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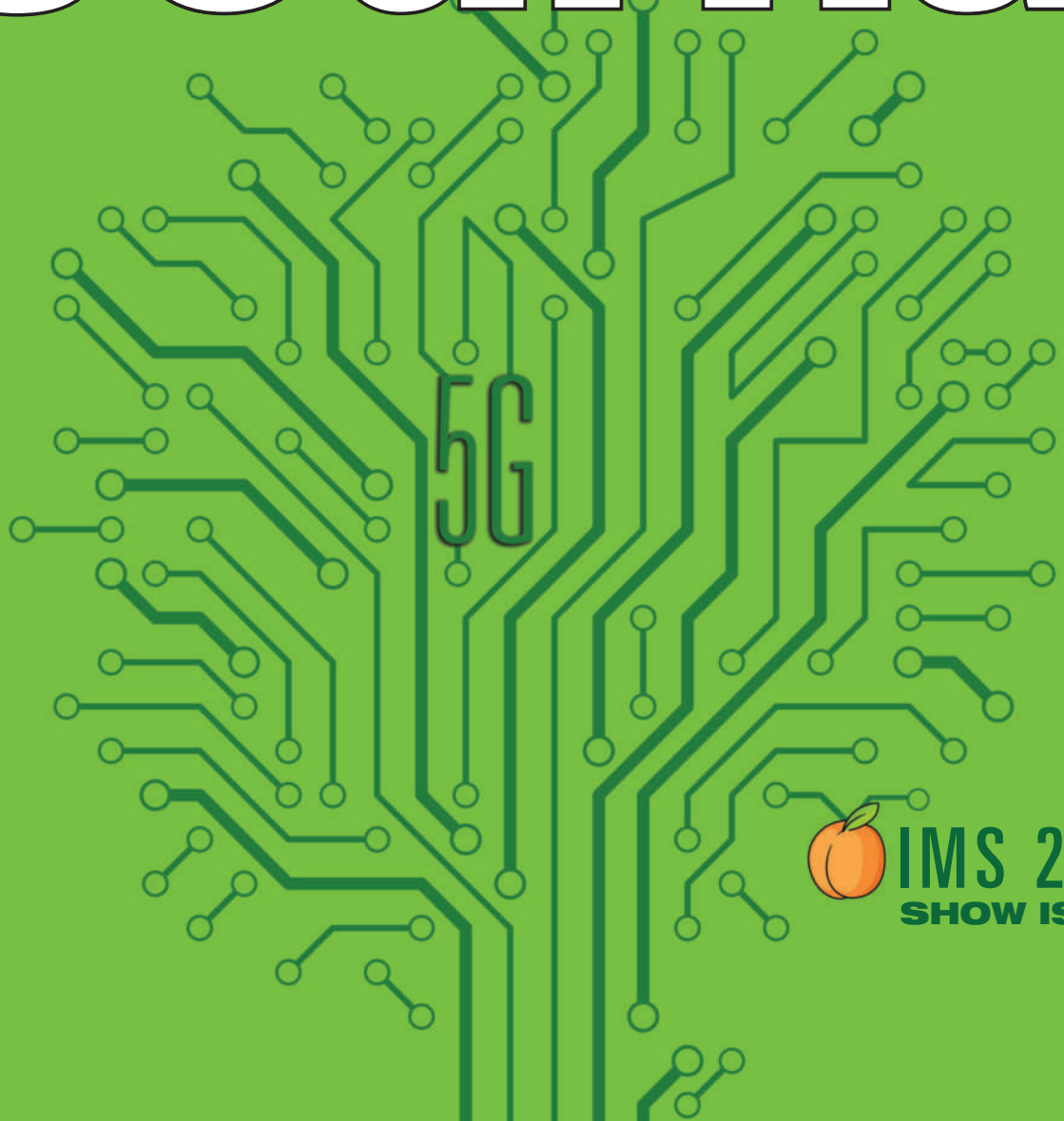
Microwave Journal



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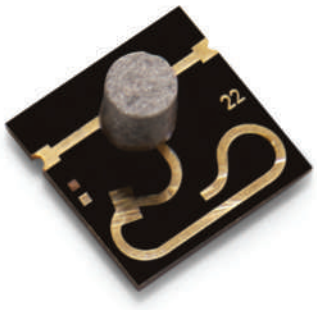
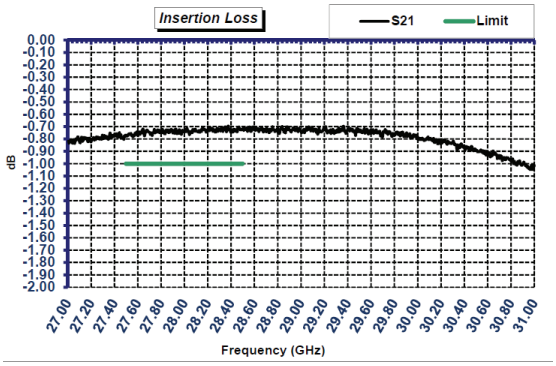
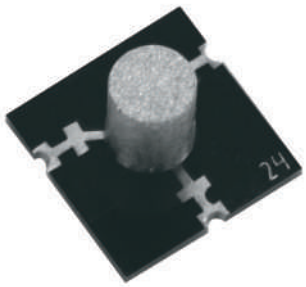
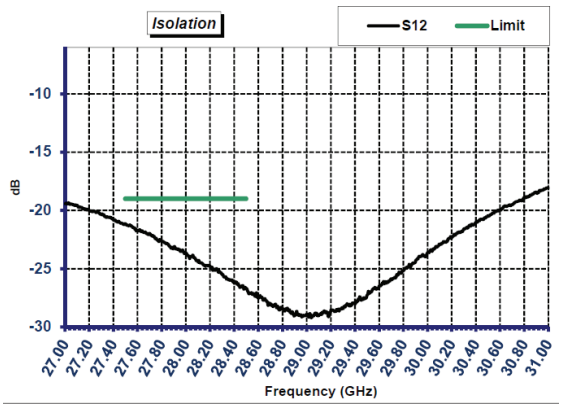




- No Metal Bias Needed
- Easy Reflow Assembly
- No Expensive Wire Bonding



- 200kpcs Sold For Similar Array Application
-Proven Technology



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PEAFS3-14-0R2535R0-6R5-23-12-292FF

PUB-14-30M20G-14-LCA

PEC3-40-30M26R5G-6R0-12-12-SFF

PEC-30-0R2520R0-5R0-22-12-SFF

PMI Model No.	Frequency Range (GHz)	Gain (dB Typ)	Gain Flatness (dB Typ)	Noise Figure (dB Typ)	OP1dB (dBm Typ)	Configuration Size (Inches) Connectors
PLNA-30-10M20-292FF https://www.pmi-rf.com/product-details/plna-30-10m20-292ff	0.01 - 20	28	±2.5	2.5	+14 (0.01 - 18 GHz) +13 (18 - 20 GHz)	0.53" x 0.70" x 0.26" 2.92mm (F) Removable
PEAFS3-14-10M22G-292FF https://www.pmi-rf.com/product-details/peafs3-14-10m22g-292ff	0.01 - 22	14	±0.8	2.5	+14 (0.01 - 18 GHz) +13 (18 - 22 GHz)	
PEAFS3-14-0R2535R0-6R5-23-12-292FF https://www.pmi-rf.com/product-details/peafs3-14-0r2535r0-6r5-23-12-292ff	0.25 - 35	14	±1.5	5.0	+23	
PUB-14-30M20G-14-LCA https://www.pmi-rf.com/product-details/pub-14-30m20g-14-lca	0.03 - 20	14	±2.5	3.0	+14	1.08" x 0.71" x 0.29" SMA (F) Removable
PEC3-40-30M26R5G-6R0-12-12-SFF https://www.pmi-rf.com/product-details/pec3-40-30m26r5g-6r0-12-12-sff	0.03 - 26.5	35	±3.5	5.5	+12	1.92" x 0.78" x 0.36" SMA (F) Removable
PEC-30-0R2520R0-5R0-22-12-SFF https://www.pmi-rf.com/product-details/pec-30-0r2520r0-5r0-22-12-sff	0.25 - 20	26.5	±1.5	4.0	+22	1.08" x 0.71" x 0.32" SMA (F) Removable
LNA-35-500M2D5G-0D6-25-12-SFF https://www.pmi-rf.com/product-details/lna-35-500m2d5g-0d6-25-12-sff	0.5 - 2.5	35	±1.6	0.6	+25	1.25" x 1.25" x 0.563" SMA (F)
LNA-0R518G-45-10DBM-SFF https://www.pmi-rf.com/product-details/lna-0r518g-45-10dbm-sff	0.5 - 18	45	±2.0	2.95	+10	0.90" x 1.67" x 0.36" SMA (F)
PEC-30-500M40G-20-12-292FF https://www.pmi-rf.com/product-details/pec-30-500m40g-20-12-292ff	0.5 - 40	30	±2.5	4.7	+19 (0.5 - 18 GHz) +17 (18 - 40 GHz)	1.37" x 1.00" x 0.60" 2.92mm (F)
PEC-30-0R5G50G-22-12-24FF https://www.pmi-rf.com/product-details/pec-30-0r5g50g-22-12-24ff	0.5 - 50	30	±2.5	5.0	+19 (0.5 - 30 GHz) +17 (30 - 50 GHz)	1.37" x 1.00" x 0.60" 2.4mm (F)
PE2-19-6G18G-1R6-16-12-SFF https://www.pmi-rf.com/product-details/pe2-19-6g18g-1r6-16-12-sff	6 - 18	19	±2.5	2.0	+25	1.08" x 0.71" x 0.29" SMA (F) Removable

LNA-35-500M2D5G-0D6-25-12-SFF

LNA-0R518G-45-10DBM-SFF

PEC-30-500M40G-20-12-292FF
PEC-30-0R5G50G-22-12-24FF

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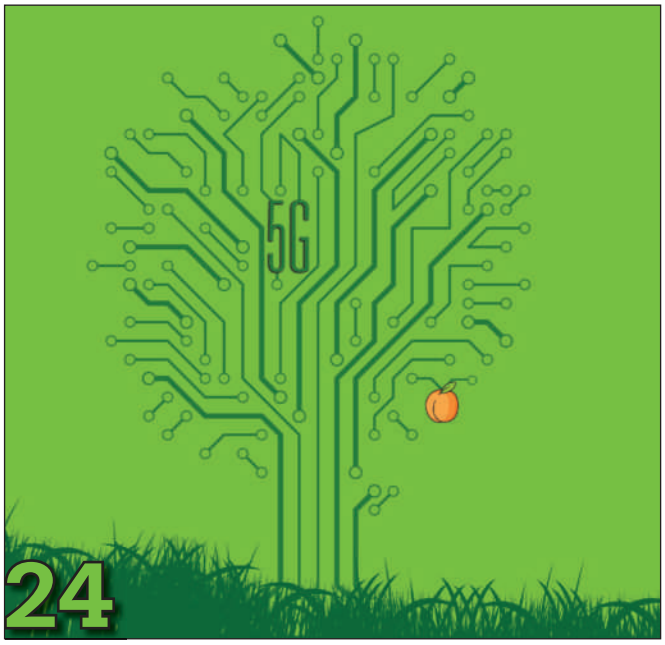

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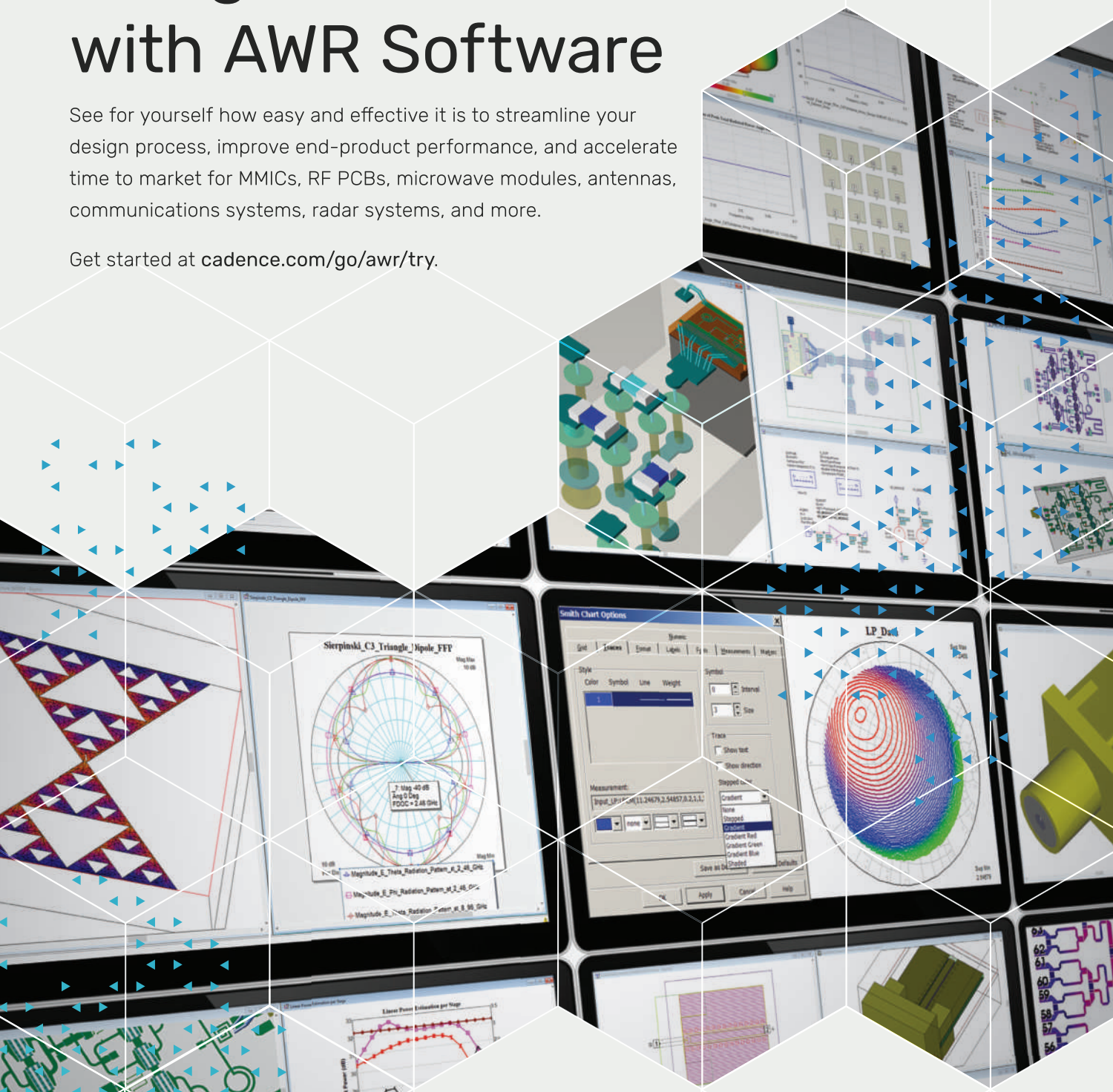

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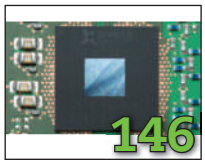

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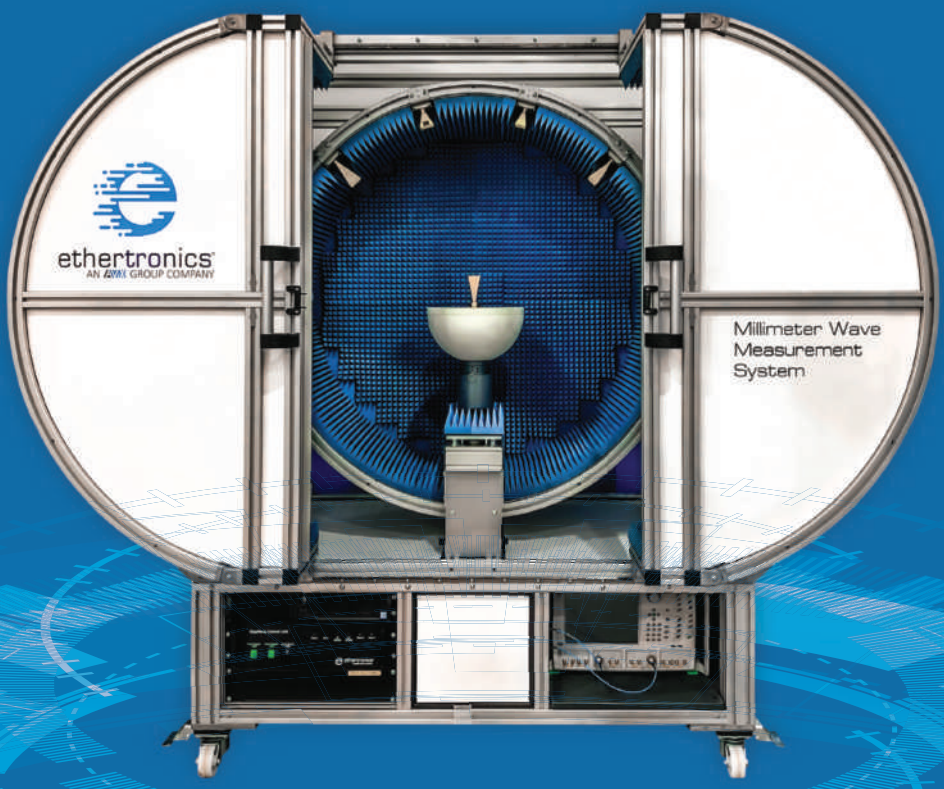

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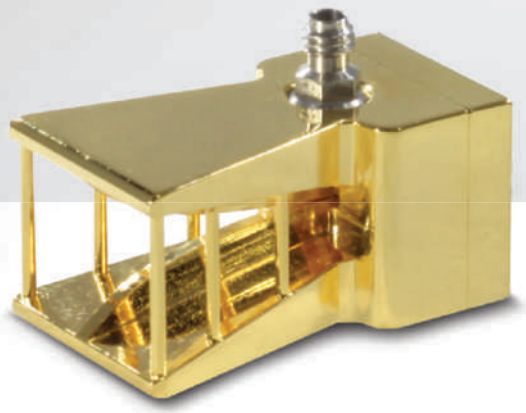

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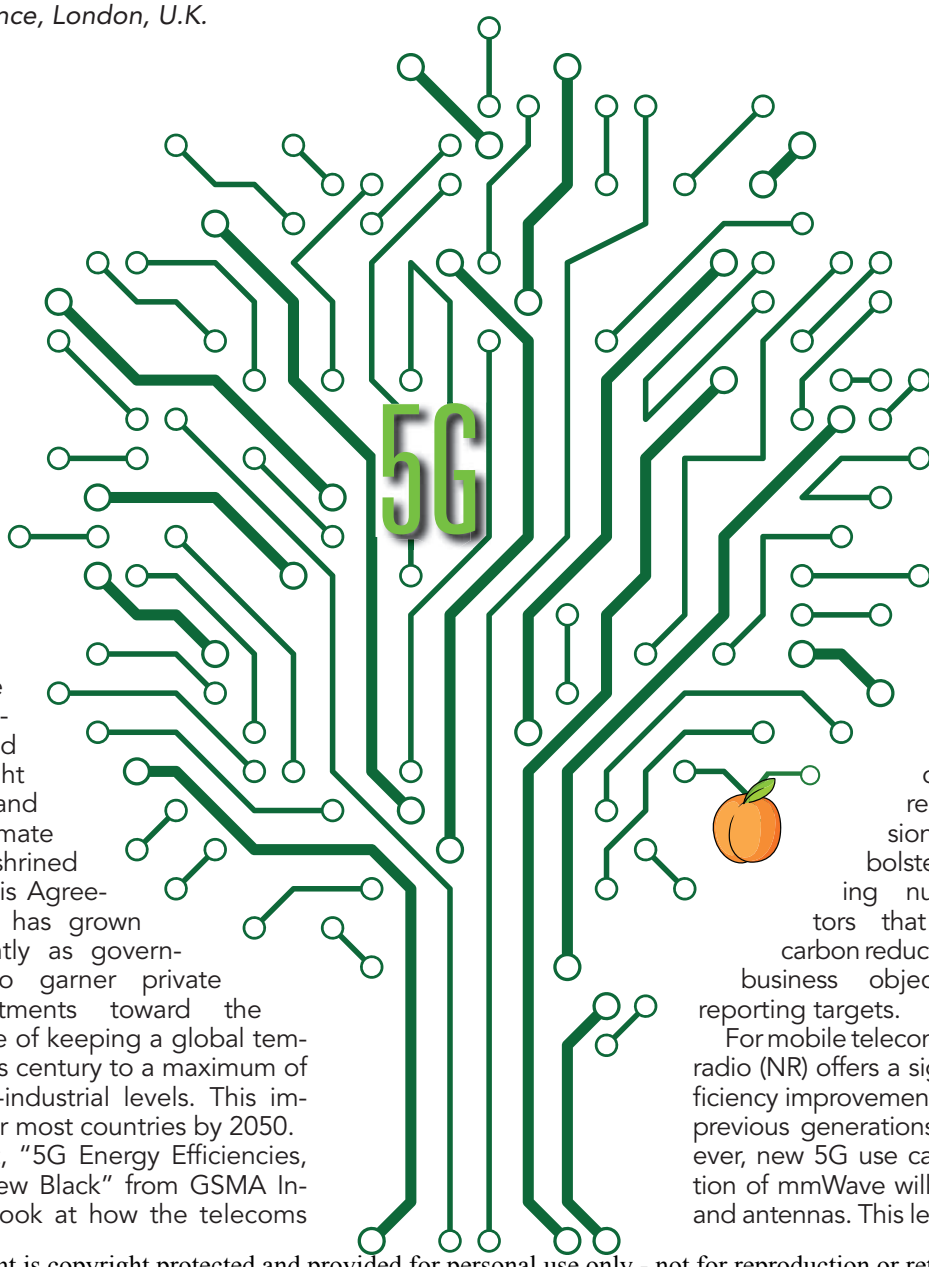
5G and Network-Wide Innovations Providing Energy Savings with Lower Power Consumption

Emanuel Kolta and Tim Hatt
GSMA Intelligence, London, U.K.



The impetus for reductions in energy emissions in the telecoms sector is anchored in the global fight to combat and mitigate climate change, as enshrined in the 2015 Paris Agreement. Urgency has grown markedly recently as governments seek to garner private sector commitments toward the central objective of keeping a global temperature rise this century to a maximum of 2°C above pre-industrial levels. This implies net zero for most countries by 2050.

In our report, "5G Energy Efficiencies, Green is the New Black" from GSMA Intelligence, we look at how the telecoms sector has emerged as a vocal supporter of proactive emissions reductions plans. This is enshrined in an industry-wide commitment to reach net zero emissions by 2050 and bolstered by a growing number of operators that have embraced carbon reduction efforts as a core business objective, with strict reporting targets.

