SKYFR-001390	Circulator	40	2300	2400	0.25	20	20
SKYFR-001439	Isolator	40	2300	2400	0.25	20	20
SKYFR-001461	Circulator	7	2620	2690	0.25	20	20
SKYFR-001460	Isolator	7	2620	2690	0.25	20	20
SKYFR-001452	Circulator	42	3400	3600	0.25	20	20
SKYFR-001512	Isolator	42	3400	3600	0.25	20	20



▲ *Fig. 1 Band 1 isolator insertion loss (SKYFR-001438).*



▲ *Fig. 2 Typical isolation of the isolator.*



▲ *Fig. 3 Typical return loss of the isolator.*

facturing and application of these materials are patented (US 8696925 and US 9263175).

PERFORMANCE AND PACKAGING

The SKYFR-001438 shows the typical performance from this new product family. A single junction isolator in a 10 mm diameter housing, the SKYFR-001438 operates from 2110 to 2170 MHz (Band 1). Typical insertion loss is 0.12 dB and is specified to be a maximum of 0.25 dB over the operating temperature range from -40° to +125°C (see ***Figure 1***). Isolation (see ***Figure 2***) and return loss (see ***Figure 3***) are both typically 25 dB at room temperature. The typical intermodulation distortion (IMD) performance is 65 dBc with two 10 W CW tones.

Skyworks' patented "robust lead" package allows the circulators and isolators to be populated on a printed circuit board (PCB) using automated surface-mount assembly. The package has a unique vertical lead that connects the center conductor of the circulator to the customer's PCB. The silver plated lead is firmly encased inside high temperature plastic, ensuring a robust design with excellent coplanarity. The main body of the device is also silver plated for excellent solderability; it can be attached to the PCB using a standard reflow profile. All robust lead devices are shipped in tape and reel packaging for automated placement.

The 10 mm circulator and isolator product family is extremely reliable. Skyworks subjected this new platform to extensive reliability testing, including thermal shock, humidity, vibration and high temperature soak. These devices will withstand up to 50 W average CW RF forward power when mounted on a PCB with good thermal grounding. The isolators include an aluminum nitride (AlN) termination and can handle up to 30 W of reverse power.

VENDORVIEW

Skyworks Solutions Inc.
Woburn, Mass.
www.skyworksinc.com

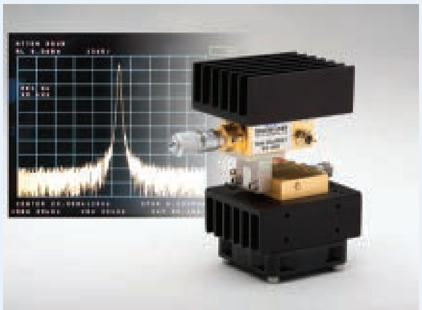
USB/Ethernet-Controlled Miniature Switch Modules

Teledyne Relays has developed three new series of miniature switch matrices that combine Teledyne's 50 Ω electromechanical coaxial switches with remote control. The MMA series controls up to four SPDT switches with three frequency band options: DC to 18 GHz, DC to 26.5 GHz or DC to 40 GHz. The MMB series controls up to four transfer switches covering DC to 18 GHz. The MMC series controls one or two SPMT switches (SP3T, SP4T, SP5T or SP6T) with three frequency range options: DC to 18 GHz, DC to 26.5 GHz or DC to 40 GHz. Switch matrix RF interfaces are SMA or 2.92 mm connectors. The operating temperature range is -40° to +65°C, and the switch actuators have a typical life of five million cycles.

Remote operation is accomplished with TCP/IP commands to the matrix's Ethernet interface. Switch control is also accessible using a USB virtual serial port and the provided command set. The interfaces enable the coaxial switch to be set to the desired position and the position read back to verify switching. The miniature switch modules features a graphical user interface (GUI) that enables the user to control the switches through graphical icons and visual indicators, instead of text-based interfaces or typed command labels. The interface is compatible with multiple system platforms, including NI's LabVIEW, which enables quick device interfacing and integrating switch control with existing programming.

Teledyne Relays has a heritage in military programs that spans more than 50 years. Teledyne Relay products are also used in industrial, commercial and medical applications.

Teledyne Relays
Hawthorne, Calif.
www.teledynerelays.com



Tunable, Wideband, Ka-Band Source with High Output Power

Spacek Labs has developed a wideband, tunable frequency source with high output power, the first in a planned product family. Model GKa-300VA-1 produces 500 mW output power over a 4 GHz bandwidth centered at 30 GHz. The Gunn oscillator is tuned using a locking micrometer that inserts a dielectric rod into the iris-coupled resonant cavity. The 30 mW output power of the Gunn source is then amplified to 500 mW with a solid-state output amplifier. The Gunn oscillator is biased with +7 VDC at 0.5 A, and the power amplifier requires +8 VDC at 0.6 A. The output interface can either be coax or waveguide.