For mobile telecom networks, 5G new radio (NR) offers a significant energy efficiency improvement per gigabyte over previous generations of mobility. However, new 5G use cases and the adoption of mmWave will require more sites and antennas. This leads to the prospect

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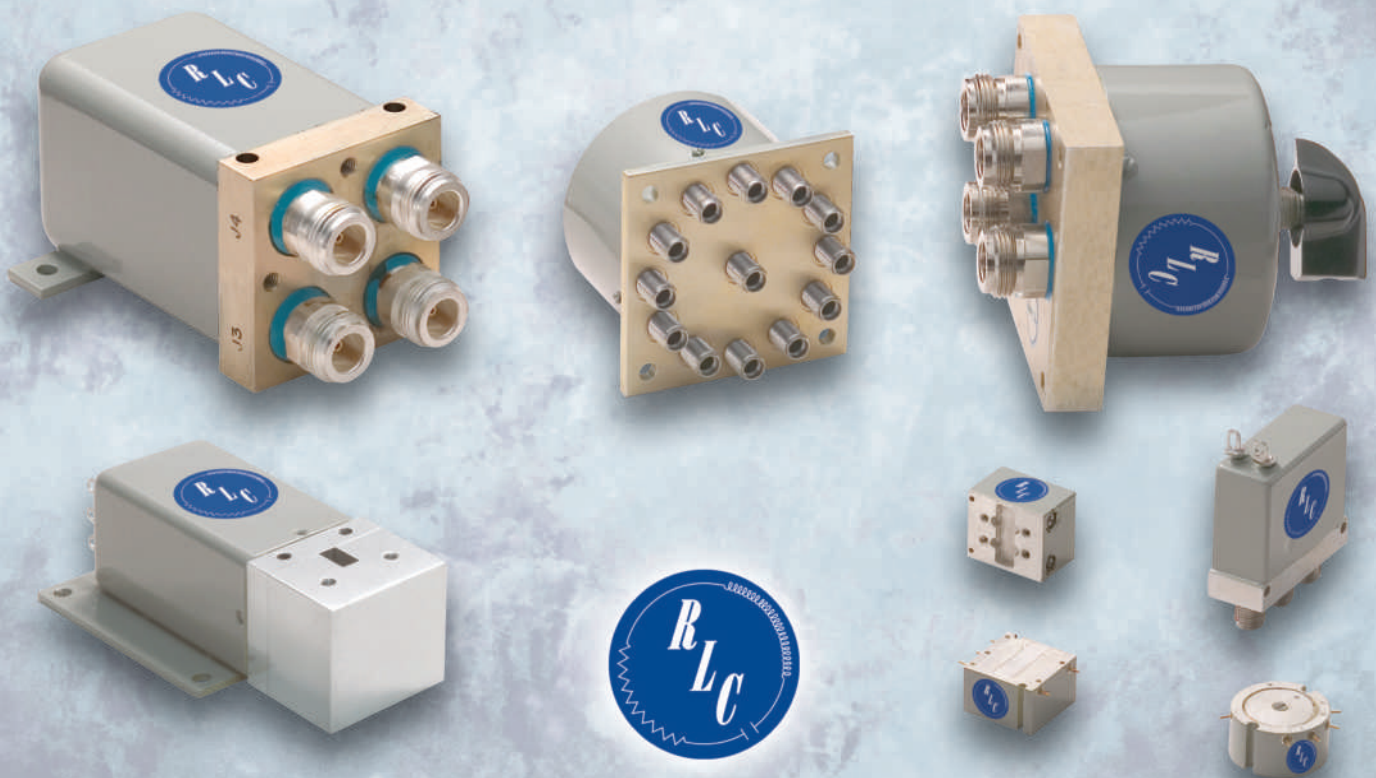

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of a more efficient network that could paradoxically result in higher emissions without active intervention.

The mix effect of 4G LTE and 5G upgrades in emerging and advanced economies (led by the U.S. and China) will result in these technologies accounting for 60 percent and 20 percent of the global mobile connections base, respectively, by 2025. The impact of this shift will be a continued rise in mobile data traffic, estimated at 6.4 GB per user per month in 2019 and forecast to grow threefold on a per user basis over the next five years. When combined with the rising costs of spectrum, capital investment and ongoing radio access network (RAN) maintenance and upgrades, this means energy-saving measures in network operations are necessary rather than nice to have.

NETWORK COSTS AND PERFORMANCE

Irrespective of climate change, impetus for energy-saving measures from telecoms operators has grown because of sustained increases in network costs in a low revenue growth environment. The telco business model is based on network scale. In times of growing revenues, margins expand as the largely fixed cost base is monetized (positive operating leverage), unless the operator is sub-scale. This is broadly what happened in the 2G and 3G eras in the 1990s and 2000s when mobile phones were still new to people and subscriber growth consequently steadily rose. However, in periods of low or negative revenue growth, fixed costs are exposed, with resulting pressures on cashflow and longer-term investments. Network capital investments have increased to fund LTE and early 5G rollouts, while free cash flow margins have been mostly preserved through reductions in personnel and other costs.

Given the industry imperative to invest in networks, Capex is followed more closely than the costs of ongoing maintenance (Opex). However, this is changing with the rapid adoption and incorporation of energy efficient technologies. Both offer material savings in Opex. Network Opex tends to account for around 25 percent of the operator cost base, or 10 percent of revenue. Around 23 percent of network opex costs are spent on energy consisting mostly of fuel consumption as shown in ***Figure 1a***. Most of this spend powers the RAN, with data centers and fiber transport accounting for a smaller share.

The good news is that the shift from fossil fuels to renewables has started to feed through to Opex savings, as have the phased retirements of legacy 2G and 3G networks that are less energy efficient than LTE or

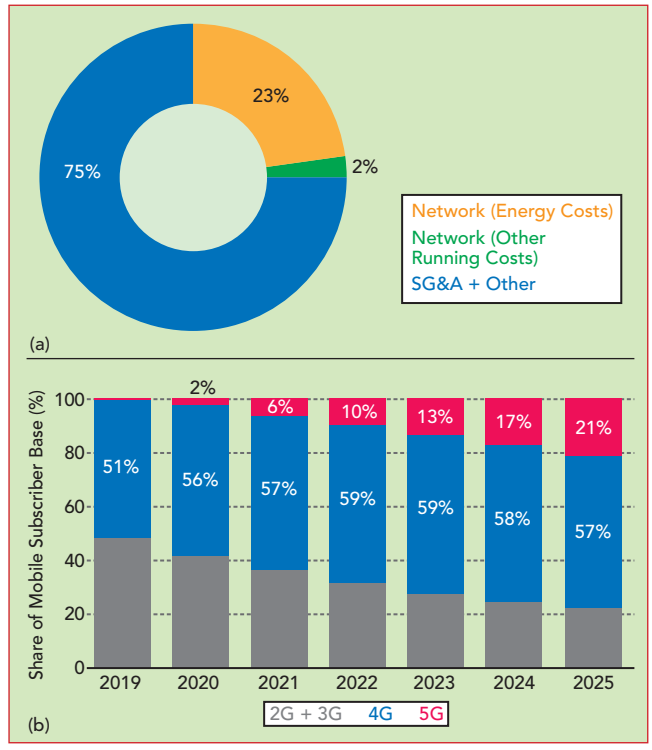

Fig. 1 Energy (electricity and fuel) is a significant cost element for mobile network operators as it is one of the largest operating costs (a). Mobile data traffic will grow almost threefold by 2025 and new 5G use cases will require more dense and complex networks (b). These are averages so will vary by operator. Source: GSMA Intelligence.

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5G NR standards. Looking ahead, however, as LTE and 5G progressively account for larger shares of the overall global user base, data traffic rises are inevitable—and with this comes the pressure on energy consumption (see ***Figure 1b***).

There is no one method of increasing energy efficiency or reducing power usage. Instead, a mixed approach is generally being used, comprising renewables, AI-driven network sleep states, more efficient batteries and decentralized site deployments with compute power pushed toward the edge. The results will feed through over a period of years.

ENERGY CONSUMPTION IN RUNNING A NETWORK

Past transitions to new wireless standards have entailed a significant improvement in the cornerstone metric of energy efficiency: kilowatt hours per gigabyte. Though 5G NR also offers a significant energy efficiency improvement per gigabyte over previous technologies, new 5G use cases and the adoption of mmWave will require more sites and antennas. This leads to the prospect of a more efficient network that could paradoxically result in higher emissions, without active intervention.

One way to visualize a network is as a linear progression of stages, or phases, across which energy flows to provide power to base station sites, radio access nodes and backhaul links. ***Figure 2*** outlines this journey, starting with energy sourcing from the grid and moving through to site and equipment consumption.

PHASE 1: ENERGY SOURCING

There are significant daily fluctuations in energy demand, while electricity supply is relatively static. This makes the price of industrial electricity vary on an hourly basis. Daytime energy prices in peak hours can be significantly higher than off-peak times during the night. Network operators can save money by buying energy at off-peak hours to be stored and used when data traffic peaks in the early evening, typically between 18:00 and 22:00. Operators can also sell excess peak-time energy back to the utility grid. This relatively nascent practice will require further investment in energy storage technology and batteries alongside partnership agreements with utility providers. Updated central energy management platforms to calculate and forecast site-level data traffic and consumption are also important to ensure each site has enough backup energy to operate safely, with no service interruptions.

PHASE 2: ENERGY CONVERSION

Energy utility providers sell AC electricity, while most of the site-level energy consumption happens in DC. For this reason, each cell site needs to have a rectifier module to convert AC to DC. Most cell sites in a typical portfolio are more than 10 years old and operate with less efficient passive infrastructure, including the rectifier module. New rectifier technology is much more efficient so it is a big opportunity for improving energy efficiency. The cost to upgrade is significant upfront but crucial to more efficient conversion and lower consumption over the long-term. New rectifiers are also key to cover the potential increased energy consumption before installing 5G equipment and ensure smooth capacity expansion.

PHASE 3: ENERGY TRANSPORTATION

When power is transmitted at high voltages, the efficiency of energy transportation increases (with a lower rate of leakage) because of a lower electric current in the conductors. Operators can improve efficiency and reduce power loss by increasing voltage with boosters, using power equipment closer to the load and decreasing the power supply distance.

PHASE 4: ENERGY CONSUMPTION

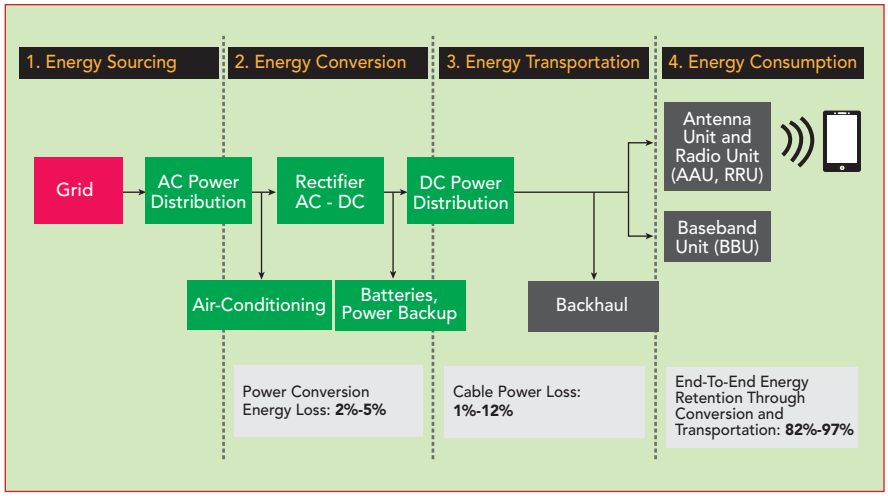
This phase represents the 'lowest hanging fruit' for efficiencies. Operators transform DC energy into radio waves and receive and process incoming signals. This category can be further broken down into areas such as architecture optimizations, signaling, network shutdowns, cooling and beamforming that wastes less energy than omnidirectional transmission.

SITE, RAN AND NETWORK-WIDE INNOVATIONS

Alongside technical improvements to reduce energy leakage as power passes through the network phases, solutions to improve efficiency holistically across the network are available. Our analysis focuses on sites, the radio access level and broader network planning considerations. We exclude efforts targeted at handsets and other end-user terminals as these do not directly contribute to a mobile operator's carbon emissions profile. ***Figure 3*** summarizes the holistic network-wide approach.

SITE INNOVATIONS—BATTERY SOLUTIONS

In off-grid areas, mobile operators are often forced to use diesel generators to guarantee the reliability of power supply for base stations. This is less than ideal considering generators emit high levels of carbon dioxide and have onerous cost



▲ Fig. 2 **End-to-end energy loss from grid to the RAN. Source: GSMA Intelligence.**

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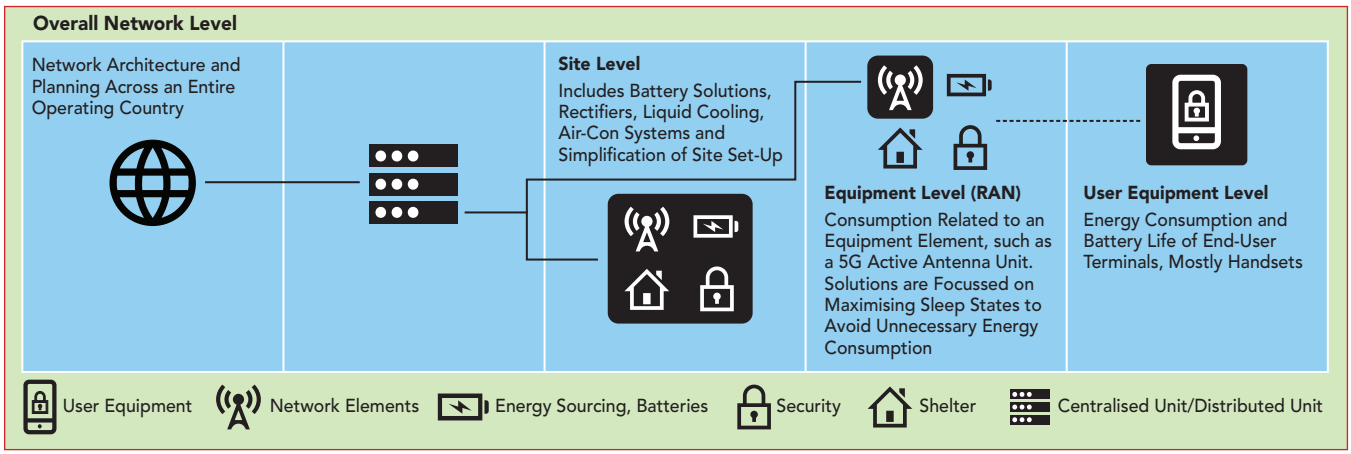

Fig. 3 **Energy-saving methods differ between site level, RAN equipment and network planning. Source: GSMA Intelligence.**

implications associated with refueling, particularly if in hard-to-reach, sparsely populated areas (such as in African countries) requiring labor callouts and security protection.

Lithium batteries have emerged as a more environmentally friendly and cost-efficient alternative. These have a smaller and lighter form factor compared to traditional lead acid batteries, saving space after installation. Lithium batteries have a significantly longer expected life-span (five or six years on average). The commonly used lead acid batteries are expected to be efficient for a much shorter period—around three years.

Further favorable aspects of lithium batteries are the improved charge and discharge capacities and related savings potential from the battery configuration. Backup batteries are fully charged at all times and discharge only when there is a power outage. By using a cycle-type lithium battery capable of daily charge and discharge, smart power control with a DC power controller can be performed, enabling flexible and efficient power supply to radio equipment. Voltage boosting is also an option with lithium technology; this can help operators increase voltage, save on energy transportation and serve newly installed 5G AAUs from longer distances more efficiently. In the event of theft, the battery is designed to automatically stop any output of power, rendering it useless to criminals. The batteries are also fitted with GPS modules, making them easily traceable.

HYBRID AND RENEWABLE ENERGY

Solar has become a competitive alternative to diesel in off-grid areas as the price of photovoltaic panels has fallen and base station battery solutions have become more advanced. Site-level hybrid energy solutions involve a mix of solar/diesel/wind/electricity/hydrogen-rich fuel and grid, providing a more efficient way to power sites. Custom-made hybrid solutions have a dedicated variable speed motor and a DC alternator which reduces loss caused by energy conversion. Advanced algorithms can select optimal energy sources and achieve significant energy efficiency improvements for the estimated 1 million cell sites globally.

More broadly, the shift to purchasing renewables will accelerate as pric-

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es continue to decline and future contracts enable long-term lock-ins. Operators can buy more of their energy from larger, centralized renewable energy sources and achieve long-term power purchase agreements or use their assets and produce their renewables in their cell sites.

RAN AND NETWORK EQUIPMENT INNOVATIONS

Turning off equipment even for a short period of time or putting it into a sleep mode when there is no traffic to serve, saves energy. With 2G, 3G and 4G, there are recurring transmissions of always-on signals called cell-specific reference signals to secure cell coverage and a connection with users. Significant energy-saving is possible from decreasing resources allocated to signaling and its 'ping-pong' effect between user equipment and the cell site.

The 5G NR standard allows more components to switch off or go to sleep when the base station is in idle mode and requires far fewer transmissions of always-on signaling transmissions. Overall, these factors allow deeper sleep periods for a longer time, which—everything being equal—confers a significant saving on network energy consumption per bit of data.

Massive MIMO requires an increased number of antennas compared with traditional MIMO technology. Laboratory tests suggest that the increased number of antennas improves energy efficiency, transmitting and receiving more data for a given amount of energy.

NETWORK-WIDE PLANNING AND OPTIMIZATION—SUNSETTING LEGACY NETWORKS

A key challenge is to square the improvement in energy efficiency per bit of data in 5G networks with the inevitability of rising traffic and the risk that overall power consumption could still increase. In this sense, strategies to reduce energy emissions have to be considered at an overall network planning level, incorporating all generations of mobility and their associated spectral elements.

Sunsetting legacy 2G and 3G networks is a major means of emissions reduction. The energy per bit of data with each new mobile generation is constantly improving, so sunsetting 2G and 3G networks can boost overall network energy efficiency. As legacy mobile technologies approach the end of their lifecycles, the importance of decommissioning and refarming certain spectrum bands to LTE or 5G is growing. 5G is particularly attractive as it is more efficient than legacy generations, given the NR standard.

Although the exact difference in energy efficiency between 5G and previous technologies varies, laboratory tests suggest 5G has a significant efficiency advantage. It can also save energy and space through using fewer active antenna units and other networking elements. The process of sunsetting is already in progress and will likely continue in a staggered manner over several years to balance the risk of stranded network assets if take-up of LTE and 5G tariffs lags expectations.

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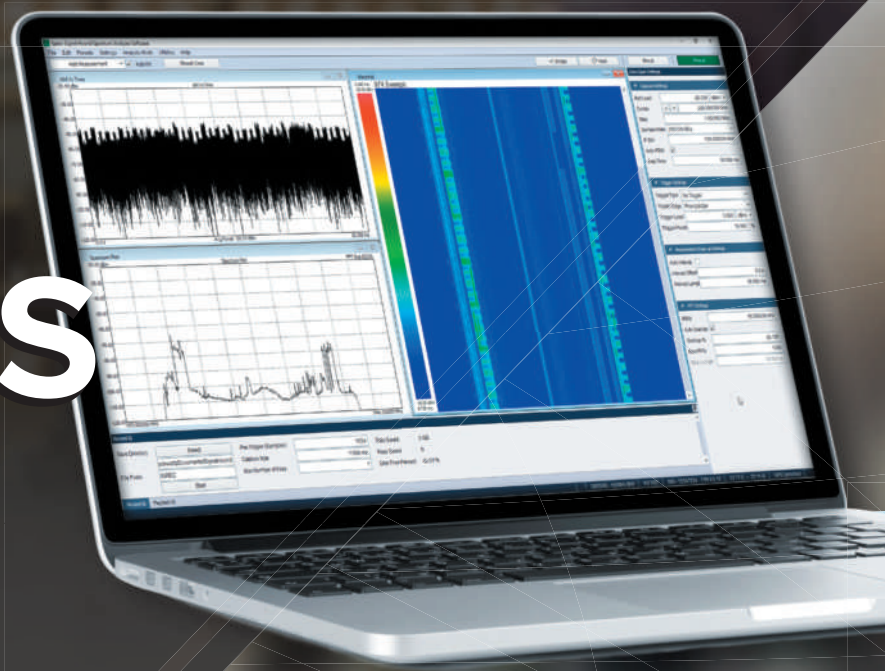

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AI-DRIVEN NETWORK PLANNING

AI-driven network management and planning applications are not a particularly new concept, but many vendors and network operators have recently launched energy management solutions that leverage AI and advanced data analytics to optimize energy consumption. AI can help operators increase energy efficiency and deal with the 5G era's increased data traffic in terms of network planning and optimization.

AI can also help in network planning by gaining insights from coverage areas, building heatmaps for network usage and recommending an optimal location for new cell sites. New algorithms could also help understand spatial and temporal patterns in the ever-changing nature of mobile data use and predict future usage profiles in different coverage areas. AI algorithms can support the interplay between indoor and outdoor small cells, Wi-Fi hotspots and macro sites to maximize energy efficiency.

AI-DRIVEN NETWORK OPTIMIZATION

Equipment vendors have started to offer AI-driven energy-saving solutions as an extension to existing network management platforms. Algorithms for power-saving in base stations can already be used to shut down power amplifiers, transceivers and other network elements. However, AI can improve efficiency and lengthen sleep periods.

Base stations are the 'low-hanging fruit' for such applications as they consume more than 70 percent of total energy. As each is unique, optimizing their operation one-by-one would be labor-intensive. AI was introduced to enable more precise energy-saving based on traffic and other site-related conditions, improving efficiency and reducing the manpower required. Large-scale deployments have shown an increase in power-saving activation of more than 80 percent.

Many device companies are now using machine learning and AI to optimize functions such as antenna tuning and power amplifier biasing to improve efficiency of the transmit and receive chains in the radio. This is a future trend to improving efficiency at the device level.

In the 5G era, the energy optimization offered by the first and second generations of algorithms is not sufficient to deliver the needed energy-saving to keep up with growing data traffic. The third generation of AI-driven energy-saving solutions can take account of the different efficiency levels of frequency bands and factors in that the power efficiency of different networks can vary. The new AI can help base stations direct services to the optimal network, resulting in greater network energy efficiency.

Major vendors are currently offering solutions that can make energy savings of 5 to 15 percent on the RAN. New software can forecast data traffic based on historical patterns, weather, events nearby and other factors, before identifying the necessary thresholds, activation and sleep periods. Based on the infor-

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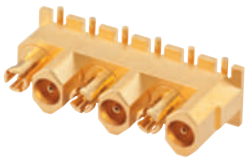

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mation, the algorithm can shut down power amplifiers, transceivers and other network elements to save energy. Alongside this power-saving potential, AI-driven shutdown solutions can constantly monitor customer experience, network availability and data traffic to ensure there is no impact on network performance.

AI can also reduce energy consumption outside the RAN—in central offices, shops and data centers—by continuously calibrating the optimal settings of heating and cooling systems, pumps and fans. Engineers can use AI-driven building management systems to prioritize work, reduce unproductive travel time, identify equipment issues, avoid costly unscheduled callouts and help ensure network reliability. Going forward, AI-driven energy-saving platforms are expected to focus more on data harvested from user devices. Anonymized coverage and data traffic insights from devices can help optimize the network further and adjust more capacity layers.

Overall, AI-driven network shutdown solutions can be broken down into three areas:

- Module (transceiver, baseband processing, etc.): The AAU components can be shut down in real-time during idle periods
- Equipment (AAU, RRU): Equipment can be completely shut down during periods of low traffic, usually at night
- Network: Large-scale, AI-driven solutions can schedule data traffic between different 5G bands (for example, from C-Band to sub-3 GHz bands) or between 5G and 4G, in a similar way to the smart data mode seen in new smartphones.

CONTENT CACHING NEARER TO THE END-USER

A surge in the popularity of video streaming over the last five years has made placing content caching facilities closer to end users strategically important—to maintain quality and for competitive reasons. Most video content passes through content delivery networks (CDNs), which transfer media across hundreds of servers worldwide. CDNs can reduce power demand as a video stream only has to travel through the network once to reach thousands of customers.

The CDN market historically mostly comprised independent groups such as Level 3 and Akamai, but major internet and consumer tech companies (Google, Facebook, Apple, Amazon, Netflix) have established their own servers to ensure control over their own content.

Reducing the distance between cache points and users results in improved latency, which preserves the customer experience for high- and super-high-definition video. As fixed-wireless access over 5G gains traction as a last-mile alternative for home broadband in some markets, the requirement for caching nearer to end-user premises would become even more pressing. CDN analytics platforms and network management systems can together capture, locate and analyze trends and events across the RF, RAN, backhaul and core, providing operators with unprecedented insight to optimize

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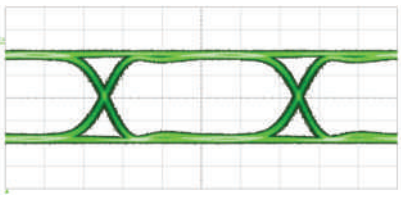

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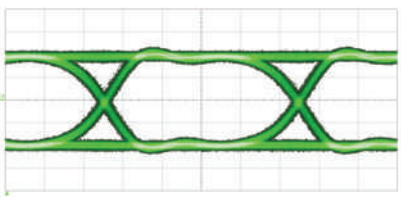
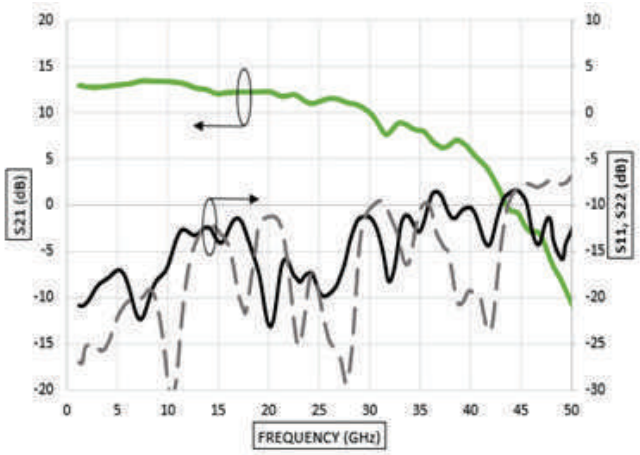


OUTPUT: 12.5 GBPS PRBS31 1100 mV



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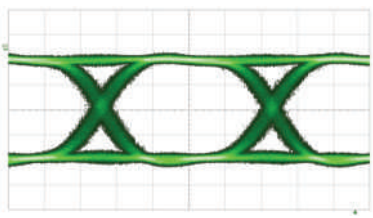
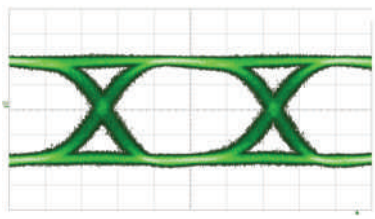


INPUT: 32 GBPS PRBS31



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their network, save energy and monitor the customer experience.

THE WAY FORWARD

Alongside technical improvements to reduce energy leakage as power passes through the network phases, a range of measures are available to improve efficiency holistically across the network. These include the following:

- User equipment and devices—energy consumption and extended battery life of end-user terminals, mostly handsets
- Site-level innovations—new lithium-ion battery solutions, rectifiers, liquid cooling, air-con systems and simplification of site set-up
- RAN and network equipment innovations—AI-driven software focused on maximizing sleep states to avoid unnecessary energy consumption in the RAN
- Network planning and optimization—including the sunsetting of legacy 2G and 3G networks and long-term purchasing contracts for renewable energy.

The big picture for operators of ultimately reducing emissions to net zero depends on wrapping energy efficient technologies into a broader 'green' strategy that encompasses all facets of operations. To put teeth behind public commitments, many large operators have implemented key performance indicators and reporting targets in line with the independent Science Based Targets initiative.

Emissions reduction goals have been set in a phased approach to first reach carbon-neutral status before the more difficult and ambitious objective of net zero. Our analysis indicates that progress has generally been solid so far, enabled by advances in the renewable energy markets.

Despite this progress, reporting targets are not yet in place in most operators. There are also several persistent barriers, including emissions data availability and tracking mechanisms, lack of partnerships with energy sector producers and, in some cases, outdated organizational structures that augur for more cross-team working and less hierarchy.

The data aspect is of particular importance; we hope this research will help raise awareness of the issue. The construction of comprehensive data 'pipelines' with associated analytics would help uncover costly anomalies. Deploying smart sensors at various points of the network would help measure equipment-level energy consumption, battery status, active hours of generators, fuel levels, outside and indoor temperatures and air conditioning. Operators would need to build their comprehensive and real-time data repository, but we believe this would be money well spent. With reliable measurements and data pipelines established, big data applications can monitor and adjust network power—a key ability for the software-defined networks set to be the default option in the 5G era.■

For the full report, 5G Energy Efficiencies: Green is the New Black, visit: www.mwjournal.com/gsma

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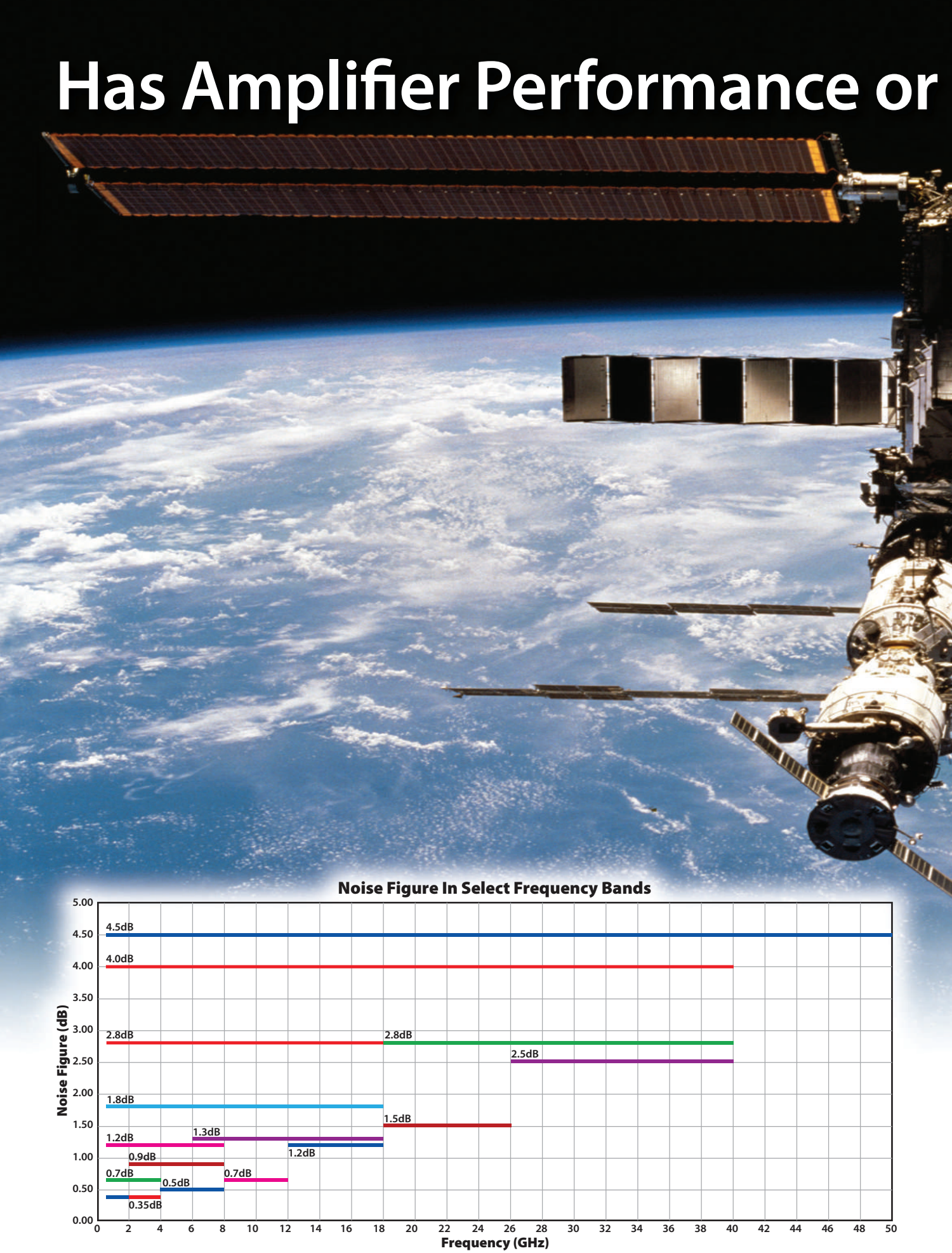

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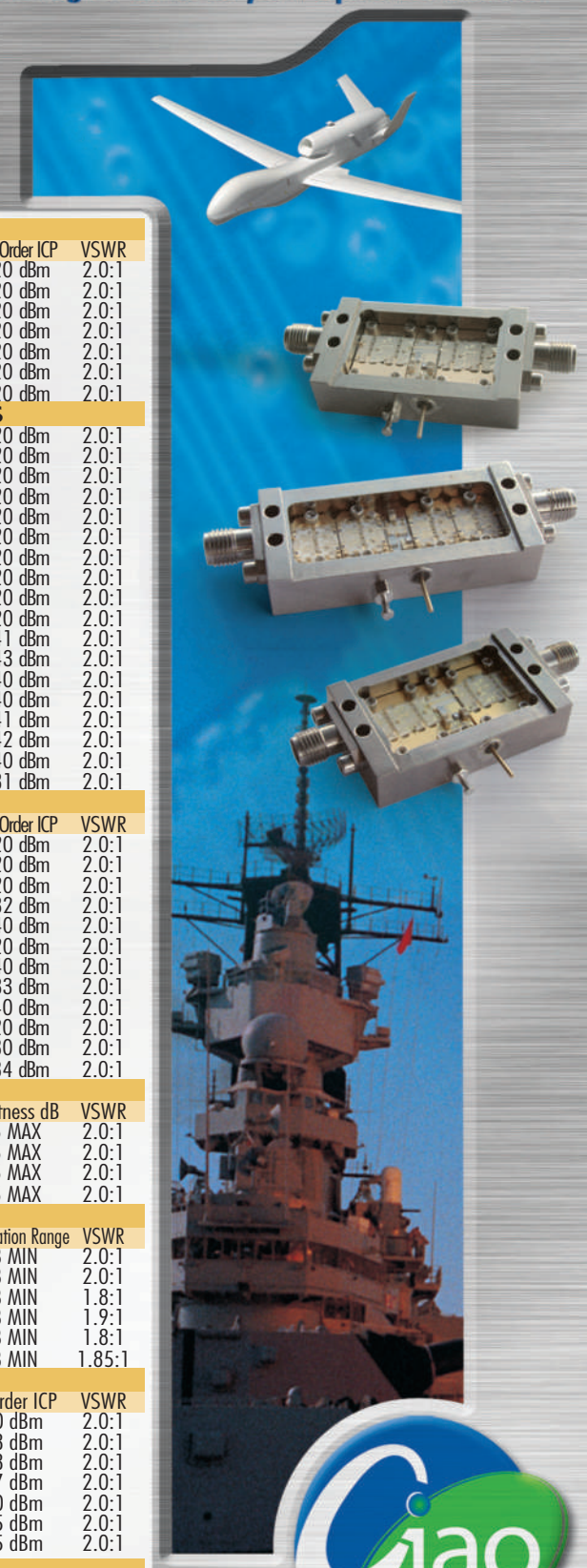

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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A New Era for the Tomahawk Missile

The Tomahawk cruise missile has been the U.S. go-to precision weapon for long distance strikes. It launches from ships and submarines. It can fly into heavily defended airspace 1,000 miles away. It hits high-value targets with minimal collateral damage.

And it just keeps getting better.

The U.S. Navy is recertifying and modernizing the Tomahawk missile, extending its service life by 15 years and resulting in a new series known as Block V. Raytheon Missiles & Defense will begin producing the new Block V missiles later in 2021, and has delivered the first upgraded Block IV systems to the Navy.

The mature, highly advanced Block IV variant is upgraded with improved navigation and communications systems. A multimode seeker is in development that will allow Tomahawk to engage moving targets at sea.

"Tomahawk" (NAVAIR Photo)

"Range and precision are important to counter moving targets at sea," said Kim Ernzen, vice president of Naval Power at Raytheon Missiles & Defense, a Raytheon Technologies business. "These enhancements take an already effective weapon and raise it to a new level."

Raytheon Missiles & Defense is also expanding Tomahawk's long-range, land-attack capability with a programmable warhead that can hit more diverse land targets.

The Navy completed Block V flight tests in December 2020. All Block IV missiles will be recertified, modernized and delivered as Block V missiles.

Harnessing Light to Enable Next-Generation Microwave Systems

Electronic oscillators lie at the heart of virtually all microelectronic systems, generating the clock signals used in digital electronics and the precise frequencies that enable RF sensors and communications. While an ideal oscillator provides a perfect signal at a single frequency, imperfections degrade the spectral purity of real-world components. Such impairments, broadly quantified as phase noise, ultimately limit the performance of many military radars and commercial 5G systems. The issue is becoming increasingly burdensome as the airways become more congested and defense needs to evolve.

Today's best microwave oscillators can achieve extraordinarily low phase noise, but the highest performing technologies make large sacrifices in pursuit of performance. Trade-offs lead to oscillator modules with undesirable size, weight, power and cost (SWaP-C), limited tunability and high sensitivity to their surroundings, all of which limit their use in advanced defense systems.

DARPA's recently announced Generating RF with Photonic Oscillators for Low Noise (GRYPHON) program seeks to eliminate the shortcomings of today's microwave oscillators by developing ultra-low-noise versions that are simultaneously compact, widely tunable, robust and volume-manufacturable. To achieve its objectives, GRYPHON will employ emerging innovations in optical frequency division, integrated photonics and non-linear optics.

Recent benchtop demonstrations using laser-based techniques have set world records in microwave phase noise. In parallel, ongoing innovation in the fields of integrated photonics and non-linear optics has enabled dramatic reductions in SWaP-C of key components needed to implement photonic oscillators. This includes chip-scale laser resonators with high-quality factors and optical frequency combs.

GRYPHON will explore innovative microwave sources using state-of-the-art microfabricated photonic components to achieve the target program metrics while creating a path to manufacturability. To accomplish the target objectives, the program will focus on two specific research areas. The first aims to develop a prototype that can be readily tested within an application and brought to maturation quickly. During the first phase of the program, research teams will prioritize achieving low phase noise and compact form factor, while tuning and robustness will be emphasized in later phases.

The second research area will prioritize understanding the fundamental limits of photonic microwave generation. Research teams will be asked to offer at least an order of magnitude leap in one of three target metrics: size, phase noise or frequency span.

Collaborative Air Combat Autonomy Program Makes Strides

DARPA's Air Combat Evolution (ACE) program is halfway through Phase 1 and has notched several key accomplishments in anticipation of live subscale aircraft dogfights in Phase 2 later this year. Achievements to date include advanced virtual AI dogfights involving both within visual range and beyond visual range multi-aircraft scenarios with updated simulated weapons, live flights of an instrumented jet to measure pilot physiology and trust in AI and initial modifications to the first full-scale jet trainer scheduled to

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host an onboard AI "pilot" in Phase 3 of the program.

"Our biggest focus at the end of Phase 1 is on the simulation-to-real transition of the AI algorithms as we prepare for live-fly subscale aircraft scenarios in late 2021," said Col. Dan "Animal" Javorsek, program manager in DARPA's Strategic Technology Office. "Managing this transition to the real world is a critical test for most AI algorithms. In fact, prior efforts have been brittle to just these types of transitions because some solutions can be over reliant on digital artifacts from the simulation environment."

The goal of the ACE program is to develop trusted, scalable, human-level, AI-driven autonomy for air combat by using human-machine collaborative dogfighting as its challenge problem. In August 2020, the Johns Hopkins Applied Physics Laboratory (APL) executed the ACE program's AlphaDogfight trials, a competition of eight teams whose AIs flew simulated F-16s in 1-v-1 aerial dogfights, developed by APL. The champion AI then flew five simulated dogfights against an experienced F-16 fighter pilot in a simulator, beating the human 5 to 0.

In February, the ACE algorithm-development teams completed the next level of simulated AI dogfights in Scrimmage 1 at APL. APL has continued to design and extend the simulation environment for this phase of the ACE program. Teams demonstrated 2-v-1 simulated engagements with two friendly "blue" F-16s fighting as a team against an enemy "red" aircraft. This marked the first AI scrimmage following the AlphaDogfight trials and introduced more weapons into the mix—a gun for precise, shorter-range shots and a missile for longer-range targets.

"These new engagements represent an important step in building trust in the algorithms since they allow us to assess how the AI agents handle clear avenue of fire restrictions set up to prevent fratricide. This is exceedingly important when operating with offensive weapons in a dynamic and confusing environment that includes a manned fighter and affords the opportunity to increase the complexity and teaming associated with maneuvering two aircraft in relation to an adversary," Col. Javorsek said.

Another major focus of the ACE program is measuring pilot trust in the AI's ability to conduct combat maneuvers while the human on board focuses on higher cognitive battle manager decisions. To begin capturing this trust data, test pilots have flown several flights in an L-29 jet trainer at the University of Iowa Technology Institute's Operator Performance Laboratory. The two-seat jet is outfitted with sensors in the cockpit to measure pilot physiological responses, giving researchers clues as to whether the pilot is trusting the AI or not. The jet is not actually flown by an AI; rather a safety pilot in the front cockpit acts as a "human servo actuator" executing flight control inputs generated by an AI.

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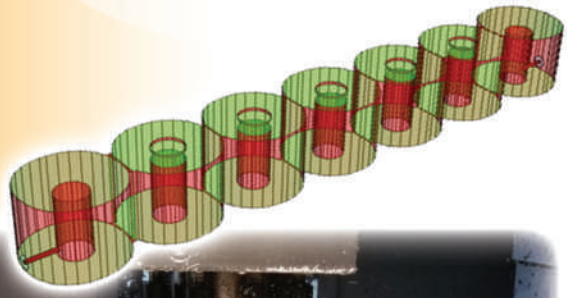

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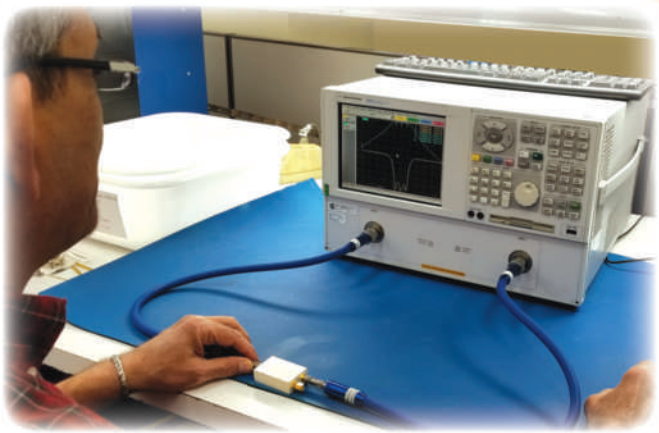

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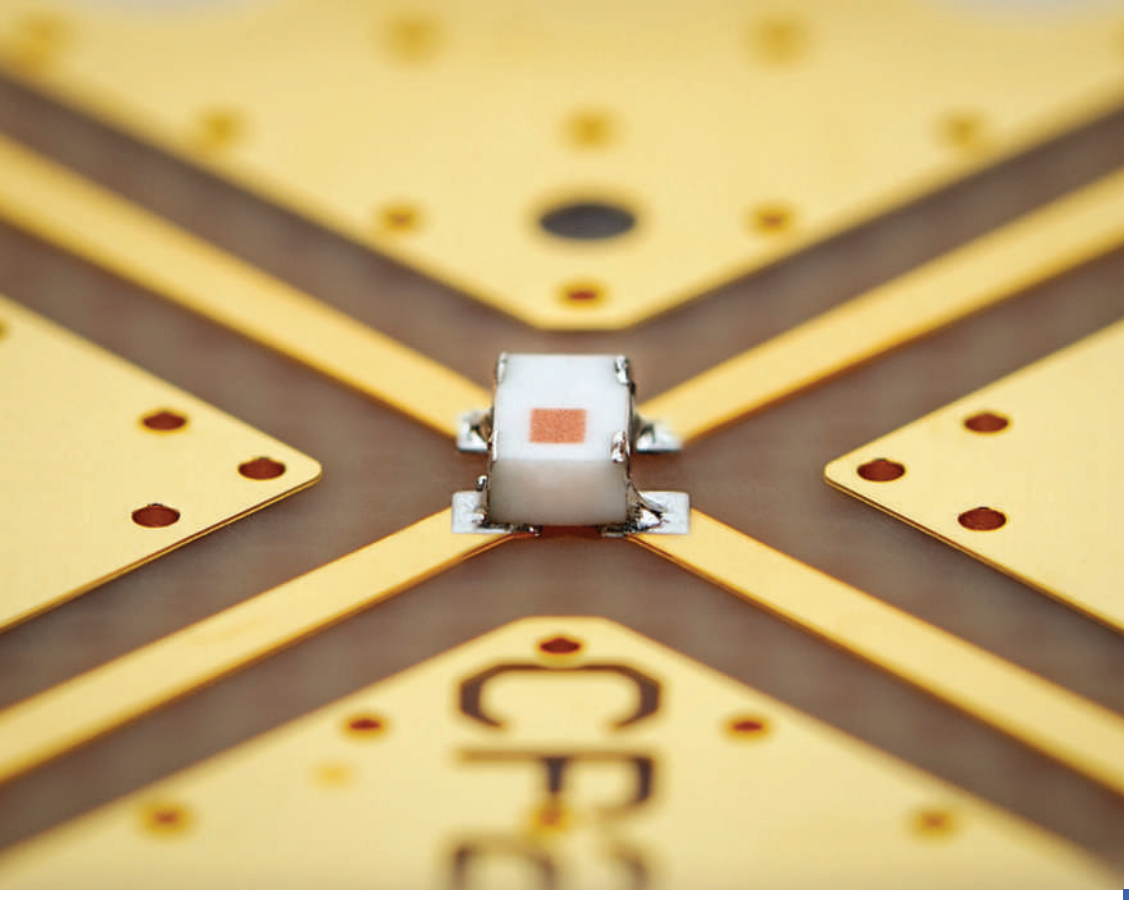

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NIST Demo Adds Key Capability to Atom-Based Radio Communications

Researchers at the National Institute of Standards and Technology (NIST) and collaborators have demonstrated an atom-based sensor that can determine the direction of an incoming radio signal, another key part for a potential atomic communications system that could be smaller and work better in noisy environments than conventional technology.

NIST researchers previously demonstrated that the same atom-based sensors can receive commonly used communications signals. The capability to measure a signal's "angle of arrival" helps ensure the accuracy of radar and wireless communications, which must sort out real messages and images from random or deliberate interference.

"This new work, in conjunction with our previous work on atom-based sensors and receivers, gets us one step closer to a true atom-based communication system to benefit 5G and beyond," project leader Chris Holloway said.

"Cesium Sensor" (Credit: NIST)

In NIST's experimental setup, two different colored lasers prepare gaseous cesium atoms in a tiny glass flask, or cell, in high energy "Rydberg" states, which have novel properties such as extreme sensitivity to electromagnetic fields. The frequency of an electric field signal affects the colors of light absorbed by the atoms.

An atom-based "mixer" takes input signals and converts them into different frequencies. One signal acts as a reference while a second signal is converted or "detuned" to a lower frequency. Lasers probe the atoms to detect and measure differences in frequency and phase between the two signals. Phase refers to the position of electromagnetic waves relative to one another in time.