Model GKa-300VA-1 is the latest addition to Spacek Labs' complete line of Gunn oscillators that cover 18 to 110 GHz. Combining broadband Gunn oscillators with power amplifiers creates a high power option for these affordable sources. The output signal can be modulated by adding a varactor to the Gunn oscillator, adding the capability for carrying data with a 100 MHz deviation and a 50 MHz modulation rate. The frequency, bandwidth and output power of the sources can be customized to address more potential applications than just using a stand-alone Gunn oscillator.

Formed in 1982, Spacek Labs is a small, woman-owned business manufacturing microwave and millimeter wave components and subsystems. Products are manufactured at the company's facilities in Santa Barbara, Calif. with all manufacturing and test equipment in house except for testing shock and vibration.

Spacek Labs Inc.
Santa Barbara, Calif.
www.spaceklabs.com

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- Doherty at Eighty
- Millimeter Wave and E-Band Vector Network Analyzer Solutions
- Making Noise Work for You
- RF and Microwave Heating Simulation and Application Design
- Critical Aspects of Dielectric Constant Properties for High Frequency Circuit Design
- Demystifying MIMO Radar and Conventional Equivalents

RF/Microwave Training Series
Presented by: Besser Associates
- Introduction to Radar
- RF and Microwave Filters
- Mixers and Frequency Conversion

CST Webinar Series
- Hybrid Simulation for Electrically Large Aerospace Platforms
- Simulation of Implanted Medical Devices

Innovations in EDA
Presented by: Keysight Technologies
- Advances in High Power RF Design
- 5G Physical Layer Modeling: A Communication System Architect's Guide
- Designing X-Band PAs Using SMT Plastic Packaged GaN Transistors

Keysight Technologies Webcast
- LTE in the Unlicensed Spectrum
- Using a Multi-Touch UI to Streamline Signal Analyzer Measurements
- Testing Voice Over LTE on Your Device

Keysight RF and Microwave Basics Education Series
- Simulating, Generating and Analyzing Custom-Modulated Satellite Signals

Keysight FieldFox Series
- Wireless Site Survey, Spectrum Monitoring and Interference Analysis

More Efficient Search Engine

The comprehensive search engine on AmpliTech's website has been significantly revamped to allow for searches based on particular specifications and partial model numbers, offering results that are closest to the entered parameters. The algorithm has also been changed to offer up the "next best" solution in case the customer has some flexibility in their specification requirements. More versatility now allows searches by using either a start or stop frequency as opposed to both. All of these advanced search features can be used in combination.

AmpliTech Inc.
www.amplitechinc.com

Benchtop PA Demo

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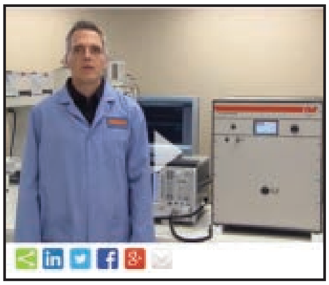

AR's 350S1G6 provides wideband high linear output power over a frequency band of 0.7 to 6 GHz. Over 350 W of output power is achieved with only 1 mW of input power. This amplifier is designed using "Hybrid Microelectronics Technology," resulting in an amplifier with greater power density, smaller size and lower production cost than previously possible. Visit www.arworld.us/html/video-AR350S1G6%20Amplifier.asp for a full product demo.

AR RF/Microwave Instrumentation
www.arworld.us

Website Launch

Daisy RS has just launched a new website. The company is currently focusing its efforts towards the wireless power monitoring distribution industry. Daisy RS produces portable systems for various remote solutions (RS). The RS2026 is designed with a patented algorithm that provides exceptional performance and accuracy. Unlike large or bulky laboratory instruments with troublesome cables, the RS2026 employs wireless technology, making it lightweight, fast and convenient with an intuitive GUI interface for quick measurements with an Android, iPhone or tablet.

Daisy RS Inc.
www.daisyrsi.com

New Brand, New Website

Delta Electronics Manufacturing Corp. unveiled a new brand identity and website that captures the company's position as a global provider of precision interconnect and innovative solutions. The company's new identity was formally unveiled at IMS2016 in San Francisco, Calif., along with their redesigned website at www.deltarf.com. The new logo reflects the strengths behind the Delta brand and the precision inherent in the interconnect products they manufacture.

Delta Electronics Manufacturing Corp.
www.deltarf.com

New and Improved

K&L Microwave's website provides information and tools to speed the identification and specification of custom design solutions from the full range of company products. The latest update features a new look, mobile device support and improved LTE Band navigation to test set components for broadband emission monitoring. K&L is part of the Microwave Products Group, a premier global supplier of mission/system-critical engineered electronic components and subsystems. Research capabilities, access datasheets, submit quote requests and download catalog sections. Visit www.klmicrowave.com today.

K&L Microwave
www.klmicrowave.com

Insights Unlocked

VENDORVIEW

Insights Unlocked, Keysight's newest blog features Keysight thought leaders who share their reflections, lessons and insights on the technology and business issues of interest to today's electronics industry. Current topics include success factors for technology refresh, an exploration of the myths and realities of 5G, an analysis of the benefits of corporate collaboration with universities, and best practices that foster innovation. Bookmark or follow www.keysight.com/find/insightsunlocked for regular updates.

Keysight Technologies Inc.
www.keysight.com

Web&VideoUpdate

Extensive Capabilities

Massachusetts Bay Technologies Inc. (MBT), an RF/microwave semiconductor diode and passive manufacturer, has launched a new website. The new site includes extensive product information to help customers understand MBT's complete product portfolio. Whether you are looking for a hi-rel diode, standard diode(s), or custom chip capacitors, the new website provides a detailed overview of MBT's capabilities. With the recent FAB closures in the RF/microwave diode marketplace MBT stands to deliver.

Massachusetts Bay Technologies
www.massbaytech.com

Competitor Cross Reference

Leaders in RF innovation and technology for more than 60 years, NXP offers an extensive portfolio of RF products for wireless infrastructure, broadcast, medical, mobile radio, aerospace and defense, cooking and industrial markets, from milliwatts to kilowatts. Access the company's competitor cross reference with other manufacturers part numbers to find an equivalent NXP RF part number match. Explore NXP's RF portfolio now at www.nxp.com/webapp/crosscheck/competitorXRef.sp.

NXP Semiconductors
www.nxp.com/RF

Configure Your Product

VENDORVIEW

Have you ever wanted to flexibly configure your loads and attenuators to make them a perfect fit for your projects? SPINNER loads and attenuators can be easily customized in three steps. First, select the power that needs to be absorbed, then choose the connector interface(s) and attenuation and you're done! Extra features such as an extended frequency range, recording of measurements or an integrated DC break can be optionally selected. This video presents the available options. Use SPINNER's sales article numbers to flexibly configure your product.

SPINNER Group
youtube.com/user/SPINNERGMBH

European Microwave Week

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London 5G

European Microwave Week

Product Showcase

For complete coverage of the EuMW conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at www.mwjournal.com/eumw2016.

EuMW 2016
Microwaves Everywhere

Stands 1-19

Maury Microwave — Stand 1A
Measurement and Modeling Solutions

Exceptional companies have superior labs - complete your lab with Maury Microwave! Maury, a leader in measurement and modeling device characterization solutions, VNA calibration accessories and interconnections, will be showcasing active and hybrid-active harmonic load pull solutions, LXI-certified mechanical impedance tuners, pulsed IV/RF compact transistor modeling as well as coaxial and waveguide VNA calibration kits and metrology adapters, in-stock color-coded precision and daily-use adapters, and test-port, phase-stable and value cable assemblies. Visit Maury for details, demos, deals and NPIs.

www.maurymw.com

Keysight Technologies — Stand 2
Handheld Analyzers with Real-Time Spectrum Analysis up to 50 GHz

Keysight Technologies now offers the industry's first handheld analyzers with real-time spectrum analysis (RTSA) up to 50 GHz. FieldFox RTSA software, Option 350, is designed for engineers and technicians performing interference hunting and signal monitoring in surveillance and secure communications, radar, electronic warfare and commercial wireless applications. RTSA can capture burst signals in real-time, making them significantly easier to detect. By capturing a range of signals, FieldFox's new RTSA option provides a composite view, allowing easy identification of the source of interference.

VENDORVIEW
www.keysight.com/find/FieldFoxRTSA

Rohde & Schwarz GmbH & Co. KG — Stand 3
True Multiport VNA up to 20 GHz

The new R&S ZNBT20 is the first true multiport vector network analyzer in the microwave range with up to 16 integrated test ports. The unique hardware architecture from the R&S ZNBT has been extended to 20 GHz. This allows users to characterize multiple DUTs in parallel and thus increase throughput tremendously. The R&S ZNBT offers the high measurement performance of a two-port network analyzer at each of its test ports. The high number of ports is relevant for the production of active and passive multiport components.

VENDORVIEW
www.rohde-schwarz.com

National Instruments/AWR — Stand 4
Software Solutions

AWR NI AWR Design Environment

Visit NI/AWR in Stand #4 to see recent advances in NI AWR Design Environment™ for the design of power amplifiers, filters, radar systems and more. Also, don't miss the opportunity to see their newest product, Antsyn™ antenna synthesis and optimization technology, a new cloud-based software as a service (SaaS) antenna design, synthesis and optimization solution. AntSyn enables both experts and relatively new antenna designers to input their antenna engineering requirements and produce antenna designs as outputs.

VENDORVIEW
www.awrcorp.com/eumw2016

Teledyne Microwave Solutions — Stand 19
High Power GaN X-Band SSPAs

TMS' GaN-based SSPAs are available with 1 GHz bandwidth from 9 to 10 GHz, and offer 350 W, 550 W, and 1000 W peak output power. Designed in a compact, environmentally sealed housing, these SSPAs can be used in airborne or ground-based environments. Features include superior spurious emissions performance, integrated

Stands 19-56

bias control for GaN devices, modular architecture for flexible design and scalability and proprietary power-combining approach.