The mixer measures the phase of the detuned signal at two different locations inside the atomic vapor cell. Based on the phase differences at these two locations, researchers can calculate the signal's direction of arrival.

To demonstrate this approach, NIST measured phase differences of a 19.18 gigahertz experimental signal at two locations inside the vapor cell for various angles of arrival. Researchers compared these measurements to both a simulation and a theoretical model to validate the new method. The selected transmission frequency could be used in future wireless communications systems, Holloway said.

The work is part of NIST's research on advanced communications, including 5G, many of which will be much faster and carry far more data than today's technologies. The sensor research is also part of the NIST on a Chip program, which aims to bring world-class measurement-science technology from the lab to users anywhere and anytime. Co-authors are from the University of Colorado Boulder and ANSYS Inc. in Boulder.

Atom-based sensors in general have many possible advantages, notably measurements that are both highly accurate and universal, that is, the same everywhere because the atoms are identical. Measurement standards based on atoms include those for length and time.

5G Achieves Mass Market Appeal

As 5G networks are now nearing a critical mass of global commercial network deployments and subscribers, it suggests a rapid upward curve of technology adoption over the next few years, according to 5G Americas, the wireless industry trade association and voice of 5G and LTE for the Americas.

According to data provided by Omdia, the world added 385.5 million 5G subscribers between Q4 2019 and Q4 2020 to reach 401 million 5G connections globally, shrugging off the challenges of a global pandemic and economic headwinds. As of December 2020, 5G wireless powered ahead at 3x the adoption rate of subscriber growth as 4G LTE, which required a full five years to reach the same level of subscriber acceptance, which represents a 2,500 percent increase in subscribers over last year. The number of 5G connections is expected to reach 619 million globally by the end of 2021.

Chris Pearson, president, 5G Americas said, "5G is in its early stages of fulfilling its full potential, as the industry has just finished the second inning of a nine-inning baseball game. In the second full year of commercially available 5G, the industry went from 15.4 million to 401 million subscribers. The uptake of 5G connections will accelerate significantly over the next few years."

Omdia projects that by the end of 2025, global 5G connections will reach 3.4 billion. Regionally, the number of connections is forecast to reach 451 million in North America and 167 million in the Caribbean and Latin America by the end of 2025.

From a commercial availability standpoint, an additional 105 5G networks went live globally in 2020, bringing the total up to 163 5G networks. The number of commercial 5G networks is expected to reach 277 by the end of 2021, according to data from TeleGeography. The growing availability of 5G-enabled devices has also blossomed, with the Global Mobile Suppliers Association (GSA) noting there are now 628 5G devices announced, of which 404 were commercially available by the end of February 2021.

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In addition to 5G, 4G LTE connections also experienced healthy growth in 2020, surpassing year-end projections of 5.73 billion to reach a total of 6 billion connections. Of those, 499 million 4G LTE connections are from North America and 407 million from Latin America and the Caribbean.

With 5G just beginning in Latin America and the Caribbean, the region saw 6,340 5G subscriptions added in the year of 2020. In contrast, LTE continued its strong growth, ending Q4 2020 with 407 million LTE subscriptions.

Consumer Device Market Set for Post-Pandemic Growth

ABI Research forecasts that consumer devices supporting ultra-wideband (UWB) connectivity, including cellular devices, smart home appliances and automotive will reach approximately 286 million units in 2021. They also predict that 1.15 billion 5G smartphones will ship in 2025 and the wearables and true wireless headsets market will see explosive growth, overcoming 1 billion shipments in 2025.

"Consumer technology device shipments will gradually recover in 2021 as the impact of the pandemic starts to wane, consumer confidence returns and device supply chains bounce back to near—pre-COVID levels. Notably, ultra-low power machine learning chipsets and devices supporting UWB are among the major consumer technologies that will take-off this year," said Khin Sandi Lynn, industry analyst at ABI Research.

While the total smartphone market saw 8.5 percent shipments decline in 2020, significant growth was witnessed in the 5G smartphones sector. "This is due to the diverse availability of 5G smartphone models and the rapid push to the lower-priced 5G smartphones segment, which will continue to accelerate adoption in 2021 and beyond," Lynn explained. The 5G smartphone market will grow at a CAGR of 43 percent to surpass 1,150 million units in 2025, accounting for 73 percent of all smartphone sales.

Demand for wireless connectivity in the consumer devices market, including products such as Wi-Fi routers, wireless hotspots, gateways and Wi-Fi CPE also increased rapidly in 2020, owing to the impact of the pandemic and an essential need to facilitate more home-based working and learning and the higher adoption and consumption of live and on-demand video streaming services and online gaming.

Ultimately, the consumer technology market is shifting from being device-centric to one that is experience-focused. Cloud services and the range of internet-connected content and apps increase the value of available personal consumer devices and smart home appliances and drive purchase decisions.

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Exodus AMP2030B-LC is a **Beast** in a compact 6U chassis! Covering 1.0-6.0GHz, produces >400W minimum, >500W nominal power, typical P1dB >300W. Excellent gain flatness with a minimum power gain of 56dB. Included are amplifier monitoring parameters for Forward/Reflected power, VSWR, as well as voltage, current & temperature sensing for optimum reliability & ruggedness. Nominal weight is 50Kg, and dimensions of 19"W x 25"L x 10.5"H.

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Exodus AMP2033LC is designed for replacing aging TWT technology. A broadband, rugged EMC Class A/AB linear design for all modulations & industry standards. Covers 6.0-18.0GHz, produces >100W Minimum, 50W P1dB, with a minimum 50dB gain. Excellent flatness, optional monitoring parameters for Forward/Reflected power, VSWR, voltage, current & temperature sensing for superb-reliability. Exodus Quiet-Cool technology in our compact 5U-chassis weighing a nominal 75lbs.

Exodus 18.0-26.5GHz, 40-Watt SSPA's replace aging TWT technology

Exodus Advanced Communications 18.0-26.5GHz, 40W Solid State Amps are replacing aging TWT Amplifiers. Designed for General EMC Testing Applications as well as Mil-Std 461(RS103) standards. Exodus Model AMP4065LC is a compact 6U design providing superb RF Performance with **Unprecedented P1dB power as compared to TWT's.** They provide 46dB min-gain, -20dBc harmonics as well as gain control with < 10dB noise figure. Exodus offers a full range of 10W, 20W, 40W, 60W & 100W versions.

Exodus 26.5-40.0GHz, 40-Watt SSPA replaces aging TWT technology

Exodus Advanced Communications 26.5-40.0GHz, 40W Solid State Amps are replacing aging TWT Amplifiers. Designed for General EMC Testing Applications as well as Mil-Std 461(RS103) standards. Exodus Model AMP4066LC is a compact 6U design providing superb RF Performance with **Unprecedented P1dB power as compared to TWT's.** They provide 46dB min-gain, -20dBc harmonics as well as gain control with < 10dB noise figure. Exodus offers a full range of 10W, 20W, 40W, 60W & 100W versions.

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10khz to 51GHz, 2W P1dB and below

Low Noise Amplifiers

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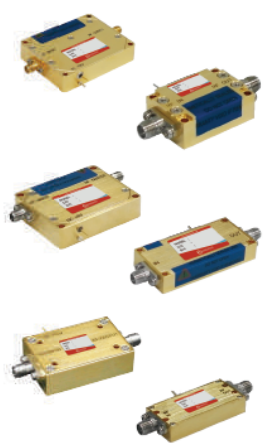

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Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

IN MEMORIAM

Tapan K. Sarkar, Ph.D., 72, of Syracuse, N.Y., passed away peacefully on Friday, March 12, 2021 in Upstate University Hospital. He was born in India on August 2, 1948. Dr. Sarkar received a B Tech. degree from the Indian Institute of Technology, Kharagpur, in 1969, a M.S. degree from the University of New Brunswick, Fredericton, NB, Canada, in 1971 and M.S. and Ph.D. degrees from Syracuse University, Syracuse in 1975. From 1975 to 1976, he was with the TACO Division of the General Instruments Corporation. He was with the Rochester Institute of Technology, Rochester, N.Y., from 1976 to 1985. He was a Research Fellow at the Gordon McKay Laboratory, Harvard University, Cambridge, Mass., from 1977 to 1978. Most recently, he was a professor in the Department of Electrical and Computer Engineering, Syracuse University. His research interests dealt with numerical solutions of operator equations arising in electromagnetics and signal processing with application to system design.

▲ *Tapan K. Sarkar*

MERGERS & ACQUISITIONS

Quantic™ Electronics, a portfolio company of Arcline Investment Management, announced the acquisition of **Corry Micronics**, a supplier of RF and microwave components and subsystems specializing in high-power and broadband solutions. Since 1970, CMI has been providing customers with a broad range of capabilities, expertise, design flexibility and customization for a broad range of RF and microwave components and subsystems. Quantic™ Electronics has also announced the acquisition of **Planar Monolithics Industries**, a leader in the design, development, manufacturing and testing of hybrid monolithic microwave integrated circuit components and subsystems. PMI was founded by Dr. Ashok Gorwara in 1989.

Catalyst Unity Solutions—a professional sales organization representing leading manufacturers of passive and active electronic components, electro-mechanical devices and value added services—announced its formation by the merging of **Catalyst Sales Inc.** and **Unity Sales LLC**. Catalyst Unity Solutions offers solutions to design challenges in the following spaces: batteries, EMI/RFI/EMC, thermal, displays, power supplies, relays, transformers and magnetics, semiconductors, switches, circuit protection, audio, sensing, RF/comm, fans, motors, passive components, optics and mechanical. Value added services include PCBAs, wiring harnesses, box builds, HMI development, kitting/assembly, low-cost sourcing and warehousing.

AMETEK Inc. announced that it has entered into a definitive agreement to acquire **Abaco Systems Inc.**, a provider of mission critical embedded computing systems, from Veritas Capital in an all-cash transaction valued at $1.35 billion. Abaco Systems specializes in open-architecture computing and electronic systems for aerospace, defense and specialized industrial markets. Their ruggedized products are designed to withstand harsh operating environments such as extreme temperature and high vibration. Abaco Systems has annual sales of approximately $325 million and is headquartered in Huntsville, Ala. The transaction is subject to customary closing conditions, including applicable regulatory approvals and is expected to close mid-2021.

COLLABORATIONS

Modelithics and **Passive Plus** have partnered to offer new circuit and 3D resistor models validated to 60 GHz. Modelithics announced the release of new models for the Passive Plus R35-1209BB and R35-2010BB flip-chip resistor products. New Microwave Global Models™ for both resistor series are now available within the Modelithics COMPLETE Library™ as well as the Modelithics mmWave & 5G Library. In addition, new 3D geometry models for the resistors are now available within version v20.8 of the Modelithics COMPLETE+3D Library for Ansys HFSS™.

MixComm, the mmWave Antennas to Algorithms™ pioneer, announced it is working with **Dreamtech**, a technology enabler that "Brings Dream Technology to Reality," to further the development of 5G mmWave systems. Through this new partnership, the companies will collaborate on network infrastructure solutions such as repeaters, customer premises equipment and more, as well as user equipment devices. Building off MixComm's deep mmWave RFSOI experience, Dreamtech will initially offer MixComm's evaluation boards and antenna array designs, which will accelerate development of 5G systems. MixComm also announced that Woonsub Kim, former executive vice president and general manager of Samsung's Network Division, has joined its advisory board.

Teledyne e2v HiRel Electronics announced a new high reliability partnership with California-based **Integra Technologies Inc**. Under the new agreement, Teledyne will leverage Integra's portfolio of GaN on SiC RF power transistor products to deliver optimized power solutions for the space market. With Integra, Teledyne e2v

For More Information **For up-to-date news briefs, visit mwjournal.com**

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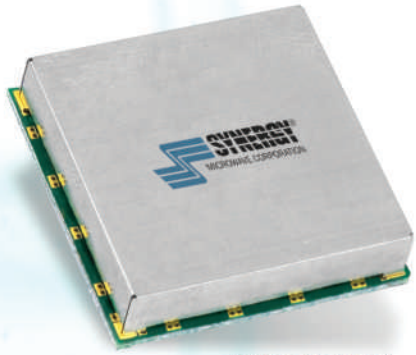
SAW VCO's



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Features:

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- Small Size Surface Mount *

Model	Frequency [MHz]	Tuning Voltage [VDC]	DC Bias VDC @ I [Max.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]
HFSO640-5	640	0.5 - 12	+5 VDC @ 35 mA	-151
HFSO745R84-5	745.84	0.5 - 12	+5 VDC @ 35 mA	-147
HFSO776R82-5	776.82	0.5 - 12	+5 VDC @ 35 mA	-146
HFSO800-5	800	0.5 - 12	+5 VDC @ 20 mA	-146
HFSO800-5H	800	0.5 - 12	+5 VDC @ 20 mA	-150
HFSO800-5L	800	0.5 - 12	+5 VDC @ 20 mA	-142
HFSO914R8-5	914.8	0.5 - 12	+5 VDC @ 35 mA	-139
HFSO1000-5	1000	0.5 - 12	+5 VDC @ 35 mA	-141
HFSO1000-5L	1000	0.5 - 12	+5 VDC @ 35 mA	-137
MSO1000-3	1000	0.5 - 14	+3 VDC @ 35 mA	-138
HFSO1200-5	1200	0.5 - 12	+5 VDC @ 100 mA	-140
HFSO1600-5	1600	0.5 - 12	+5 VDC @ 100 mA	-137
HFSO1600-5L	1600	0.5 - 12	+5 VDC @ 100 mA	-133
HFSO2000-5	2000	0.5 - 12	+5 VDC @ 100 mA	-137
HFSO2000-5L	2000	0.5 - 12	+5 VDC @ 100 mA	-133

Package dimension varies by model. (0.3" x 0.3" to 0.75" x 0.75")

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HiRel will specialize in providing high-power RF devices for emerging space applications in the LEO and GEO payload market. Teledyne will also offer high reliability options for Integra's popular GaN on SiC power devices and pallets targeted at the defense market.

Anritsu Corp., in collaboration with **Qualcomm Technologies Inc.**, announced that its 5G RF Conformance Test System ME7873NR has achieved the first approval from GCF for the mmWave 3GPP TS38.521-4 Demodulation/CSI Conformance Testing (performance test), required for 5G NR RF Conformance tests. GCF certified Anritsu's ME7873NR performance test for 5G NR frequency range 2 (FR2) non-standalone mode tests implemented in collaboration with Qualcomm Technologies at the January 2021 CAG meeting. Prior to this GCF certification, Anritsu had been a key player at 3GPP RAN5 meetings, the body responsible for formulating RF conformance test standards.

Keysight Technologies Inc. announced that **MediaTek** has used Keysight's 5G platform to establish 5G connectivity based on 3GPP release 16 (Rel-16) specifications and verified features of 3GPP technical enhancements and improvements including FR1 and FR2 carrier aggregation, new radio-new radio dual connectivity and others. MediaTek used Keysight's integrated 5G test solutions to validate the chipset maker's latest M80 5G modem, which combines mmWave and sub-6 GHz 5G technologies into a single chip to support ultra-fast data speeds. MediaTek also used Keysight's 5G Protocol Conformance Toolset to validate the protocol signaling performance of the company's M80 5G modem.

Mavenir, an end-to-end network software provider and a leader in accelerating software network transformation for communications service providers, and **Platform9**, a leading managed Kubernetes provider for private and edge clouds, announced a strategic partnership to accelerate the rollout of 5G services. As part of the partnership, Mavenir intends to leverage Platform9's Kubernetes solution to deliver a robust web-scale platform that runs containerized cloud-native network functions. Mavenir has integrated Telco platform as a service that it contributed to Opensource XGVela on top of the Platform9 Managed Kubernetes solution to meet the requirements of Open RAN and other telco workloads.

NEW STARTS

Ignited by the rapid adoption of its Virtual Antenna™ technology, **Fractus Antennas** has unveiled its new name and corporate image as a part of the company's expansion and growth mode led by Jaap Groot, **Ignion**'s new CEO, including the opening of the new U.S. office and several strategic partnerships. The company has recently announced that only in the past five years 25 million devices have been deployed worldwide using their antenna technology. Ignion and its disruptive Virtual Antenna™ technology unlock the full wireless connectivity of any IoT device in the most powerful and simple way.

Averatek Corp. has launched the A-SAP™ Community of Interest. This web-based content platform was developed as a central resource for the industry: so that all members of the supply chain—from designers to end users—can exchange information and insights about the A-SAP™ leading-edge PCB fabrication process. Averatek A-SAP™ is an advanced manufacturing process for PCB fabrication, with trace and space widths as narrow as 15 microns. This process can dramatically reduce area, layer count and weight of electronics systems—as well as provide significant RF benefits. A-SAP™ can be easily integrated with traditional PCB manufacturing equipment and materials.

Comtech Xicom Technology Inc., the premier supplier of high-power amplifiers (HPAs) for satellite communication (satcom), has launched a newly redesigned website. The website highlights the company's leadership in Ka-, Q- and V-Band HPAs and targets solutions for many new commercial and military/government applications including airborne, on-the-move, HTS Gateway, LEO/MEO constellations, datalinks as well as emerging medical and scientific applications. Users can find technical specifications, application information, white papers, technical support and request quotes. Visit the New Xicom website at www.xicomtech.com.

ACHIEVEMENTS

Accumet celebrates its 50th anniversary. Accumet is an industry-leading advanced processing manufacturer for new and legacy materials fabrication, precision laser services, lapping, polishing and critical component assembly. They provide some of the most innovative manufacturing techniques in the industry—techniques they not only perfected over the past half century, but invented. When Accumet Engineering Corp. first opened its doors in 1970, America was in the throes of the Vietnam War, the Cold War, the Space Race and innumerable sociopolitical turmoil. The American landscape was post-industrial, but pre-automation; man had been to the moon, but had yet to even dream of the worldwide web.

CONTRACTS

Lockheed Martin received a $1.12 billion contract from the **U.S. Army** for Lot 16 production of guided multiple launch rocket system (GMLRS) rockets and associated equipment. The contract calls for the production of more than 9,000 GMLRS unitary and alternative warhead rockets, more than 2,000 low-cost reduced-range practice rockets and integrated logistics support for the U.S. Army, U.S. Marine Corps and international customers. Work will be performed at the Lockheed Martin facilities in Camden, Ark.; Dallas and Lufkin, Texas; and Ocala, Fla., and will be completed by September 2023.

AeroVironment Inc., a leader in unmanned aircraft systems (UASs), announced the **U.S. Army** exercised the second of three options under the sole source flight control systems domain of the Army's multi-year small UAS contract. The value of the contract option is $20,979,905 and includes avionics and data link upgrade packages to modify RF employed by the Army's existing fleet of Raven® tactical UAS. The period of

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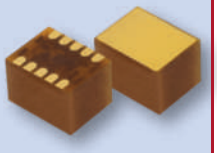


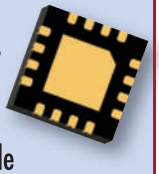
Test & Measurement

- Coax Adapters
- Terminations
- Open/Shorts
- Couplers
- Switches
- Phase Shifters
- Attenuators

- Documentation Related Services
- Obsolete Parts Replacement
- Solder Tinning
- Packaging
- Kitting

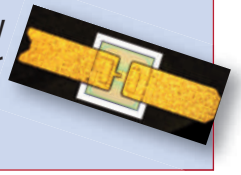
Amplifiers

- Gain Blocks
- Linear Drivers
- Low-Noise
- Variable Gain
- Coaxial Module



Diodes

- PIN
- Schottky
- Varactor
- Limiter
- Gunn



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Antennas

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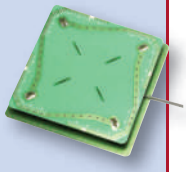
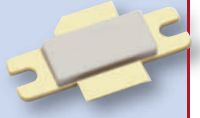
- Patch
- Coaxial
- Goose Necks
- Body-Worn



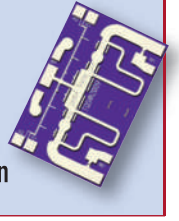
Transistors

- mW to kW
- GaN
- LDMOS
- High Frequency
- Packaged & DIE



Switches

- SMT
- Coaxial
- DIE
- High Power
- High Isolation

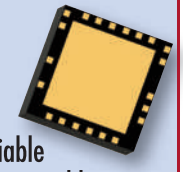


Cable Assemblies

- High-Performance Test
- In-Box Solutions
- Pigtails
- Conformable
- Flexible
- Semi-Rigid

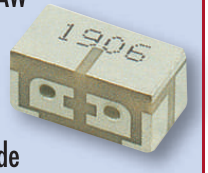
Attenuators

- Fixed
- Digital
- Coaxial
- Chip
- Voltage Variable
- Temperature Variable



Filters

- BAW / SAW
- Ceramic
- LTCC
- Cavity
- Waveguide



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performance ends June 30, 2022. The contract option was exercised under the Army's FCS domain awarded to AeroVironment in June 2019 with an initial base delivery order of $862,488.

Cubic Corp. announced **Nuvotronics**, which operates within its Cubic Mission and Performance Solutions business division, was awarded a contract worth more than $10 million from the **Department of Defense (DoD)** through the National Spectrum Consortium to develop a dual-band, ultra-high performance and low size, weight and power 5G wireless network communications transceiver (WNCT) for military applications. Cubic Nuvotronics will support the DoD's "5G to Next G" Program which was established to accelerate the implementation of wireless communications for the military. WNCT's simultaneous dual-band operation provides greater operational resiliency and ensures high speed data with low latency, with no interference on current DoD operational frequencies.

Sivers Semiconductors AB announced that the company has received two volumes orders totaling SEK 7 million. The orders are for RFICs to be used for licensed and unlicensed 5G products. The RFICs will be delivered during Q1 and Q2 2021. Sivers Wireless has previously communicated 24 design wins for licensed and unlicensed 5G products, where customers have existing agreements or ongoing design and development activities with Sivers' products. Both orders come from North American customers that have been listed as design wins.

Comtech Telecommunications Corp. announced that during its third quarter of fiscal 2021, its subsidiary, **Comtech Xicom Technology Inc.**, a leader in HPAs, received a contract valued at more than $1.0 million for X-Band SSPA/BUCs for transportable military satcom ground systems. X-Band is set aside for government satellite service, primarily military applications that require low interference, low rain-fade and small terminal size, even if data rates are limited. One of the major challenges of X-Band is that, unlike other satcom bands, the receive band is adjacent to the transmit band, making it critical that any RF leakage be extremely low to avoid interfering with the receive signal.

Thales Alenia Space, a joint venture between **Thales** (67 percent) and **Leonardo** (33 percent) has signed a 772 million EUR contract with the **European Space Agency**, acting in the name and on behalf of the European Union represented by the European Commission, to provide six satellites part of the Second Generation of Galileo constellation. The first satellites of this second generation will be placed in orbit by the end of 2024. With their new capabilities relying on high innovative technologies (digitally configurable antennas, inter-satellites links, use of full electric propulsion systems), these satellites will improve the accuracy of Galileo as well as the robustness to interference and jamming and resilience of its signal.

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The confluence of advances in supporting technologies, such as processors and memories – as well as developments in **UAVs** and **SmallSats** – coupled with geopolitical demands for increased homeland security and greater intelligence gathering has pushed SAR (synthetic aperture radar) into the ISR (intelligence, surveillance and reconnaissance) spotlight.

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Around the **Circuit**

PEOPLE

QuadSAT announced the appointment of **Dr. Carlo Rizzo** as chief commercial officer. He will lead QuadSAT on its commercial journey and be responsible for overseeing the objectives and implementation of all commercial strategies within QuadSAT. Taking ownership of the customer and the customer interface with the product and service offering, he will make sure all functions of the organization are aligned to meet its strategic commercial objectives. With more than 25 years of experience, he has a proven ability to develop new business and increase sales through success in reading and anticipating the market for specialized products and services, developing sales opportunities and building lasting relationships with customers.