VENDORVIEW

www.teledynemicrowave.com

Teledyne Relays — Stand 19
RF121 Relay

Teledyne Relays announced its new RF121 relay. The RF121 is a high repeatability, SPDT, broadband, magnetic-latching RF relay with performance to 16 GHz and industry leading signal integrity to 40 Gbps. It is ideal for switchable RF attenuators, RF switch matrices, high frequency spectrum radios, ATE and other applications that require dependable high frequency signal fidelity and performance. The RF121 is available in through-hole and surface-mount stub pin configurations.

www.teledynerelays.com

LPKF Laser & Electronics — Stand 24
ProtoLaser S4 Laser System

The LPKF ProtoLaser S4 laser system uses a green laser wavelength and can laser etch PCBs in minutes on a wide range of laminated substrates, FR4 and PTFE or woven PCB materials. Prototypes and small production batches can also be produced on short notice if required. The LPKF ProtoLaser S4 is even more precise than the mechanical systems and is therefore ideal for HF and microwave circuits, as well as digital and analog circuits.

www.lpkf.com

API Technologies — Stand 39
Low PIM Attenuator

API Weinschel's portfolio of low PIM attenuators includes the newly introduced Model 264 LIM series for applications up to 10 GHz. These resistive-based designs offer size, weight and economic alternatives to airline coupler and cable-wound low PIM attenuator solutions. Maximum IM3 of -155 dBc is achieved for 30 and 40 dB units when testing with two carrier tones, each with an average power level of +43 dBm. Connector configurations include Mini DIN, 7-16 DIN and Type N.

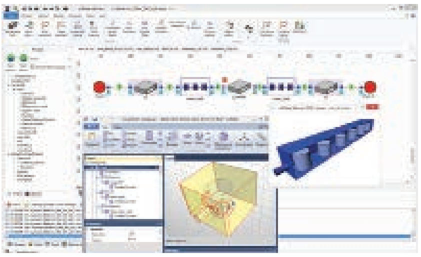
www.weinschel.apitech.com

Micran — Stand 49
Measurement Equipment

Micran is a modern innovative enterprise with a strong team of specialists, combining experience in the different spheres of microwave electronics, communications, radio location, test and measurement equipment and information security. This unique, talented, multi-disciplinary team is viewed very positively by our current customers and partners. They are always ready to bring their wide expertise to accept new challenges.

www.micran.ru

Mician — Stand 55
EM Software Tools



Mician is recognized as a leading developer of EM software tools for the design and optimization of waveguide components, feed networks and horn antennas. Version 8, the latest release of Mician's signature product μWave Wizard, now includes a modeler for user defined elements and comes with a new ribbon based graphical user interface. Speed up of GUI launch for very large projects is now up to 10 times faster, and includes a new direct and iterative solver, and parallelization is possible.

www.mician.com

Mini-Circuits — Stand 56
High Power Amplifier

The ZHL-100W-272+ is a high power amplifier module supply which can be used for a wide variety of laboratory testing applications. This rugged amplifier is capable of amplifying signals up to 100W output power over its entire operating frequency range

of 700 to 2700 MHz. Built-in safety features include over-temperature protection and the ability to handle short/open Mismatch at output while delivering up to 3 dB compression output power, preventing amplifier damage and providing excellent reliability.

VENDORVIEW

www.minicircuits.com

Rosenberger Stand 60

Multifunctional Site Analyzer

For efficient on-site tests and measurements, Rosenberger introduces its new CPRI and RF PIMmultifunctional Site Analyzer α, the world's first analyzer for all kinds of mobile network infrastructure—with copper or fiber interface. With exchangeable filter units, this portable equipment is ultra-broadband and presents various options in terms of test and measurement functionality: CPRI PIM, RF PIM, RF Return Loss/VSWR, isolation and the most accurate distance to fault in the market.

www.rosenberger.com/pia

Planar Monolithics Industries Inc. Stand 77

Vector Phase Shifter

PMI Model PS-2G18G-360-8D is a 2 to 18 GHz, 8-Bit, vector phase shifter ideal for frequency translation where continuous monotonic phase shifting is required. This model features high speed switching (<410 ns measured), phase shift 360 with a ±15 accuracy (typical), 18 dB maximum insertion loss and typically lower than 60 dB harmonic distortion. Package size: 4.25" × 3.50" x 1.00", SMA(F) connectors, DC-37P, sub miniature D multi-Pin control connector and operates using ±12 to ±15 V @ ±100 mA maximum.