▲ *Dr. Carlo Rizzo*

▲ *Gur Ballas*

Curvalux UK Ltd. announced the appointment of **Gur Ballas** to the position of chief technology officer (CTO). Ballas brings with him nearly 30 years of experience in research and development of advanced wireless communication systems. For the past 22 years, he held leading positions at Ceragon Networks, a global leader of wireless backhaul solutions, including Radio CTO, 5G CTO and in various senior R&D roles. In his new role with Curvalux, Ballas will be helping the company to define its new product roadmap, driving continuous innovation and supporting the company in its mission to connect the unconnected in rural and suburban areas around the world.

REP APPOINTMENTS

Altum RF, a supplier of high performance RF to mmWave semiconductor solutions for next-generation markets and applications, announced a sales representative agreement with **GLOBES Elektronik GmbH & Co. KG (GLOBES)**, covering customers located in Germany, Austria and Switzerland. Founded in 1995 with headquarters in Heilbronn, Germany, GLOBES specializes in deep technical knowledge of high frequency, microwave and RF technologies. GLOBES also has expertise and strong relationships in communications, military, ISM and satellite markets. Altum RF is an international company, with strategic partnerships and office locations that span the globe to support its growing product portfolio.

EMA Design Automation®, a full-service provider and innovator of **Electronic Design Automation (EDA)** systems solutions, announced it is expanding its operations in the U.K. with the addition of **Parallel Systems** to its sales channel. This announcement marks EMA's continued growth and commitment to bring leading-edge technology and first-class support to the worldwide EDA Market. Parallel Systems has served as the Cadence

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- Butler Matrices
- Coaxial Terminations
- Bias Tees, DC Blocks and Power Dividers
- Gain Equalizers
- Surface Mount Attenuators, Terminations, Resistors

Around the **Circuit**

channel partner for the U.K. and Ireland since 1997. This addition will allow them to leverage EMA's three decades worth of experience to further support the U.K. and Ireland engineering teams and expand their coverage.

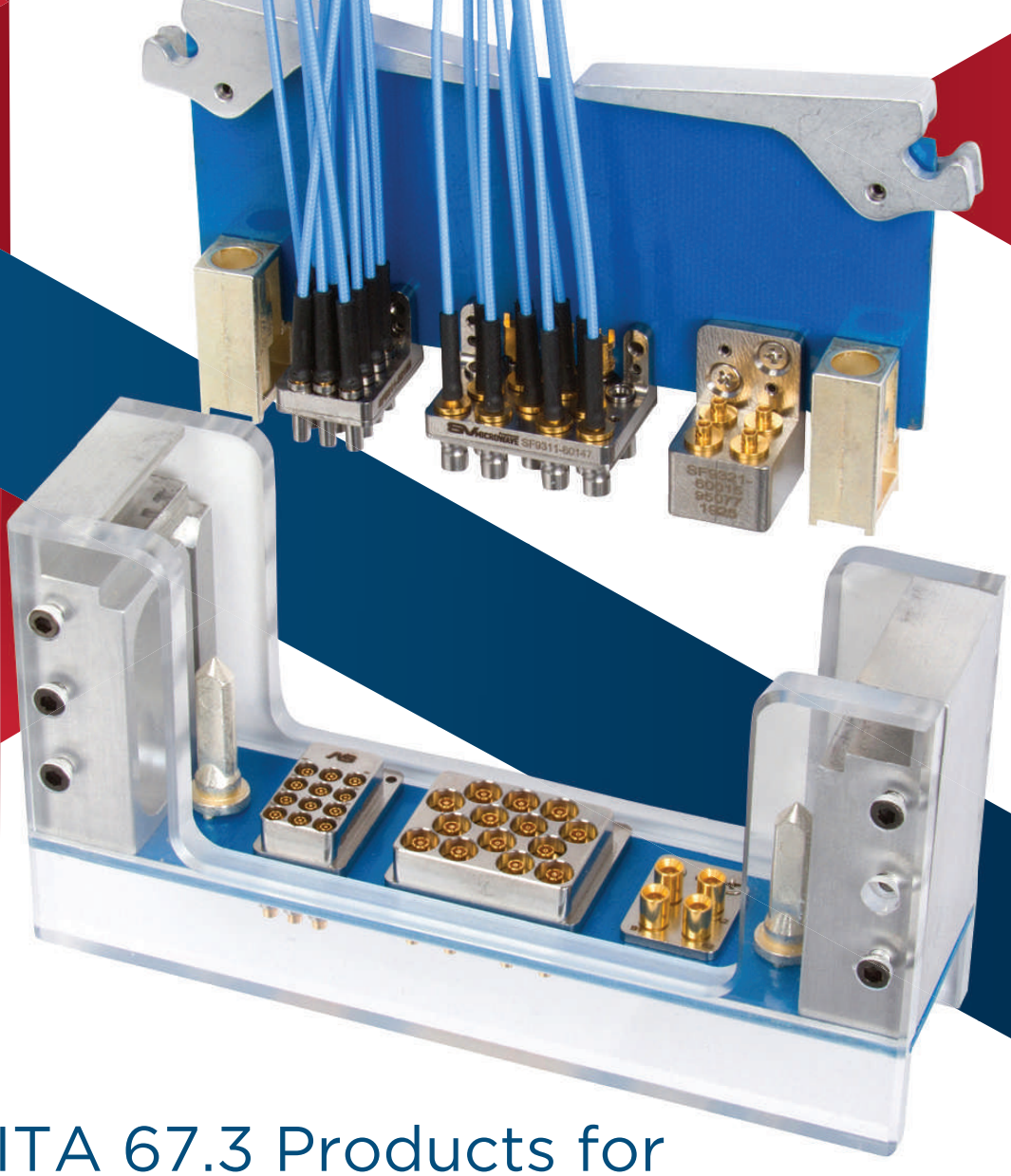
Fractus Antennas announced **Comp Tech Sales** as the latest representative of the Virtual Antenna™ technology servicing New Jersey, New York City, eastern Pennsylvania and southern Connecticut. As a well-known and highly respected representative for world-class leading manufacturers offering technology solutions for OEM systems customers, Comp Tech Sales is adding the Virtual Antenna™ products to its portfolio. From sensors to wearables on cellular, NB-IoT, LTE-M, GNSS (GLONASS, GPS, BeiDou, Galileo, IRNSS), LoRa, BLE5.1, Wi-Fi 6 or Wi-Fi 6E bands, among others, the combination of Comp Tech Sales and Fractus Antennas offers faster designs with high performance and efficiency in the smallest of devices for the entire IoT ecosystem.

RFMW announced a global distribution agreement with **Marki Microwave** of Morgan Hill, Calif. Under the agreement, RFMW is franchised for worldwide marketing and sales of Marki Microwaves' portfolio of broadband, low conversion loss and highly linear mixers, high directivity, low return loss couplers, directional bridges, well-balanced power dividers and hybrid couplers and many other quality products. Marki Microwave offers an extensive range of multi-octave bandwidth products in multiple packaging options, from bare die, to surface mount and coaxial-connectorized solutions that will fit the design needs of virtually any engineer.

Richardson Electronics Ltd. announced a new distribution agreement with **Quantum Microwave**, a U.S.-based manufacturer of microwave and mmWave solutions. This is a global agreement, excluding Japan, China and Taiwan. With a specialty in mmWave and microwave products, Quantum Microwave offers a variety of waveguide components and adapters that reach up to 325 GHz as well as connectorized amplifiers, antennas and mixers. Quantum Microwave also has a range of cryogenic microwave components that support the newly emerging quantum computing market, which work at temperatures as low as 10 mK.

PLACES

Santander Teleport, a leader in the teleport operations industry, and **Kymeta Corp.**, the communications company making mobile global, have entered into an agreement to open a technical and customer support center at the Santander Teleport facilities in Spain. The new venture will extend Kymeta´s existing support operations to the other side of the Atlantic. The technical center will be operated by highly skilled multilingual engineers and will launch later this month. The agreement supports Kymeta's goal to deliver unmatched and world-class support that is available 24x7. Kymeta Support provides a first line of support and seamless workflow from order placement to delivery.



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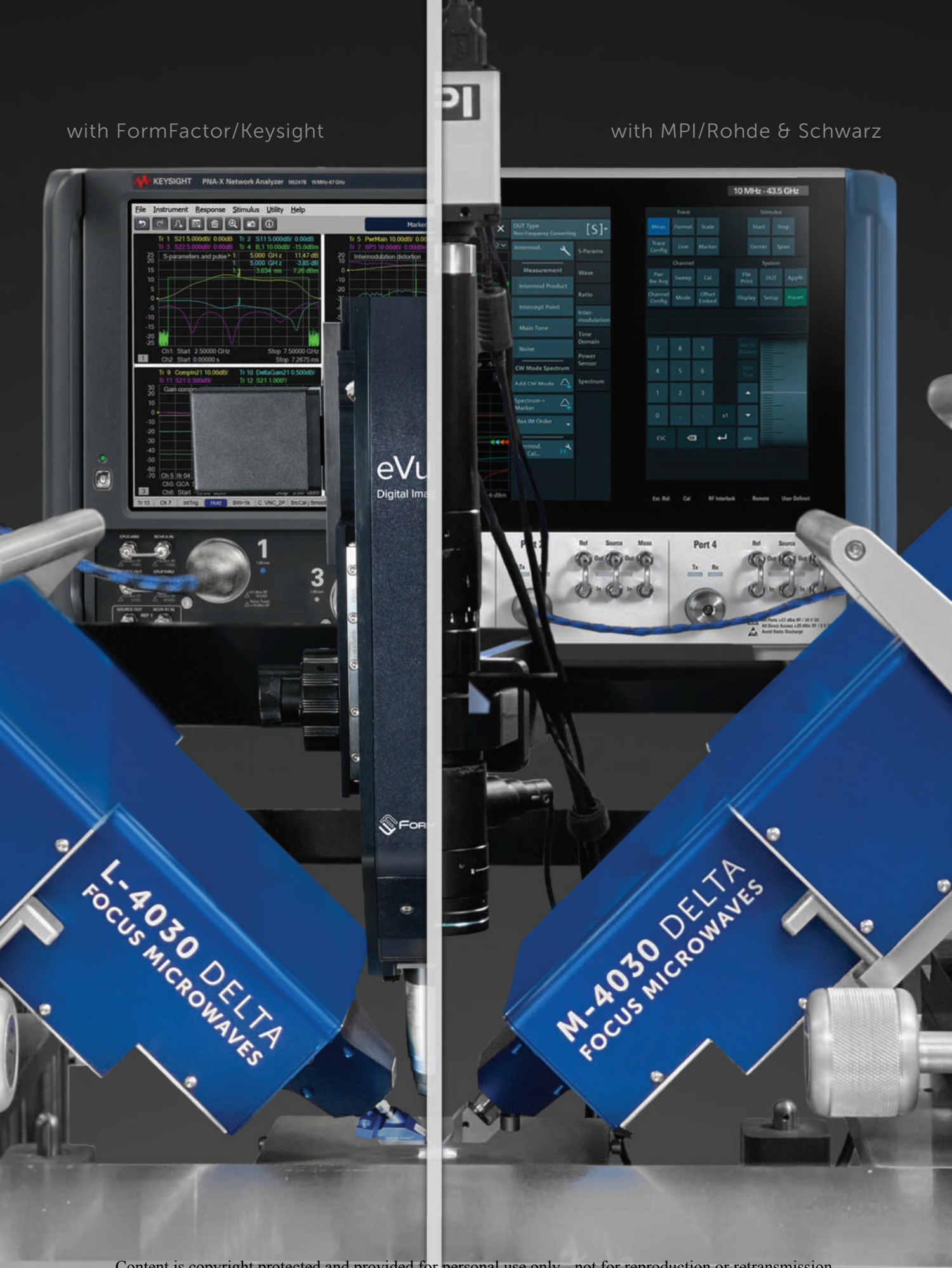

INVITED PAPER

Telecom Infrastructure: A Unique Utility

Antoine Bonnabel and Cédric Malaquin
Yole Développement (Yole), Lyon, France


Access to the internet and voice calls can be considered a utility, like water, power, gas or railways. In this context, telecom infrastructure is quite similar to other general utility infrastructure, as it consists of a large set of facilities and systems required to support a basic consumer need. Yet telecom infrastructure has two intrinsic differences with the infrastructure of other utilities. On the one hand, telecom infrastructure requires significant and frequent upgrades; on the other hand, telecommunications is the only utility where the subscription price has continuously declined over the last decade. Data services become less profitable for operators while, for example, the worldwide cost of energy or water keeps increasing.

These two points are of interest to understand the telecom infrastructure market's dynamics and trends. First, the continuous need for network upgrades stimulates the creation of new technological approaches, such as active antenna systems (AASs). Second, reduced profitability has motivated telecom operators to look for additional sources of growth and the development of new protocols to address new markets, such as enterprise and industrial. These two trends are directly linked to 5G and how it has been defined.

WHAT IS 5G?

As a general observation, 5G is not what is motivating the opening of new markets, allowing new applications and offering new technological approaches. 5G is the tool that the telecom industry developed to reach these goals. The economic development expected from this new generation was conceived and defined before the first 5G base station was even installed.

Over past decades, multiple concepts have emerged regarding the connection between people, machines and vehicles. The concept of a wireless sensor network has been around since the early 2000s, with multiple developments such as ultra-low power electronics that did not reach large scale market acceptance. The idea of networks of sensors easing industrial automation and increasing plant performance has been actively looked at, yet one of the main hindrances has remained, the access to efficient protocols and infrastructure. Similarly, communication among automobiles has received intense attention from regulators, leading to the allocation of the 5.9 GHz frequency band for vehicle-to-vehicle communication. Again, the concept had limited potential, as it could not communicate with the general network.

In this context, operators and system makers understood the opportunity for a communication protocol that could unite all these new markets, offering tremendous growth as well as a solution for the world's communication needs. This was the core focus of 5G during its definition a decade ago.

WHAT CONSTITUTES 5G?

5G technology is often referred to as the intersection of three concepts: enhanced massive broadband (eMBB), ultra-reliable low latency communication (URLLC) and massive machine type communication (mMTC). These three come directly from the world's communication demands. URLLC is linked to mission-critical communication, such as safety for inhabited vehicles or disaster management; mMTC is linked to large-scale sensor networks, such as wearables and industrial/building automation; eMBB is linked to consumer demand for increased data throughput, resulting from the development of video content, cloud gaming and virtual reality. Therein lies the essence of 5G, designed as the one communication technology to rule them all.

Once this is understood, it is easier to apprehend the focus for the future of telecom infrastructure. Apart from standard network upgrades, it will need to cover the newly appearing use cases, providing a new approach for networks in plants and enterprises while offering tele-transmission on roads and so on. Unfortunately, even though these use cases have been motivated by industry, an actual market pull is not really evident today in most of these prospective markets. Proposed solutions, albeit appealing, have not reached massive deployment…for now.

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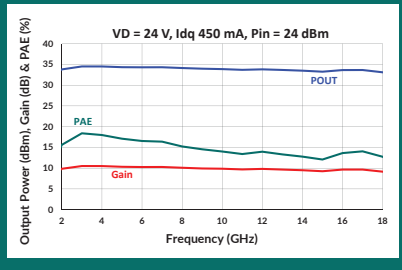

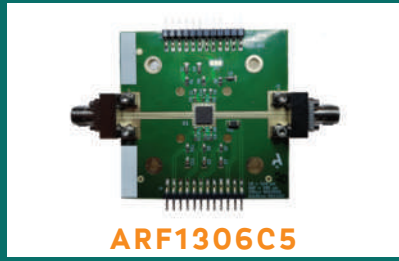

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THE TECHNOLOGY INSIDE

From a technological standpoint, this market-oriented approach has direct repercussions for protocols, frequency bands, transmission capabilities and so on (see ***Figure 1***). To illustrate, we can correlate the technical trends to foreseen applications: the need for URLLC means, among other things, a strong backhaul link, which creates the demand for dual-band backhaul connectivity when using wireless links and boosting the use of optical fiber backhaul connections. Today, URLLC is the toughest challenge for technologists regarding 5G implementation. The high throughput requirements of eMBB coupled with the lack of available spectrum motivated the use of the mmWave FR2 bands, i.e., frequencies above 24 GHz. The need for higher throughput also led to the use of more advanced OFDM modulation techniques that require ever more precise communication, i.e., with less interference and better coverage. This led to beamforming and the creation of AAS. The new frequencies needed for increased throughput led to adoption of a new semiconductor technology platform for power amplifiers and the transition from LDMOS to GaN. The requirements of industry and enterprise applications led to an aggressive development of small-cell structures and distributed antenna systems.

This list can go on and on. Nonetheless, when looking at how the 5G infrastructure will meet the increases in throughput (eMBB), number of devices addressed (mMTC) and reliability (URLLC), the main RF system innovations are:

- New frequency bands, both sub-6 GHz (FR1) and mmWave (FR2)
- AAS
- Smaller-reach devices (e.g., small cells and distributed antenna systems).

For the RF front-end, the RF system innovations lead to:

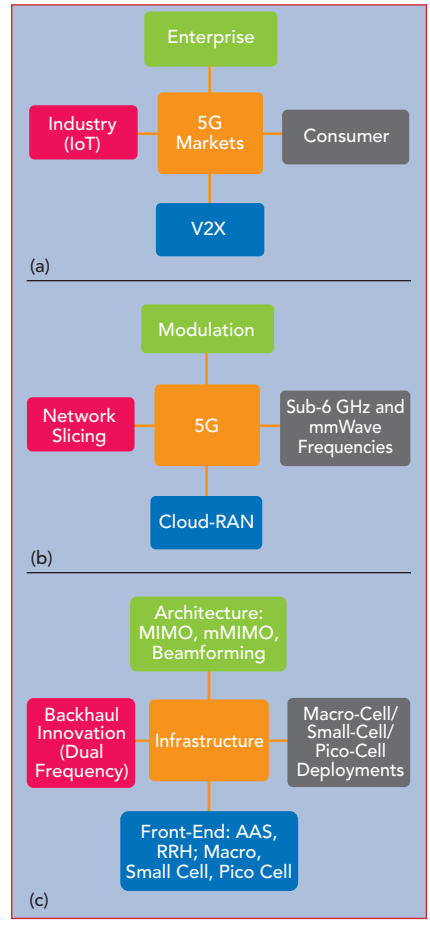

Fig. 1 Flow-down from market need (a) to 5G architecture (b) to infrastructure capabilities (c). Source: 5G's Impact on RF Front-Ends for Telecom Infrastructure report, Yole Développement, 2021.

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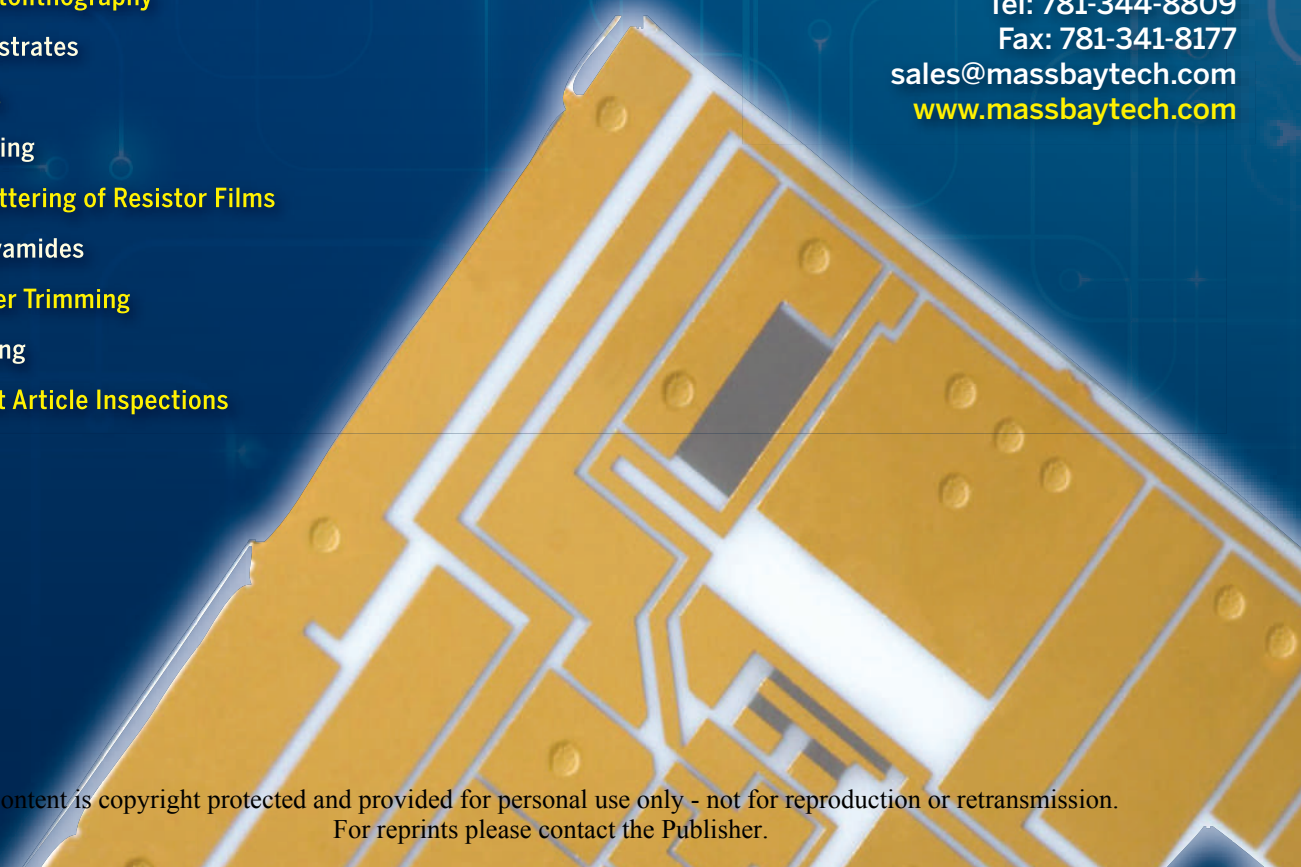

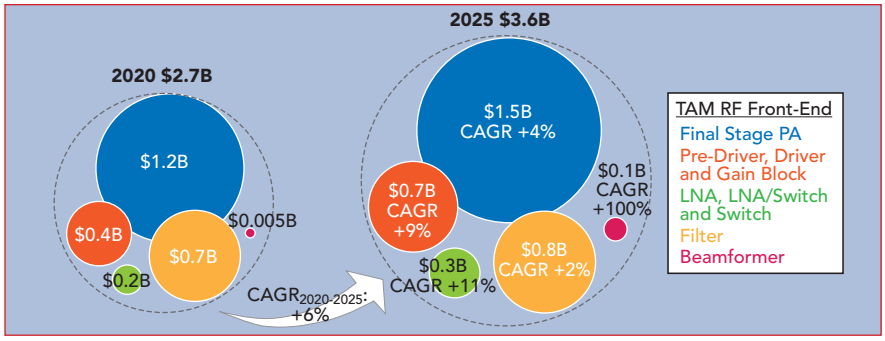

Fig. 2 RF infrastructure front-end market forecast. Source: 5G's Impact on RF Front-Ends for Telecom Infrastructure report, Yole Développement, 2021.