VENDORVIEW

www.pmi-rf.com

IMST GmbH Stand 86

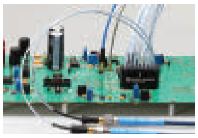
3D EM Field Solvers

EMPIRE XPU is one of the leading 3D EM field solvers for RF and microwave antennas, components and systems. Due to its unique just in time compilation it has proven to be the fastest simulation engine which allows the modeling of highly complex structures within minutes. The new version EMPIRE XPU 7.5 features a professional 3D Design mode and the XPU FDTD simulation technique reaching 14,000 million FDTD cells per second on a modern PC.

www.empire.de

Huber+Suhner Inc. Stand 102

MXP – Multicoax Test Solution



In a world where performance, speed and density matter, the MXP multicoax solution is the perfect fit. The small form factor and outstanding electrical characteristics combined with reliable mating and ease of use make our MXP an excellent solution for benchtop and system testing with a large selection of bandwidths. MXP50 (50 GHz), MXP40 (40 GHz) and MXP18 (18 GHz) cover current data rate requirements. The entire MXP family comes with the highly flexible and ultra-stable MULTIFLEX cable as a standard.

VENDORVIEW

www.hubersuhner.com

MPI Corp. Stand 109

Fully Automatic Probe System

MPI TS2500-RF is designed specifically for advanced RF device testing in production. Available for ambient/hot temperature operation modes, the TS2500-RF can reach max. speed of 10 dies/second. The unique wafer chucks and lift pins can safely handle wafers of thickness down to 50 µm, enabling testing of thin III-Vs compound wafers. Advanced alignment features such as off-axis and chuck mounted upper-looking cameras make TS2500-RF an ideal platform for production testing with complex RF measurement configurations.

www.mpi-corporation.com

Stands 114-156

Spectrum Elektrotechnik GmbH — Stand 114

Push-Pull Connectors

Spectrum's most innovative designs are the push-pull connectors and adapters. They mate with standard connectors of types SMA, N, TNC and 7/16. The function is very simple. The push-ons slide onto the mating connector and can also lock automatically. For disconnecting just release and pull off. No special instructions have to be followed, no special handling is needed. Using these devices means saving time when testing products! Buying just the push-on adapter turns your assembly into a push-on assembly.

www.spectrum-et.com

OML Inc. — Stand 120

WR-10 VNA Compact Module

OML introduces the new VxxVNA3 Series compact version of its frequency extender for Vector Network Analyzers (VNA). Without compromising performance, OML's new compact, V10VNA3-T/R module covering 75-110 GHz, is now 6.16"(L) × 1.70" (H) × 3.72" (W). This innovative small compact design module is targeted for ease of use with probe station configurations while still fully compatible with VNA setups. Contact OML for more details.

www.omlinc.com

Infineon Technologies Americas Corp. — Stand 146

GaN RF Power Transistors

Infineon introduces a new family of GaN over SiC RF power transistors for L-Band radar and commercial avionics amplifier designs. The GTVA-123501FA offers 350 W (P3dB) of output power from 1200 to 1400 MHz, minimum of 70% drain efficiency and 17 dB of gain. The GTVA104001FA offers 400 W (P3dB) of output power across the entire 960 to 1215 MHz frequency band while providing minimum of 17.5 dB of gain and 70% drain efficiency. Engineering samples and broadband evaluation boards are now available.

www.infineon.com/rfpower

Greenray Industries Inc. — Stand 152

OCXO

Greenray Industries Inc. has announced the availability of the YH1485 OCXO. The new, high performance YH1485 oven controlled oscillator, available from 10 to 120 MHz with +10 dBm sinewave output, features low phase noise down to -180 dBc/Hz. The YH1485 is also available with low acceleration sensitivity down to $< 3 \times 10^{-10}$/g for better performance during shock and vibration. Packaged in a compact, 1 in. square, low profile package, the YH1485 uses +15 VDC or +12 VDC supply. EFC (electronic frequency control) is provided for precise tuning or phase locking applications.

www.greenrayindustries.com

Wolfspeed — Stand 156

HEMTs

Wolfspeed is a global supplier of gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistors (HEMT) and monolithic microwave integrated circuits (MMIC). Wolfspeed introduces a new 50 V, 900 W GaN HEMT device that provides high output power for L-Band radar applications. The CGHV14800 provides 70% efficiency at pulsed PSAT, with a 3 μs pulse width and 3% duty cycle. Visit Wolfspeed at Stand 156.

www.wolfspeed.com/rf

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www.mwjournal.com/eumw2016

Stands 159-175

European Microwave Week

Coilcraft Stand 159

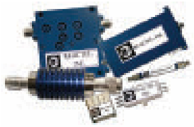
Chip Inductors

Developed for use in mobile devices and cellular infrastructure equipment, Coilcraft's new 0402DF series chip inductors are available with inductance values ranging from 20 to 3300 nH, with a 5% tolerance for all values. They offer the lowest DCR currently available in a 0402 package and are fully optimized for use as a harmonic filter element for NFC applications. They can also be used as filter elements in band-stop and low pass filters, a one-pole filter or RF choke in cellular bands, and for ground-to-ground isolation.

www.coilcraft.com/0402df.cfm

Reactel Booth 160

Filters, Multiplexers & Multifunction Assemblies



Reactel manufactures a line of filters, multiplexers & multifunction assemblies covering up to 50 GHz. From small, lightweight units suitable for flight to high power units capable of handling 10 kW, connectorized or surface mount. Reactel's talented engineers can design a unit specifically for your application. Visit Stand 160 to learn more.