- High frequency and wideband components and new technology platforms (e.g., GaN and SiGe) and new circuit designs (e.g., triple-stage Doherty)
- Completely integrated mmWave systems for infrastructure, which did not previously exist
- Reduced component power consumption, as active antennas use more RF channels to transmit a similar EIRP
- Increased number of components (e.g., switches, PAs, LNAs) as AASs have more RF channels
- Complex last-mile backhaul for small-cell deployment, such as integrated access and backhaul.

Yole Développement has assessed these changes and their impact on the market, in terms of player landscape, industrial dynamics and market value. In our market report, "5G's Impact on RF Front-End for Telecom Infrastructure 2021," we forecast the infrastructure market is expected to grow from $2.70 billion in 2020 to $3.66 billion in 2025, peaking at $4.26 billion in 2023 (see ***Figure 2***).

These technological changes are only the visible part of the proverbial iceberg. For baseband processing and data management, 5G has massive repercussions. The tremendous network slicing innovation enables the complete virtualization of the communication network and the creation of seamless communication across industries, as well as enabling private networks supported by worldwide operator coverage. For the radio access network (RAN), significant changes in infrastructure management are being implemented through innovative approaches like cloud RAN and open RAN (O-RAN). "Mutualizing" RAN resources will decrease the cost of network operation and the environmental impact.

5G'S ENVIRONMENTAL IMPACT

A short digression is appropriate regarding the environmental impact of all these innovations and new applications on 5G infrastructure. 5G is power hungry. AASs consume more power and increasing the number of data exchanges also increases power consumption. On the other hand, there is tremendous effort at

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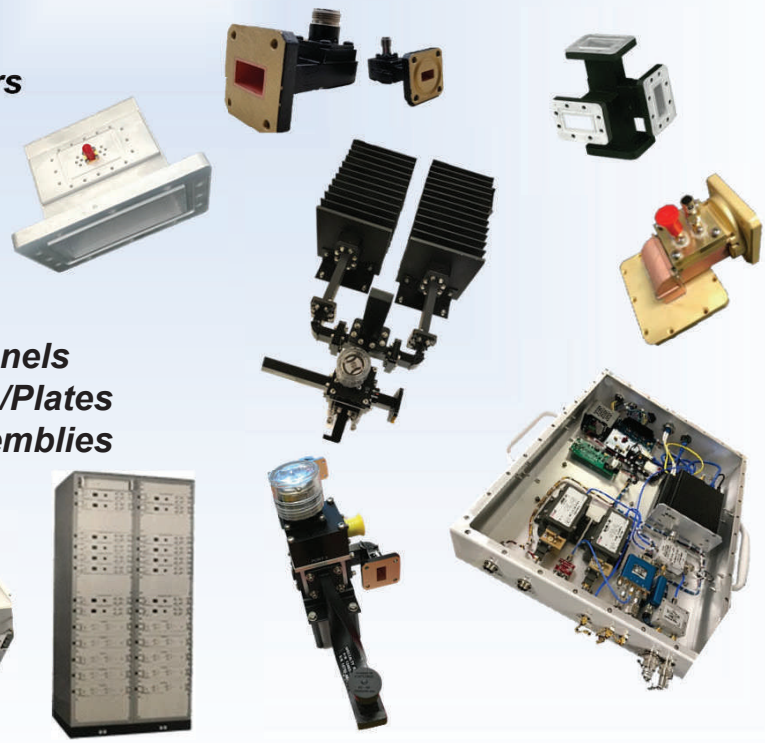

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the technology level to increase efficiency and reduce the power consumption per bit of data processed and exchanged. But the actual mitigating force in this environmental mess is not at the transmission and processing level, it is at the application level.

As stated before, 5G means connecting industry, connecting enterprises and so on. One of the objectives of using 5G in industrial automation is reducing manufacturing cost through process optimization. Although not the primary objective—cost improvement is—this directly leads to a reduction of manufacturing power and material consumption. For example, NB-IoT will help with fleet management and reduce gas consumption for package delivery. In-plant mmWave networks will help "smart" management and machine vision to improve manufacturing yields. With such a direct impact on the industrial environment, creating a connected world can mean creating an energy-efficient world. Looking at the big picture should be the focus for environmental improvement. In any case, continuous work on energy optimization must be ongoing at all levels of 5G, and this is clearly one of the industry's focuses.

CONTRIBUTING TO INFRASTRUCTUE EVOLUTION

Telecom infrastructure diverges from other utilities by its need for continuous upgrades, with future generations of standards directly linked to a pre-defined vision of how the future should look. 5G was defined at an abstract level a decade ago, and the current technological choices are just the practical implementation of this vision—the main goal being unifying communication across industry, with global automation and efficiency improvements.

Today, 6G is already being defined, and it follows the current global technological trends for artificial intelligence, cloud computing and data needs, with a strong focus on improved throughput, reduced power consumption and optimized data manipulation. Any industry member can contribute to the collective future by acting now to define 6G, through participation in ongoing consortiums and workshops, especially as 5G technology and its implementation are fixed and cannot be changed.

Defining the future of the telecom infrastructure is in everyone's hands, not only those of the telecom operators. Any member of society can take part in defining the longer term "7G" evolution. As the future of communication is dictated by our way of consuming data, anyone can act on these next generations by adopting the behavior of what the future should look like. Telecommunication infrastructure will always be the translation—10 to 20 years in the making—of the technological dynamics of our complex society.■

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INVITED PAPER

Virtual Cable Calibration for OTA Testing of 5G mmWave Devices

Taro Eichler, Ute Philipp, Heinz Mellein and Lorenz Rädler
Rohde & Schwarz, Munich, Germany

5G New Radio (NR) is the first standard to use the mmWave frequency region for highest data transfer rates. The highly integrated front-ends and array antennas necessitate advanced over-the-air (OTA) testing methods and new RF test metrics for assessing current and future mobile communication. Such test metrics include virtual cable calibration (VCC), which is mandatory for reproducible and reliable OTA throughput testing. For performance tests where fading is emulated—such as radio resource management (RRM) conformance and demodulation testing—the VCC method is crucial to assess defined antenna correlations with minimal crosstalk from the OTA link. The measurement results presented in this article demonstrate the proposed concepts for VCC can be applied to ensure device compliance to the 3GPP standard.

5G has pioneered the use of mmWave frequencies with large bandwidths to enable the reliable, high data transmission rates necessary for demanding real-time applications with low latencies. To increase the system capacity, as well as data rate, and to handle diverse services, 5G NR deploys at much higher frequencies and bandwidths compared to LTE, as well as very high configuration flexibility. A signal bandwidth of up to 400 MHz can be used in 5G NR, compared to 20 MHz in LTE. Since the spectrum below 6 GHz is already used extensively, high bandwidths are only available at higher frequencies, with two mmWave frequency ranges identified (see ***Figure 1***).

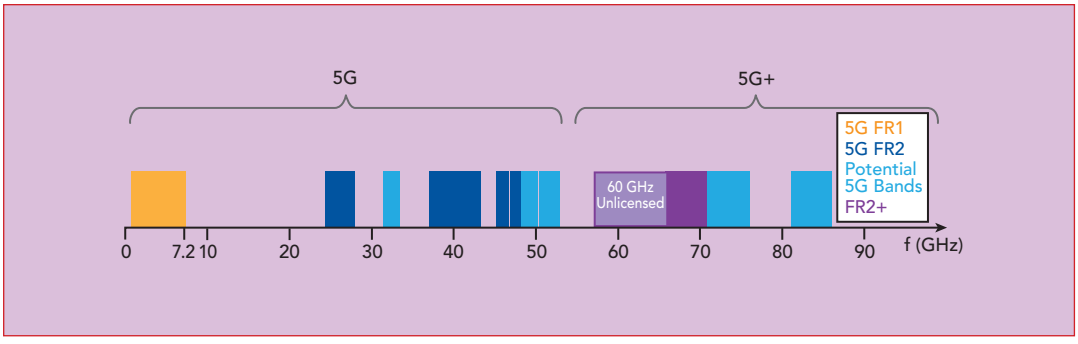

Fig. 1 **Designated 5G NR frequency bands (FR1, FR2 and FR2+) and possible future bands.**

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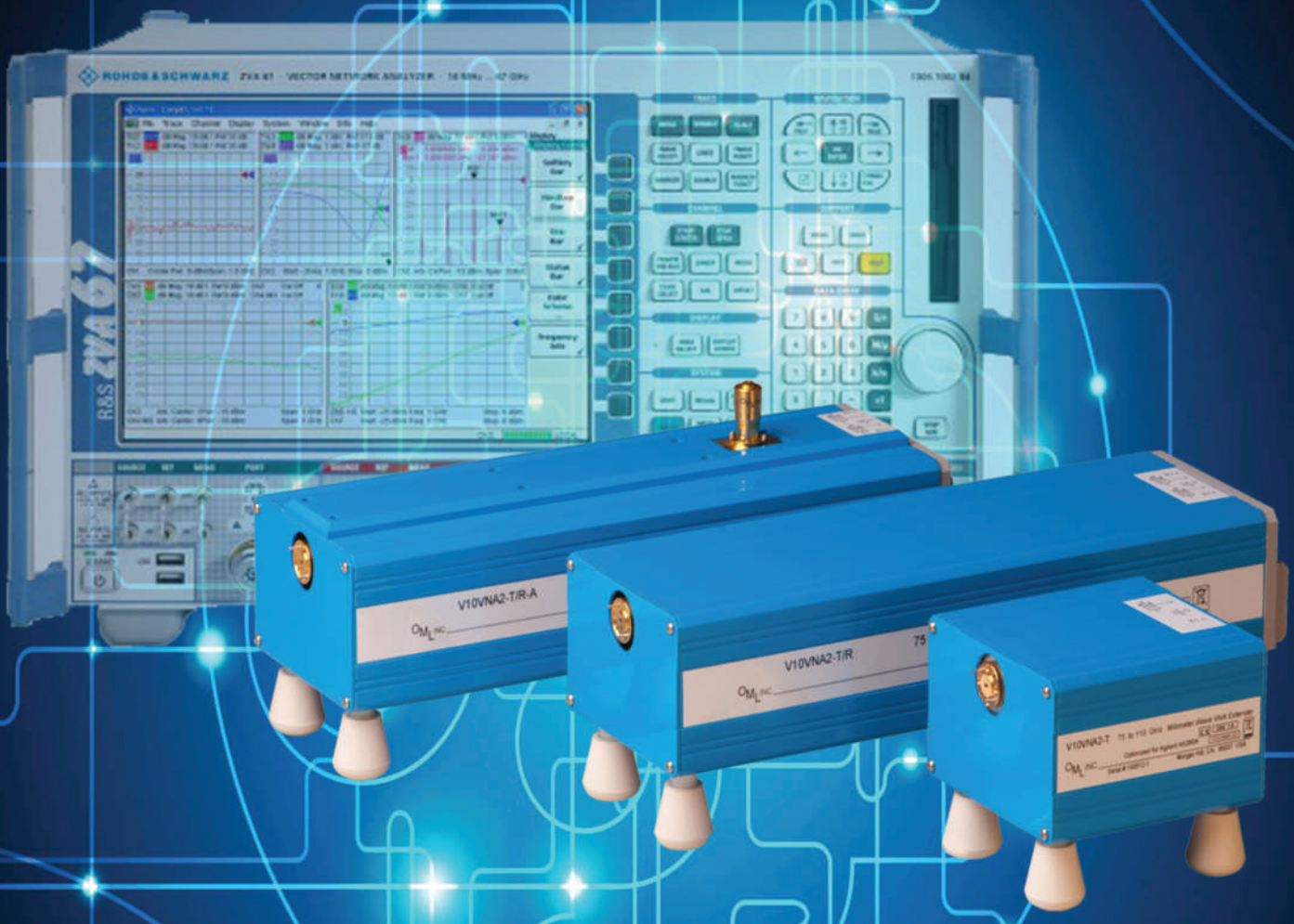

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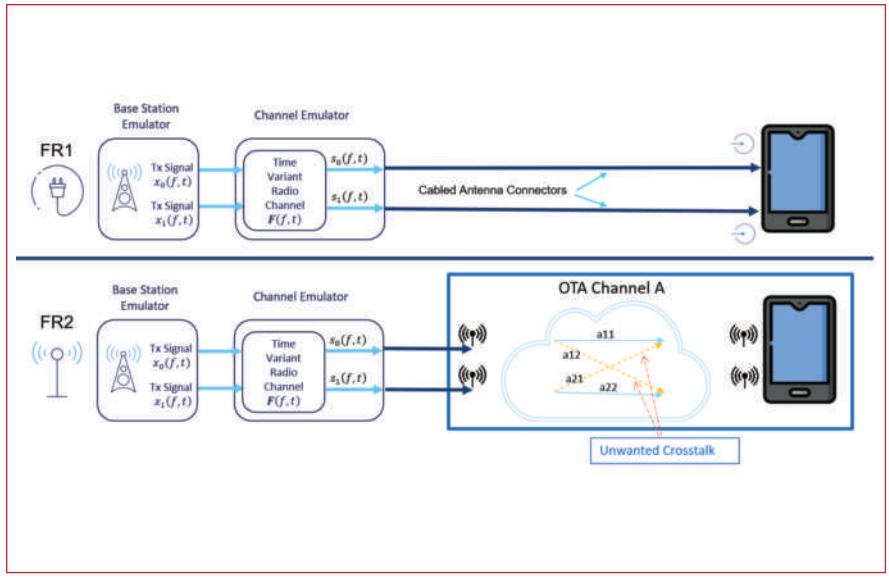

▲ Fig. 2 **UE testing for 2 x 2 MIMO with channel fading, showing connected (FR1) and OTA (FR2) approaches. OTA testing introduces unwanted crosstalk.**

The overall bands used for 5G NR are:

- Frequency range 1 (FR1) spans frequencies from 410 MHz to 7.125 GHz.
- Frequency range 2 (FR2) is the spectrum from 24.25 to 52.6 GHz.
- For future extension, the frequency range designated FR2+ covers 52.6 to 71 GHz.

5G technologies such as massive MIMO and beamforming further increase the complexity of testing user equipment (UE), as defined in 3GPP TS 38.521-4,[1] where highly integrated antennas require radiated test methods.

VCC FOR 5G MIMO

One of the biggest challenges for test and measurement manufacturers is implementing standardized evaluation and verification methods for UE under repeatable and realistic conditions, which are also reliable with mass production processes. For LTE and 5G NR FR1 tests, conductive testing methods are the norm for MIMO devices. During testing, the antennas of the device under test (DUT) are disconnected from the antenna ports, and the DUT is directly connected to the test system using a coaxial cable (see ***Figure 2***). However, for testing UEs in the FR2 bands, this approach is not practical: the large number of integrated antennas on the UE for spatial multiplexing and beamforming requires testing OTA, without cable connections.

OTA testing introduces challenges. The transmitted signal propagating in the air channel, represented by OTA Channel A in Figure 2, is affected by other signals and noise, becoming distorted. To have defined and reproducible conditions similar to conductive testing, the effects of the OTA channel must be eliminated. One approach to solve this issue is to calculate the unknown transfer matrix A by accounting for the complete OTA environment, including the transmitter and receiver antenna characteristics. This approach is complex and, in most cases, not possible: UE manufacturers are not required to give detailed information about their antenna characteristics, including the phase information required to apply this method.

An alternative approach, described here, equalizes the channel matrix using only the Reference Signal Received Power per Branch (RSRP-B) feedback parameters, which can be retrieved from an FR2 UE per the 3GPP standards. This enables having a quasi-conducted or "virtual cable" connection or "virtual cabling" in an FR2 radiated test environment.[2] The approach lays the foundation for practical 5G UE performance testing for maximum throughput, as well as testing under

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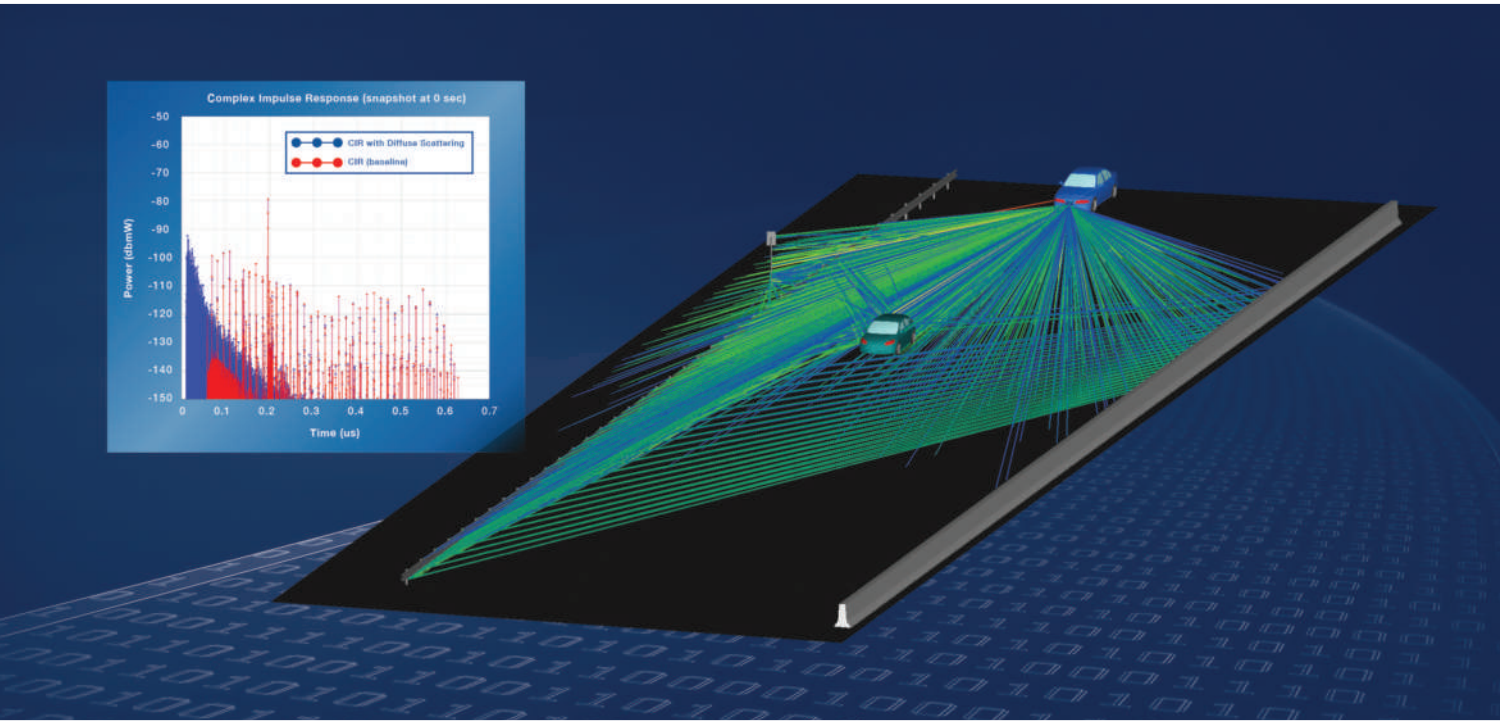

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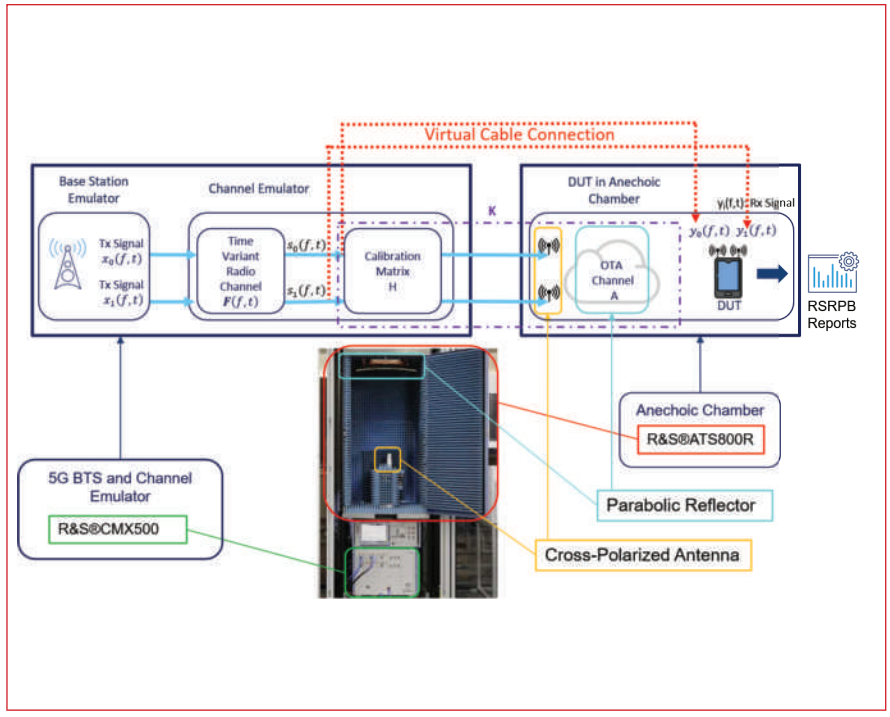

▲ Fig. 3 **Setup for calibrating 2 x 2 MIMO OTA measurements.**

various channel conditions, such as fading. An equalized channel is also mandatory for conformance tests with fading, which are needed for RRM tests.

SIGNAL QUALITY USING RSRP-B FEEDBACK

The secondary synchronization RSRP-B (SS-RSRP-B) is defined as the linear average power per branch, in watts, of the resource elements that carry secondary synchronization signals. For FR2, the SS-RSRP-B is measured for each receiver branch based on the combined signal from the antenna elements corresponding to the receiver branch. The RSRP-B is an important parameter to assess signal quality, and it is the UE's task to calculate the SS-RSRP-B and fulfill the accuracy requirements. The power per resource element is determined from the energy received during the useful part of the symbol, i.e., excluding the cyclic prefix. In 5G NR, RSRP measurement is performed and reported at layer 1, the physical layer, and layer 3, the radio resource control (RRC) layer. For example, a 5G capable device can provide SS-RSRP measurements at layer 1 when sending channel state information and at layer 3 when sending an RRC protocol measurement report to the next-generation node B (gNB).

The level 1 measurements are relevant for the following implementation, and the SS-RSRP-B reporting range is defined from -140 to -40 dBm with 1 dB resolution. The RSRP-B is the linear average power measured at each receiver branch of the DUT. 3GPP requires the 5G NR FR2 device to support RSRP-B, which enables the determination of a calibration matrix which can equalize the channel.

CALIBRATION METHOD

As propagation conditions and antenna characteristics are the most important factors for field performance of MIMO devices, mobile receiver performance tests must include these parameters. These conditions are generally simulated through a fading simulator or channel emulator. The channel emulator is a measuring instrument for reproducing the actual radio wave propagation environment described by the matrix F(f,t), which can include dynamic scenarios in moving environments. It reproduces the fading environment defined by 3GPP and the virtual environment of multiple MIMO channels.