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www.reactel.com

Dow-Key Microwave Corp. Stand 175

Standard Matrix

Designed for microwave, RF and audio test applications in the DC to 18 GHz frequency range, Dow-Key's Standard Matrix product line includes standard configurations ranging from 1 × 100 to 12 × 12. Packaged in a self-contained 19" rack-mountable enclosure and provided with remote interfaces such as RS232, RS-422, GPIB, USB and Ethernet along with a touch-screen LCD front panel display or keypad for manual override. Dow-Key uses its own line of coaxial switches for these matrices, providing low loss and excellent isolation. Visit Dow-Key at Stand 175.

www.dowkey.com

Stands 175-193

K&L Microwave — Stand 175

Ultra-Miniature Lumped Element Filter

Ultra-miniature lumped element filters provide reduced size and weight while affording ultimate flexibility. Bandpass, lowpass, highpass and notch filters, including elliptic and pole placed designs are available in very small surface mount packages. Integrated covers assure performance in sizes typically less than 0.2" wide by 0.15" tall. Join K&L at booth number 175 to discuss your custom requirement.

www.klmicrowave.com

Pole/Zero Corp. — Stand 175

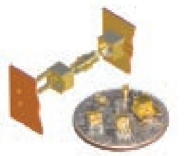
Extended Range Filters

Pole/Zero is showcasing the production release of its new NANO-ERF® series of extended range filters that covers the entire 30 to 520 MHz tuning range in a single 28 × 28 × 0.216 (mm) surface mount package. Tuning speeds are 25 µsec typical, 35 µsec max with inband RF power handlings of +6 dBm. Pole/Zero's complete product line includes tunable filters, integrated cosite equipment and low noise and cosite power amplifiers. Visit Pole/Zero at Stand 175.

www.dovermpg.com/polezero

Southwest Microwave Inc. — Stand 179

Blind-Mate Connectors



High-performance SuperMini Board-to-Board DC to 67 GHz blind-mate connectors optimize transmission line dependability for PCBs stacked as tightly as 3 mm. Ideal for defense, aerospace, communications, networking and test applications, these unique board-to-board, edge-mount to backplane, or board-to-panel interconnections maximize electrical performance between connector and circuit while accommodating axial misalignment of .010" and radial misalignment of ± 10° via superior bullet and receptacle designs. Low mating insertion force allows for high connector density and extended mating/de-mating cycles.

www.southwestmicrowave.com

Spinner GmbH — Stand 193

Low PIM Switches

At European Microwave Week, SPINNER will present its updated portfolio of low PIM test and measurement products. The company's low PIM switches, for example, have been taken to the next level. Also on display will be a computer-controlled switch matrix with multiple input and output ports for antenna testing. In addition, SPINNER will exhibit the latest generation of its EasyDock push-pull measurement adaptors, including both nonlocking and lockable versions for manual and automatic uses.

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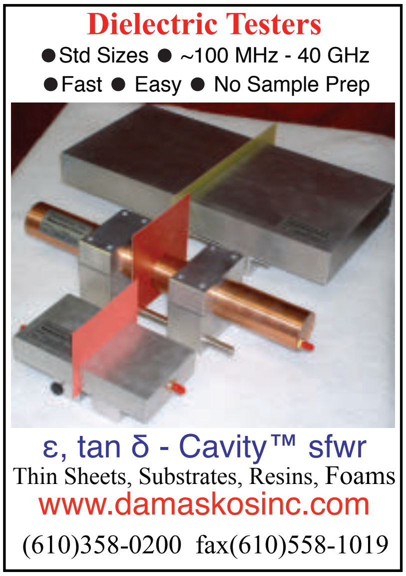
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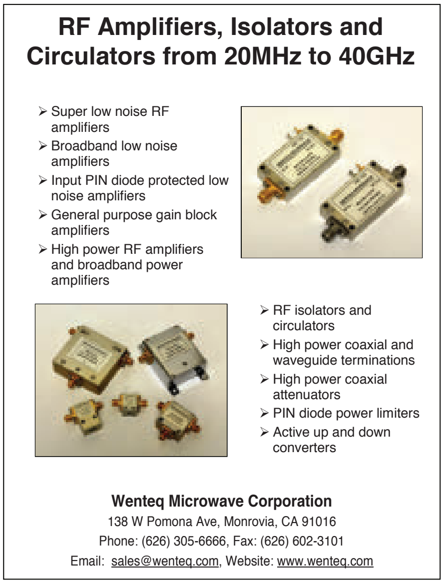
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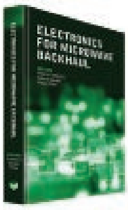

Electronics for Microwave Backhaul

Editors:
Vittorio Camarchia,
Roberto Quaglia,
Marco Pirola

Since the inception of mobile telephony, microwave radio has been the primary backhaul technology used to link base stations to the so-called core network. They now connect over 50 percent of the world's base stations, and backhaul represents over 85 percent of point-to-point radio usage. As cellular technology has evolved from analog to LTE, with data traffic increasing exponentially, microwave backhaul has had to keep pace to remain technically viable, and it faces continuing transformation as cells "densify" and data rates accelerate toward 5G nirvana.

Considering the historic and undiminished role for microwave radios in mobile infrastructure, and not finding a comprehensive technical treatment elsewhere, Vittorio Camarchia, Roberto Quaglia and Marco Pirola decided to write "Electronics for Microwave Backhaul." The three combined their knowledge and experience and solicited contributions from technologists working in the industry to create a single volume that discusses the major building blocks of the radio, explaining the evolution and covering trends and future developments.

The first of seven chapters begins with a tutorial of the mobile network and the role played by the radio. This includes a treatment of propagation and fade margin. The second chapter provides the history of microwave radio and how radios perform compared to copper and fiber. Subsequent chapters delve into the architecture of the radio, techniques to increase capacity and the various subsystems: modem, receiver, transmitter and antenna. "Electronics for Microwave Backhaul" is thorough, readable and a good reference for design, marketing and sales engineers working in this segment.

All three editors received technical degrees from Politecnico di Torino, where Carmachia and Pirola serve as professors. Is it coincidental that Torin is not far from Milan, long a technology center for microwave radio development, including the well known names Ericsson, Huawei and SIAE Microelettronica?

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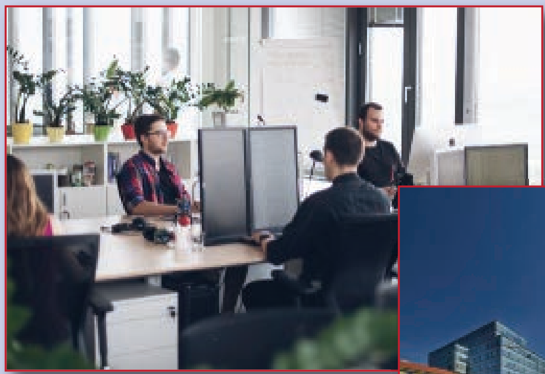

The name Anritsu is familiar to most RF/microwave engineers. Not by chance, the company was formed the same year Marconi demonstrated the world's first wireless telegraph, in 1895. Over the course of its 121-year history, the company has become a $1 billion stalwart of test and measurement (T&M), known for a full range of benchtop and portable equipment. Given this common notion of Anritsu, you may be surprised to learn that the company has an engineering center in Slovakia that consults on information technology (IT) and develops custom software for over 100 clients — only one of which is Anritsu — with projects that address multiple applications, such as telecommunications, aviation, e-commerce, retail and finance.

Anritsu Solutions SK (ASSK) was born in 1998, the confluence of several themes. Companies, particularly in Europe, that outsourced the development of embedded software or mobile/web apps wanted to minimize software development costs but not sacrifice close collaboration and clear communication with their external partners. This tension supported the growth of a technology sector in central and eastern Europe. The area is close to the rest of the continent, yet costs are lower, the work cultures are similar and a technical workforce is readily available. Anritsu had developed a software competency to support its own T&M needs and understood the technical aspects of the markets that were using the company's equipment.

Combining these seemingly unrelated threads, ASSK has grown to be the biggest engineering branch of Anritsu in the European region, with 85 engineers based at a modern office complex in the center of Bratislava, next door to Slovak University of Technology and 40 minutes from the Vienna airport. Not just offices, their 1100 m^2 facility houses a 20 m^2 Faraday cage for testing products isolated from interfering signals and a climate chamber for testing embedded systems under different temperature conditions.

Anritsu's T&M heritage leads to many engagements for telecom applications. In 2009, ASSK established one of the first LTE networks for RF conformance testing, and they continue to implement the latest LTE capabilities. Typical telecom projects involve passive and active monitoring, real-time traffic monitoring and interoperability testing. As one example, ASSK worked with one of the largest telecom operators in Europe on the rollout of a next-generation active testing platform, including VoIP/IP multimedia subsystems (IMS) monitoring. With this longstanding telecom experience, ASSK is well positioned to support the growth in the Internet of Things (IoT), whether developing embedded software for data acquisition or mobile/web applications for data processing and presentation. ASSK's reputation and reach extend well beyond telecom and Europe: they are developing a mobile app for the consumer sector with a Silicon Valley firm and have created embedded software for home appliances, such as a Bluetooth connected electric toothbrush.

As products become more complex and development cycles shorten, companies are being forced to focus on their strategic cores and establish partnerships to handle their other business processes. Gartner Group forecasts that the demand for IT and software outsourcing will grow at an average rate of six percent per year through 2018, and it is arguable that the mobile and IoT segments will grow faster. ASSK's goal, to be a trusted partner for companies needing their unique blend of software expertise and technical understanding has proven to be quite successful. Over an 18-year history, they have built long term relationships with their clients, who return for multiple engagements. They intend to keep it that way.