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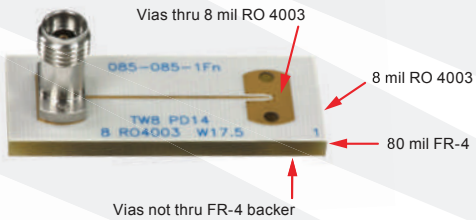

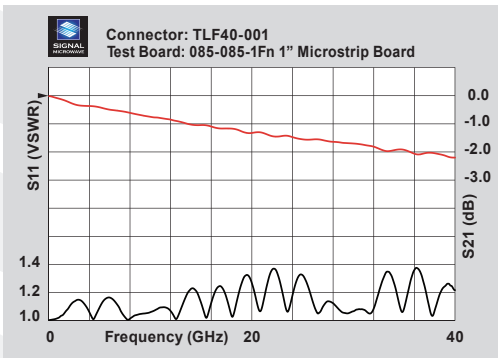

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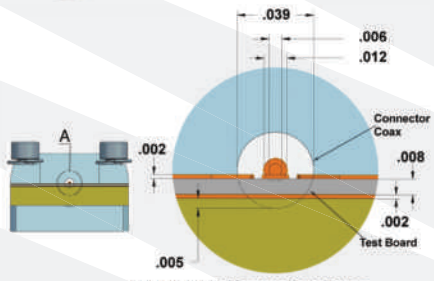
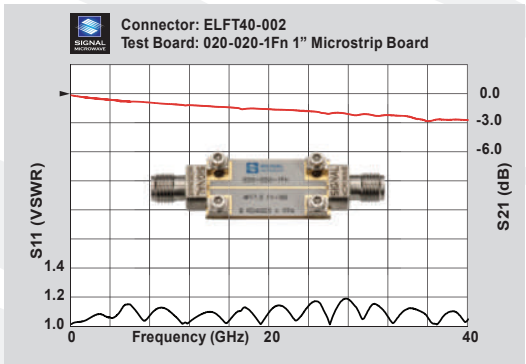


DETAIL A; 8 mil Test Boards and Connector Cross Section



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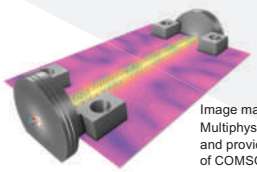

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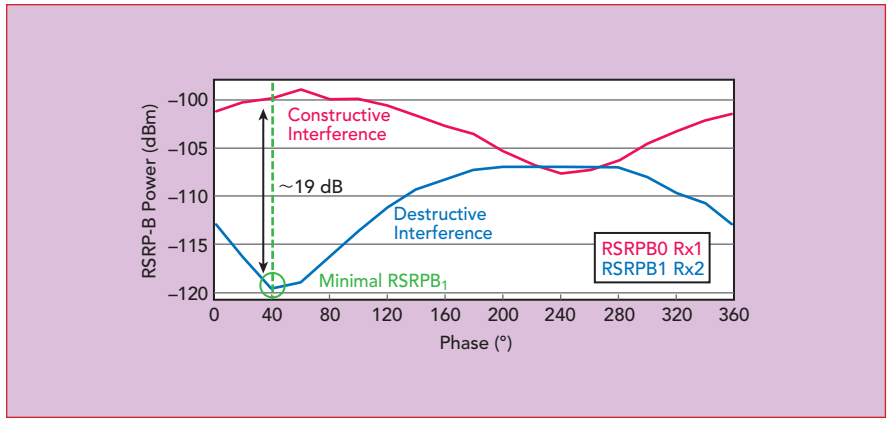

Fig. 4 **Commercial UE measurement in an anechoic chamber, showing RSRP-B power levels vs. calibration phase for one branch.**

As shown in ***Figure 3***, the UE is placed in a controlled wireless environment, such as an anechoic chamber, to minimize the distortions caused by multipath propagation and reflection. The setup in the figure shows the case of 2 × 2 MIMO; however, the concept can be extended to N × N, where N > 2.

For development and conformance tests, the base station emulator simulates a mobile 5G base station's operation, enabling the DUT to perform a network entry procedure and establish a communication link. The modulated signals then pass through the channel emulator with various fading and propagation parameters, simulating real life scenarios.

In the case of a perfect conducted situation without any crosstalk between the cable branches, the OTA channel matrix A is identical to the unity matrix. With the OTA measurement, the objective of the calibration procedure is to determine the calibration matrix H so the channel K, which is the combination of the calibration matrix H and the OTA channel matrix A, is as close as possible to the unity matrix: $K = A \times H \approx I_2$. After calibration, the combined channel matrix K will approximately equal the unity matrix, effectively establishing a virtual cable connection with s_0 and s_1 connected directly to the UE antennas.

DEMONSTRATION RESULTS

To demonstrate the procedure, a 5G NR signal at 39 GHz (band n260) was generated using a 5G radio communication tester as a base station emulator. The precoding matrix H was generated using the channel emulator of the tester to simulate fading. The resulting signal was transmitted via two cross-polarized antennas in an anechoic chamber containing a compact antenna test range (CATR) reflector. A CATR has a parabolic reflector with a feed antenna placed at its single focal point to transform a spherical wavefront into a planar wave and vice versa. In this case, the plane wave impinges on the DUT, which returns the RSRP-B value for each branch, i.e., corresponding to its two antennas.

The VCC procedure requires the presence of a signaling connection between the DUT and base station emulator. To find a suitable matrix H which fulfills the requirement for quasi-conducted conditions ($K \approx I_2$), the matrix H is defined so the phase applied for the contributions from the two input signals can be controlled by a single complex factor for each branch (i.e., the secondary diagonal elements). The calibration itself comprises three major steps: initialization of the gain factor, search for the optimal phase and final tuning of the gain. The calibration of the two branches can be carried out independently by disabling the input signal, which is currently not calibrated. This process can be followed by an optional step of branch equalization.

Figure 4 shows an example measurement sweeping the phase multiplier for the first branch. The top RSRP-B0 curve represents the measured power at antenna Rx1 of the DUT; the bottom RSRP-B1 curve represents the power at antenna Rx2

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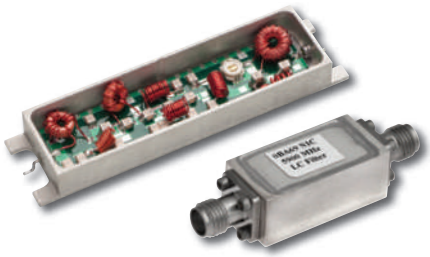

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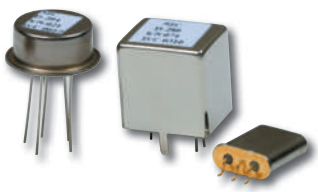

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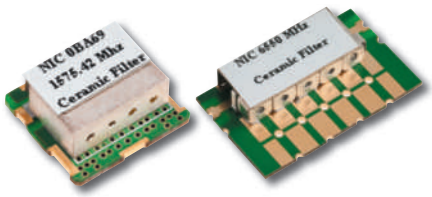
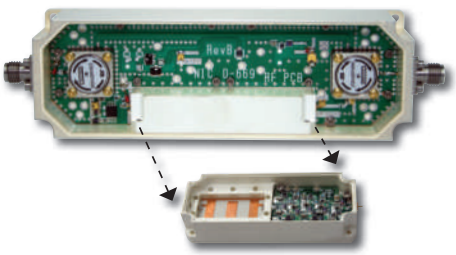
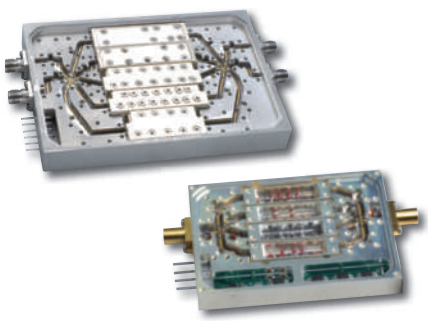


Integrated Assemblies



Switch Filter Banks



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of the DUT, the crosstalk from Tx1. 3GPP specifies that the crosstalk between the virtual cables should be less than 12 dB.[1,3] The measurement shows the peak isolation is 19 dB, which exceeds the 3GPP requirement for a virtual cable.

The calibration method implemented in the test system uses "intelligent" search algorithms to determine the channel parameters in the minimum time, which is crucial for cost-effective device verification. The approach and results confirms this method is an effective way to implement a quasi-connected testing environment with reproducible and defined channel conditions for throughput performance measurements and assessing performance under fading conditions.

CONCLUSION

Although 3GPP specifies crosstalk limits between virtual cables, it does not specify the calibration method to be used. Repositioning a DUT could, in principle, be used; in practice, however, this method would be too slow, not systematic and likely not possible with every DUT. The VCC method described and demonstrated in this article provides a systematic approach with fast convergence to determine the precoding calibration matrix parameters, which will be a crucial component for FR2 testing. For RRM measurements to assess handovers among multiple base stations, the method can be extended using a setup with multiple CATRs.[5]

As 6G research is aiming at frequencies beyond 100 GHz, the trend toward more integration of antennas will continue, requiring the same OTA testing. This same measurement approach can be extended to D-Band (i.e., 110 to 170 GHz)—one of the bands for 6G research.■

ACKNOWLEDGMENT

The authors thank the following Rohde & Schwarz colleagues for fruitful discussions regarding the concepts and measurements: Jimson Eng and Oussema Harguem.

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5. Corbett Rowell, Benoit Derat and Adrian Cardalda Garcia, "Design of a Multiple CATR System for Multiple Angles of Arrival Measurement of 5G mmWave Devices," *Microwave Journal*, March 2021.

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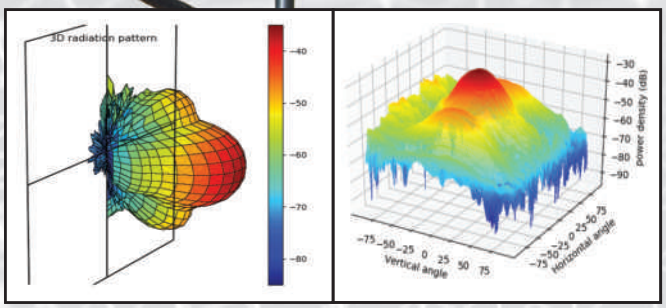

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INVITED PAPER

Combining CLOS and NLOS Microwave Backhaul to Help Solve the Rural Connectivity Challenge

Erik Boch and Julius Kusuma
Facebook Connectivity, Menlo Park, Calif.

The hybrid combination of clear-line-of-sight (CLOS) and non-line-of-sight (NLOS) techniques can often be employed to create a practical and cost-effective networking solution for rural and deep-rural connectivity challenges.

The deployment of rural and deep-rural cellular networks faces many challenges, including the cost per covered population and low average revenue per user projections for many rural communities; this is especially acute in less developed countries. Globally, the population not covered by broadband networks is about 1 billion,[1] consisting largely of people in rural and deep-rural areas where network deployments suffer from business performance challenges.

A critical component of rural and deep-rural network buildouts is the cost of backhaul. Terrestrial microwaves relying on a CLOS link is often the technical design approach because of its ability to enable rapid and cost-effective buildout and deliver backhaul high capacities. Thus, a significant percentage of cell sites globally use terrestrial CLOS microwave backhaul. Although this is supported with data from GSMA,[2] the rural and deep-rural use of microwave backhaul in high capacity mobile networks (i.e., 3G, 4G, 4G+) is expected to be more prevalent than shown because the larger distances involved in this use case amplify the superior cost/distance performance.

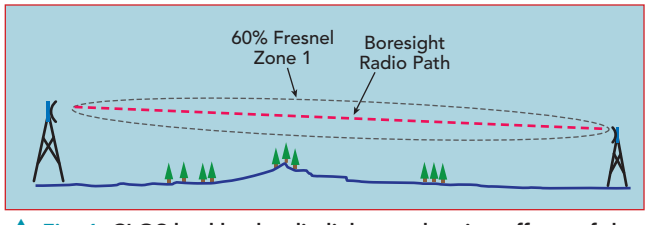

Fig. 1 **CLOS backhaul radio link, not showing effects of the Earth's curvature.**

Despite its utility in providing backhaul functionality, the additional cost of microwave towers for repeater sites is undesirable. In some instances, this is due to the conventional design requirement to deploy microwave backhaul networks using only CLOS paths. For example, terrain and foliage can require tower heights to be increased, towers to be located in undesirable locations or repeaters added at intermediate sites. All have the undesired effect of driving up deployment costs. In many global rural and deep-rural deployment scenarios, the target population and economic circumstances can place upward pressure on deployment costs.

In cases where terrain is a problem for CLOS microwave backhaul links, complementary, additive use of diffracted NLOS radio links may be employed. The combination of these techniques (CLOS + NLOS backhaul) may yield a cost-optimized network design.

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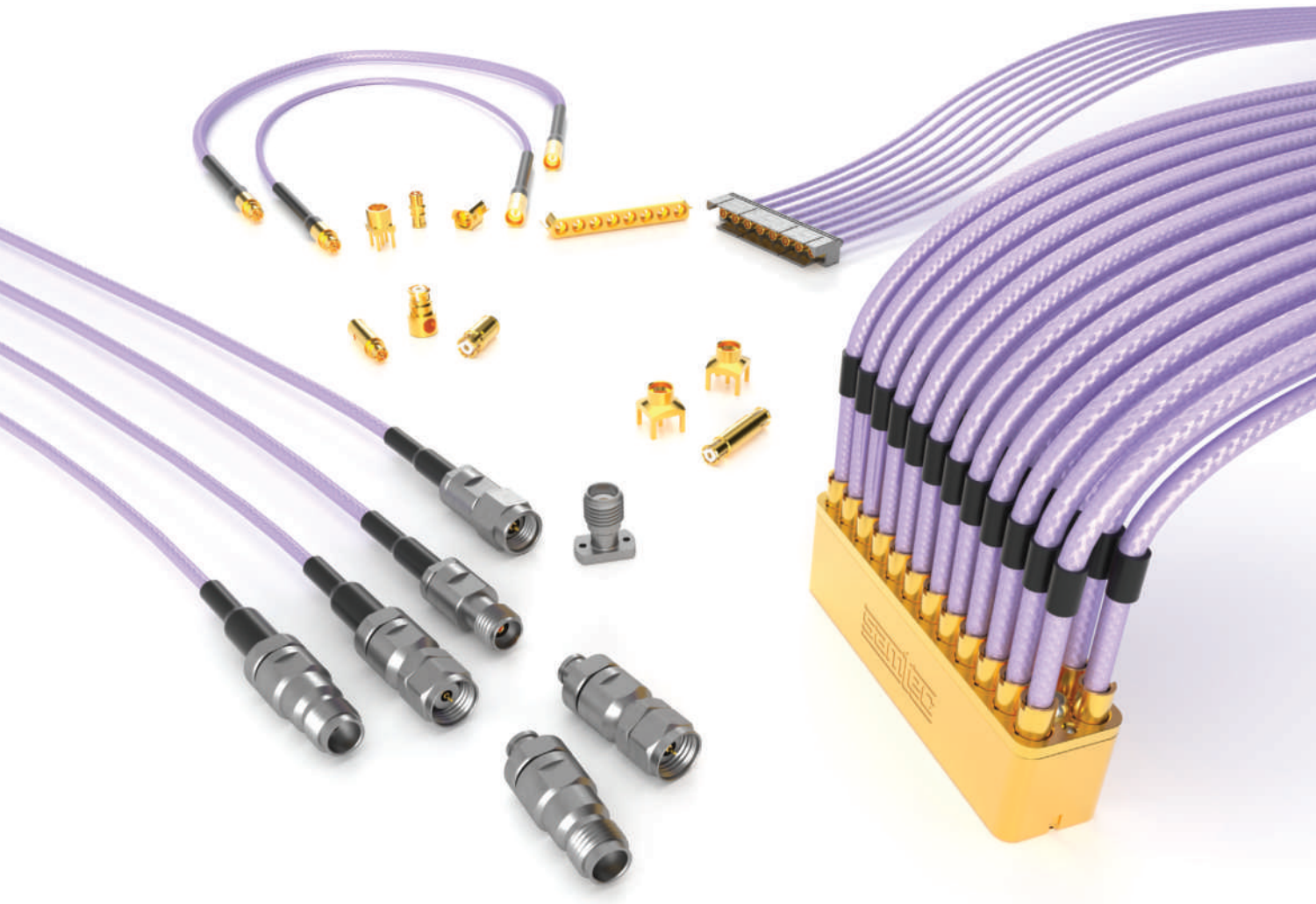

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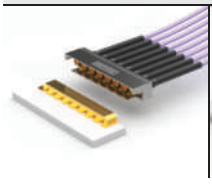

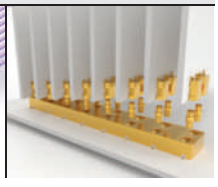

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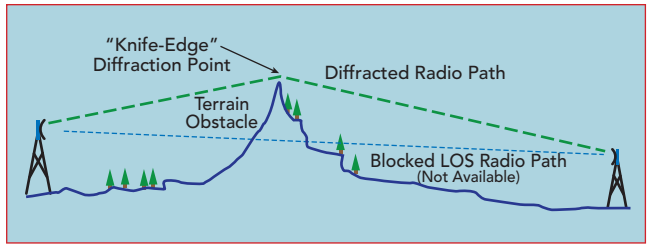


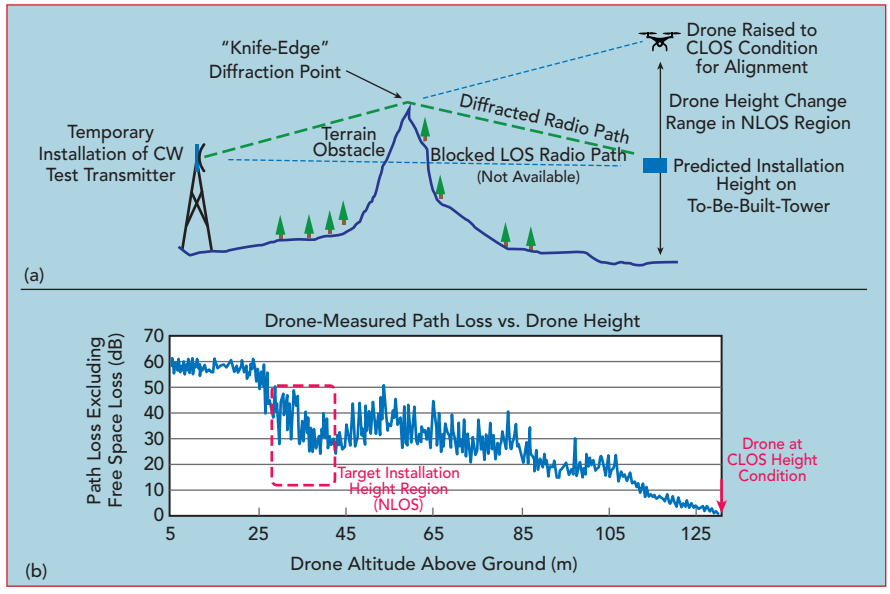
▲ Fig. 2 **NLOS backhaul radio link, not showing effects of the Earth's curvature.**

WHAT IS CLOS VS. NLOS?

As shown in ***Figure 1***, CLOS refers to a radio link path that has no obstructions within 60 percent of the first Fresnel zone.[3] When there are obstructions within this zone—terrain, foliage, built structures—a link budget penalty must be included in the radio link budget. As the obstructions increase, losses also increase. When there is little obstruction in the first Fresnel zone, the incremental losses can be small; as the first Fresnel zone becomes completely obstructed, incremental losses become much larger. At the point where the first Fresnel zone becomes completely obstructed, radio propagation between the link's end sites transitions from a Fresnel blockage condition to a diffracted link condition (see ***Figure 2***).

When designing terrestrial wireless backhaul networks, CLOS radio links are preferred when feasible; however, a CLOS requirement can demand the need for high towers, towers in difficult-to-access locations and repeater sites. CLOS radio link design is generally more challenging the rougher the deployment terrain. A NLOS diffracted radio link systematically scatters the radio signal across the top of the blocking terrain features, creating a "bent" link. The use of diffraction, however, increases path losses, which must be accommodated in the link budget. NLOS links tend to be shorter range because of the incremental path losses associated

▲ Fig. 3 **3D signal survey for pre-build NLOS tower design, measured with a drone.**



▲ Fig. 4 **Using a drone for pre-build field verifications of NLOS links (a) and example path loss measurement (b).**

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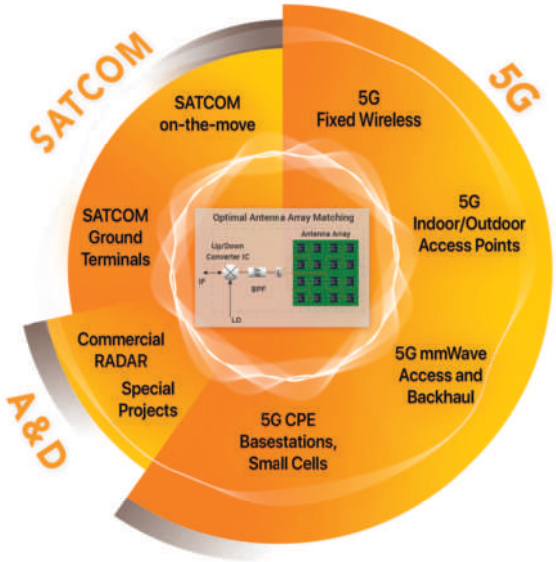

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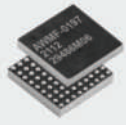

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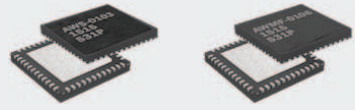

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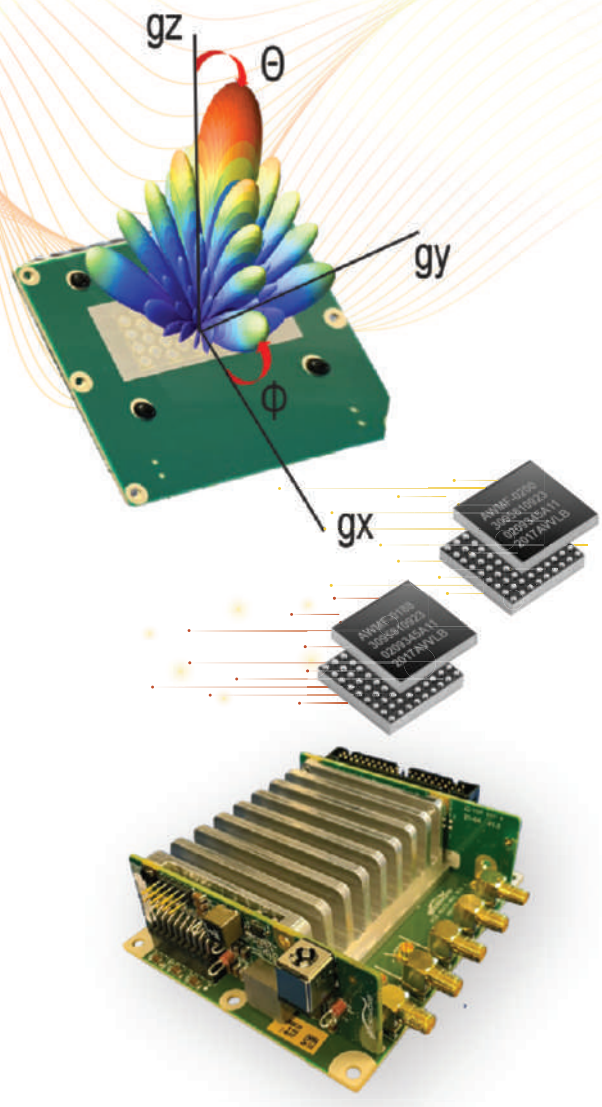

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with diffracting obstacles. They do, however, enable using shorter end-site towers and expanding placement options for radio tower infrastructure. NLOS radio link design is generally more useful the rougher the deployment terrain.

CHALLENGES USING NLOS LINKS

Historically, diffracted NLOS radio links have received little modeling or validation attention since the hallmark work by Longley and Rice.[4] Although much of this found its way into the International Telecommunications Union (ITU) standards[5,6] and into available predictive software tools,[7,8] NLOS links are largely in the category of "put it in and see what happens," rather than a fundamental backhaul design methodology.