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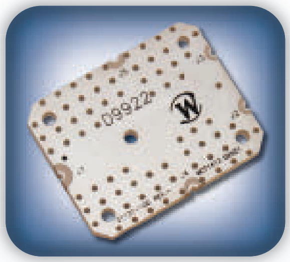
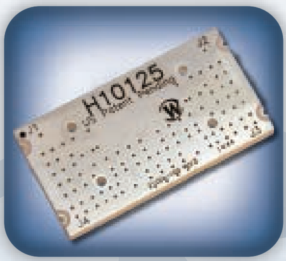
Directional Couplers

0° Combiners



90° Hybrid Couplers

180° Combiners



Directional Couplers

Model	Type	Frequency (MHz)	Power (W CW)	Coupling (dB)	Insertion Loss (dB)	VSWR (ML)	Mounting Style	Size (Inches)
C8740	Dual	20-512	200	40	0.3	1.15:1	Tabs	1.5 x 0.95 x 0.55
C9655	Dual	20-1000	100	30	0.7	1.25:1	Tabs	1.5 x 0.95 x 0.55
C8631	Dual	20-1000	150	40	0.35	1.25:1	Tabs	1.5 x 0.95 x 0.55
C10561	Dual	20-1000	250	50	0.1	1.25:1	SMT	1.35 x 1 x 0.15
C7962	Bi	450-2500	100	30	0.2	1.20:1	SMT	1.15 x 0.7 x 0.07
C8025	Bi	500-3500	125	30	0.3	1.25:1	Drop-In	1.3 x 1 x 0.07
C8098	Bi	800-2000	200	30	0.7	1.20:1	Drop-In	1.3 x 1 x 0.07

0° Combiners/Dividers

Model	Type	Frequency (MHz)	Power (W CW)	Insertion Loss (dB)	VSWR	Isolation (dB)	Mounting Style	Size (Inches)
D9888	2-Way	1000-3000	500	0.35	1.35:1	15	SMT	2.8 x 2.2 x 0.27
D9922	2-Way	2000-6000	200	0.35	1.40:1	15	SMT	1.4 x 1.1 x 0.14

Hybrids

Model	Type	Frequency (MHz)	Power (W CW)	Insertion Loss (dB)	VSWR	Amplitude Balance (±dB)	Mounting Style	Size (Inches)
QH10738	90°	20-1000	150	0.8	1.40:1	0.25	Tabs	3 x 2.75 x 1
QH9056	90°	30-520	400	0.8	1.30:1	1.2	Drop-In	4 x 1.7 x 0.29
QH9304	90°	60-1000	150	1.0	1.40:1	1.0	Drop-In	2 x 1 x 0.16
QH8849	90°	80-1000	250	0.65	1.40:1	1.0	Drop-In	2.9 x 2.1 x 0.31
QH8100	90°	100-512	250	0.45	1.30:1	0.5	Drop-In	3.3 x 1.52 x 0.28
QH10245	90°	100-1300	150	0.75	1.30:1	0.75	SMT	2.5 x 1.7 x 0.16
QH8922	90°	150-2000	100	0.75	1.40:1	1.0	SMT	1.47 x 1.13 x 0.16
QH7900	90°	450-2800	125	0.55	1.35:1	0.45	SMT	1.5 x 1.1 x 0.095
QH7622	90°	500-3000	150	0.55	1.35:1	0.6	Drop-In	1.65 x 1.1 x 0.09
QH10541	90°	700-6000	100	0.5	1.35:1	0.6	SMT	0.66 x 0.86 x 0.09
QH10089	90°	800-2800	200	0.35	1.30:1	0.4	SMT	1.25 x 0.55 x 0.08
QH7741	90°	800-3000	200	0.3	1.40:1	0.45	Drop-In	1.35 x 0.65 x 0.09
H10125	**180°**	**1000-3000**	**350**	**0.5**	**1.35:1**	**0.2**	**SMT**	**2.31 x 1.21 x 0.25**
QH10637	90°	1000-6500	100	0.65	1.45:1	0.6	SMT	0.86 x 0.66 x 0.09
QH8193	90°	2000-6000	100	0.25	1.30:1	0.75	SMT	0.85 x 0.33 x 0.14
QH10148	90°	2000-6000	100	0.3	1.30:1	0.5	SMT	0.75 x 0.45 x 0.08
H10126	**180°**	**2000-6000**	**100**	**0.8**	**1.35:1**	**0.4**	**SMT**	**1.15 x 0.6 x 0.14**
QH10707	90°	2500-5500	200	0.25	1.25:1	0.35	SMT	0.65 x 0.4 x 0.12
QH10651	90°	3000-3500	150	0.2	1.20:1	0.25	SMT	0.56 x 0.35 x 0.1

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