A key concern of the wireless network design community is the prediction of radio link availability and performance. In the case of CLOS, the ITU has created, evolved and maintained standards[9] that have been broadly adopted by the microwave engineering community. After many decades being applied in millions of deployments, the standards have earned recognition as being reasonably representative of real-life conditions. In the case of NLOS, there is still research to be done to better quantize the margining processes needed for NLOS links to achieve specific in-field availability performance levels.

A traditional CLOS radio link deployment is usually accompanied by a field inspection or technical site

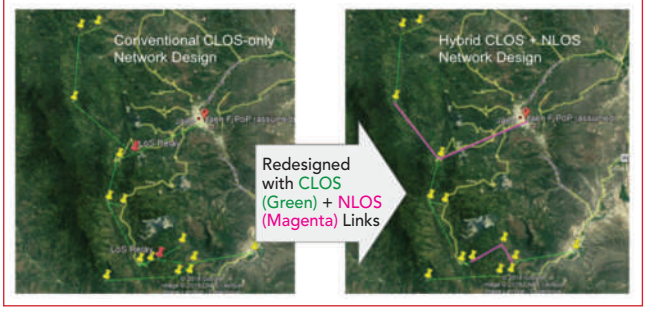

Fig. 5 Optimizing a backhaul network combining CLOS and NLOS radio links.

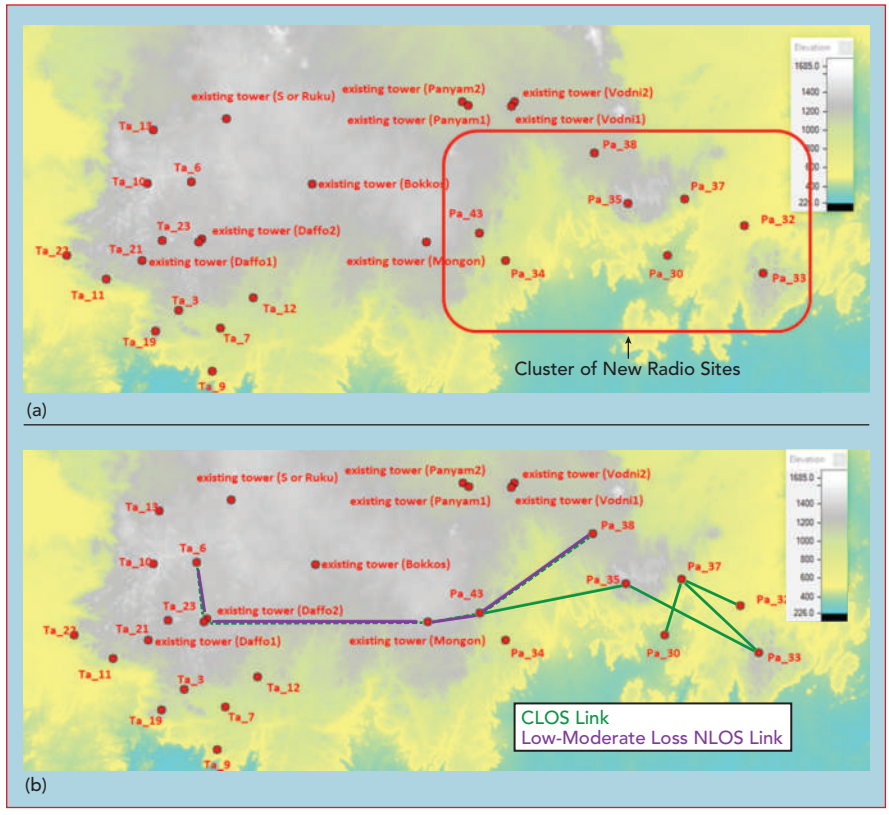

Fig. 6 A rural/deep-rural area with a cluster of new radio sites (a); most can be connected to the existing network using a combination of CLOS and low-to-moderate loss NLOS links.

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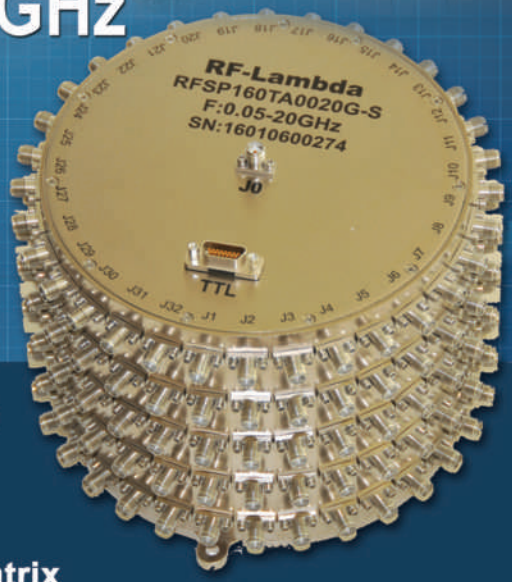

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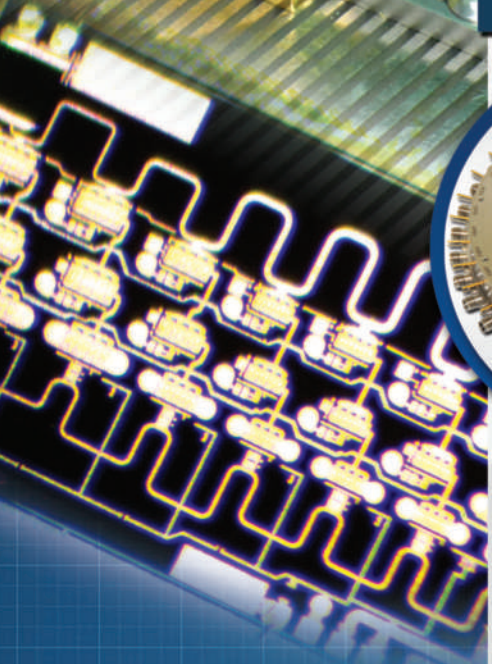

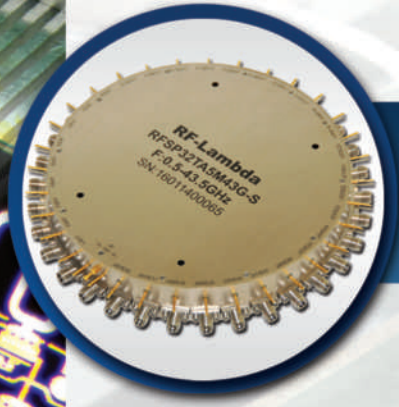

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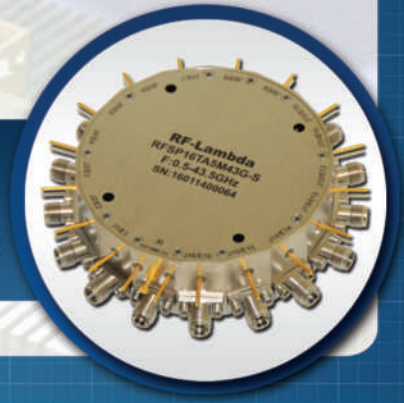

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survey, which confirms visual line-of-sight (LOS) between the link ends. Binoculars, balloons or mirrors can be used to verify the LOS and clearances. For NLOS radio links, inspection becomes more challenging. The specific height and geometry of the blocking obstacles and/or the height of ground cover (trees) may play a role in the overall link path loss. Using a drone can address the NLOS risks by enabling an in-situ signal measurement at relevant heights.

Alignment can also be challenging because the backhaul antennas typically must be pointed toward the crest of the obstructing obstacle or hill as a starting point for alignment. The iterative process of fine tuning the NLOS link alignment to achieve target receive-signal-levels requires techniques that, although similar to CLOS, are different.

To address these challenges, Facebook has found significant benefits constraining the application of NLOS techniques to cases with

- A single obstructing obstacle blocks the link
- Foliage cover and height on or near the obstructing obstacle or hill can be assessed
- The overall diffraction angle is less than approximately 3 degrees
- Overall predicted additive losses associated with diffraction are less than 25 to 30 dB.

In cases where NLOS conditions are more severe, Facebook uses low-cost drone technology, developed with Plexus Controls in Ottawa, to measure the path loss as part of pre-build field survey and path confirmation (see ***Figure 3***). ***Figure 4*** illustrates how signal level measurements using drones can map path losses throughout a 3D volume to determine the optimum location for a tower and its height.

NETWORK DESIGN COMBINING CLOS AND NLOS

The combination of CLOS and NLOS to optimize microwave backhaul networks has been previously reported,[10] illustrating the utility of this combination of techniques in creating improved rural and deep-rural connectivity and simultaneously reducing costs (see ***Figure 5***). In other cases, reaching a remote cluster of settlements can be impeded by challenging terrain between a developed part of the network and a target coverage area where new radio access network deployments are required. The example illustrated in ***Figure 6*** shows a targeted area for delivering coverage to a cluster of dispersed rural/deep-rural settlements. CLOS backhaul radio links within the cluster may be feasible, but the cluster itself cannot be reached easily or cost-effectively using terrestrial CLOS backhaul links.

In larger scale deployments, Facebook has partnered with Internet para Todos (IpT) in Peru to deploy 4G networks in large segments of the unserved and underserved population in rural and deep-rural Peru. In one phase of network buildout, the hybrid combination of CLOS and NLOS has achieved a

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significant improvement in the network's coverage. When this article was written, IpT had incorporated diffractive NLOS microwave backhaul links in its network by deploying 28 diffractive NLOS links in the production network. These links provide both backbone and endpoint connectivity. The hybrid use of NLOS and CLOS wireless backhaul in the network redesign yields a substantial increase in the network's coverage and cost performance. Further, the hybrid network enables IpT network designers to efficiently expand the terrestrial network without modifying the infrastructure, which would be necessary if only CLOS links were used.

In many target settlements, terrain and foliage obstacles make CLOS links unfeasible. Without NLOS, this means those settlements would be served with satellite backhaul. With NLOS, IpT has been able to provide wireless broadband coverage via NLOS microwave backhaul, an option available to other service providers.

SUMMARY

Solving rural and deep-rural connectivity challenges in a cost-effective manner requires the application of various technologies and techniques. High capacity mobile radio networks can be backhauled using terrestrial microwave systems; however, using only CLOS links can be impractical. The hybrid combination of CLOS and NLOS techniques can often be employed to create a practical, lower-cost networking solution.■

ACKNOWLEDGMENTS

We thank our partners at IpT de Peru: Renan Ruiz Moreno, Joel Aragon Valladares and Manuel Garcia Lopez. We also thank our partners at TeleworX: José Huarcaya and Diego Mendoza. Their work on the development and implementation of NLOS has been critical to the success of this endeavor.

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Dynamic Range (BW=10Hz, dB, typ)	120	120	120	120	120	120	120	120	115	115	100	110	100	95
(BW=10Hz, dB, min)	110	105	110	110	110	110	110	110	110	105	80	100	80	75
Magnitude Stability (±dB)	0.15	0.15	0.10	0.10	0.10	0.15	0.25	0.25	0.3	0.3	0.5	0.5	0.4	0.5
Phase Stability (±deg)	2	2	1.5	1.5	1.5	2	4	4	4	6	6	6	4	6
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Design of a Cobweb Shape Chipless RFID Tag

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University of Engineering and Technology, Taxila, Pakistan

Hannu Tenhunen
Royal Institute of Technology (KTH), Stockholm, Sweden

Jonathan Loo
University of Hertfordshire, Hertfordshire, U.K.

A nested octagon passive chipless radio frequency identification (RFID) tag with an encoding capacity of 12 bits has polarization diversity and 1:1 slot-to-bit correspondence. Its compact 23 × 23 mm footprint yields a bit density of 2.26 bits/cm². The tag is fabricated on a flexible Rogers RT/duroid® 5880 laminate.

RFID is an evolving technology[1] that uses wireless data capturing techniques for identifying and tracking objects.[2] Due to its qualities such as inexpensive fabrication, non-line-of-sight communication[3] and swift reading capability, it is largely replacing barcode technology.[4] RFID is penetrating the retail industry for intelligent and smart tracking[5] and for the creation of smart entities in IoT environments.[6]

An RFID system consists of transponders generally known as tags, also called labels, and an interrogator or reader connected to RFID middleware.[7] RFID tags are further classified as chip-based and chipless. Chip-based tags require dedicated silicon ICs for encoding information,[8] while chipless tags need no external IC or power source, reducing the total cost of production and maintenance. Chipless tags are classified mainly as either frequency or time domain dependent. Surface acoustic wave tags are examples of time domain tags. Their manufacturing involves a complex and costly submicron photolithographic fabrication process, requiring economies of scale.[9] Frequency domain tags store information in the form of frequency signatures using metallic or directly printable radiating and conducting structures.[10]

Due to characteristically low-cost, robustness and miniaturized footprints, frequency domain chipless RFID tags have been of most interest to researchers. These structures may vary in their shapes, geometrical aspects and underlying technologies. Different shaped radiating structures have been reported, including spurline resonators,[10] rectangular resonators,[11] L- and I-shaped resonators[12] and triangular patterns.[13] Nijas et al.[14] used stepped-impedance resonators. Frequency selective surface (FSS) inspired tags with an extensive physical dimension and with a ubiquity of active elements have been reported in the literature.[15] Due to the existence of higher order spectral harmonics and a direct relationship between encoding capacity and physical size, electromagnetic performance is compromised. This hampers the use of a wide frequency band, since higher order harmonics may interfere with high frequency resonances.

In this article, a compact frequency domain dependent, polarization independent, chipless RFID tag with an encoding capacity of 12 bits is described. The design offers a 1:1 slot-to-bit resonance in its radar cross section (RCS) response. This provides an encoding capacity of 12 bits or 2^{12} distinct possible combinations, for a total of 4096 items that can be uniquely tagged.

TAG DESIGN

The tag occupies a small 23 × 23 mm footprint containing 12 discrete octagonal slot-based structures. A single resonating element is shown in ***Figure 1***. The length of a side is L, the slot width is M and the

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gap width at the defected vertices is G. The tag is fabricated on an ungrounded 0.508 mm thick Rogers RT/duroid 5880 substrate. The RCS response of a conventional octagonal slot resonator with no gaps has an unwanted resonance, as shown in ***Figure 2a***. The defective gaps G on alternate vertices suppress this response while enhancing the desired resonance (see ***Figure 2b***).

The dimensional parameters were chosen after iterative parametric analyses. For example, as L is changed from 9 to 11 mm, the resonant frequency shifts down, where the slot width M varies the absorption level of each corresponding resonant peak. Changing the defective gap G has no effect on the RCS response, although it helps reduce mutual coupling between resonating elements. The surface current distribution and RCS response of a single element illuminated at 6.87 GHz are shown in ***Figure 3***. The surface current distribution at opposite defective points G′ is maximum, indicating inductive effects and minimum at the other vertices G″, indicating capacitive characteristics. Their simultaneous presence indicates resonance. Geometrically, the tag is equiangular and equilateral, making it polarization insensitive (see ***Figure 4***). The frequency signature of a single resonant element is identifiable with illumination from both E and H probes.

Symmetrical nesting of the elements results in a cobweb, polarization independent, chipless RFID tag

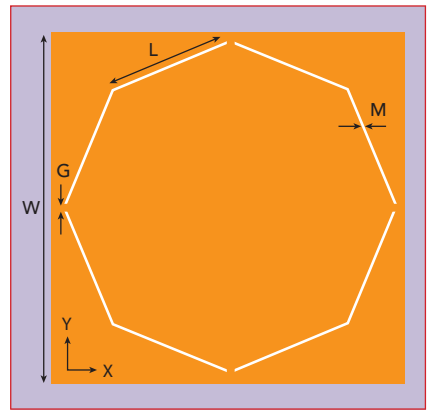

Fig. 1 Single resonant element.

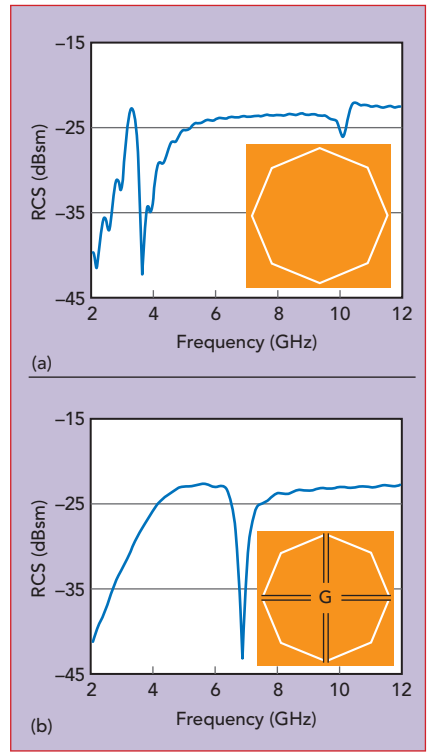

Fig. 2 RCS response of a conventional (a) and truncated (b) octagonal slot resonators.

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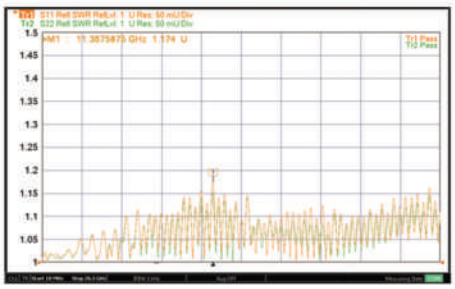
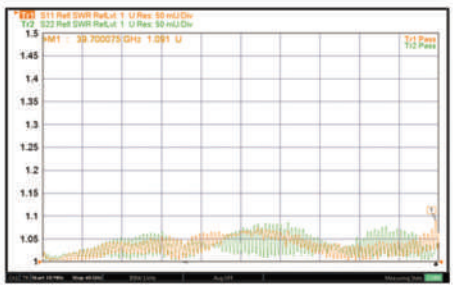
6	14.62	22.12	32.74	15.86	21.03
10	16.48	24.52	35.43	17.83	23.43
12	17.41	25.72	36.78	18.81	24.63
16	19.27	28.12	39.48	20.77	27.02


26.5GHz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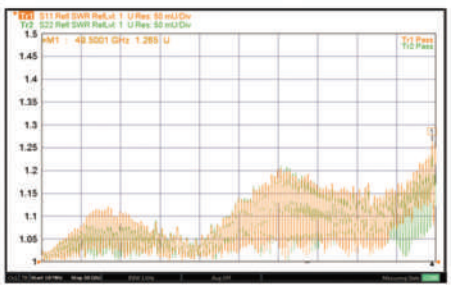
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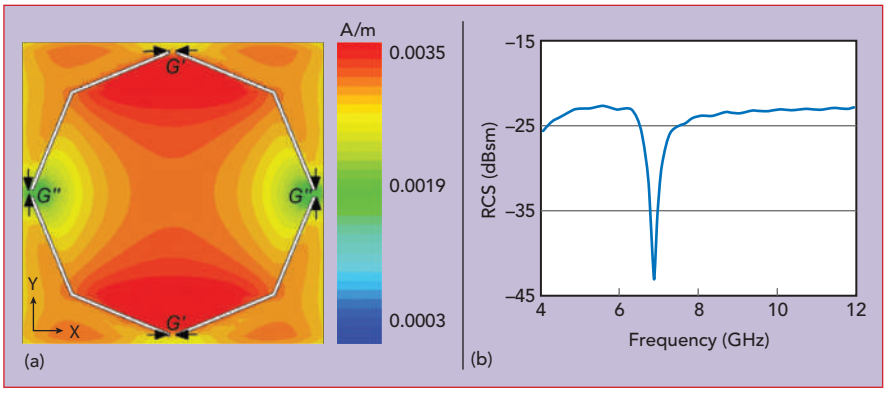
(see ***Figure 5a***). The FSS is designed to resonate at multiple frequencies, corresponding to the resonance of each slot. A resonant peak in the RCS response signifies a 1 at a given frequency; a 0 is represented by the absence of a resonant peak. Optimal dimensions of the structure were obtained iteratively through simulation using CST MICROWAVE STUDIO®. G and M for all resonators were kept equal. Parameters L_2 through L_{12} were computed using L_1 and M, resulting in the values shown in ***Table 1***. Fabricated samples of the tags are shown in ***Figure 5b***.



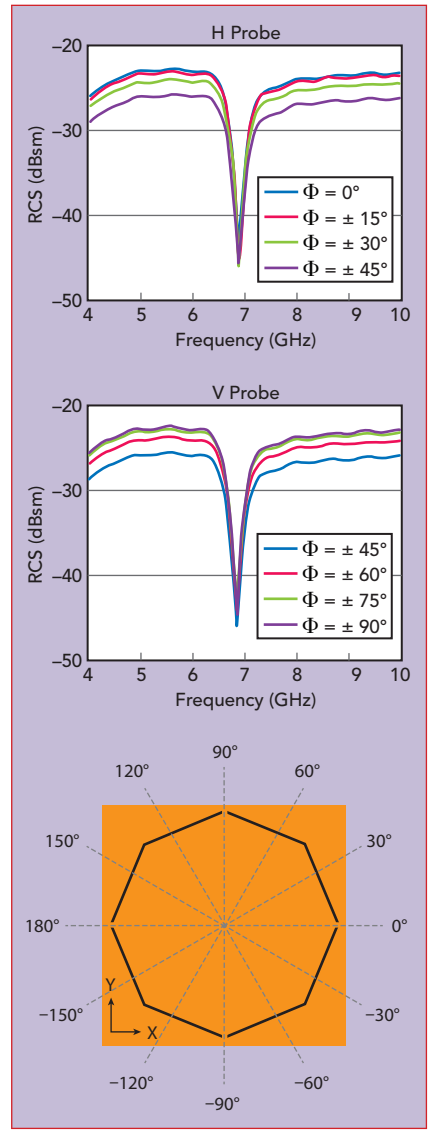
▲ Fig. 3 **Single resonator surface current distribution (a) and RCS response (b).**

TABLE 1
OPTIMIZED TAG DIMENSIONS

Parameter	L_1	L_2	L_3	L_4	L_5	L6	G
Size (mm)	8.14	7.71	7.29	6.86	6.43	6.0	0.5
Parameter	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}	W
Size (mm)	5.57	5.14	4.71	4.29	3.86	3.43	23

RESULTS

The tag measurement setup comprised a Rohde & Schwarz R&S® ZVB-20 vector network analyzer (VNA), a pair of linearly polarized transmit and receive horn antennas and fabricated prototypes of the tag (see ***Figure 6***).[16] A resonant peak at a particular frequency because of the presence of a resonating element is interpreted as a 1, signifying complete absorption; in the case of complete reflection, i.e., no resonating element, a 0 is encoded. Adding and removing resonating



▲ Fig. 4 **The symmetrical design makes the RCS relatively insensitive to polarization.**

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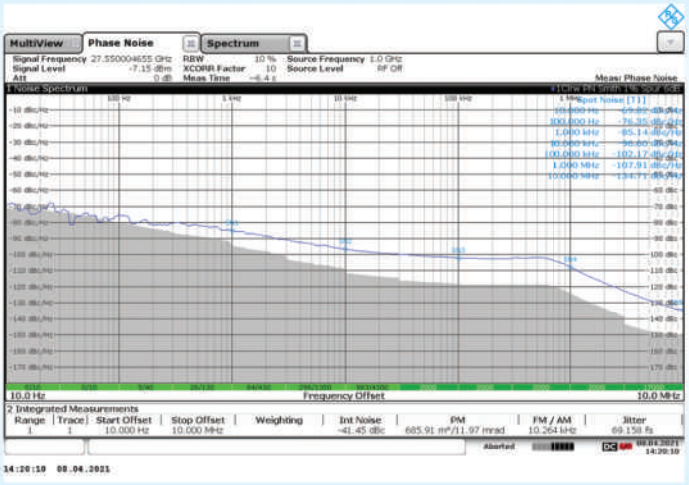
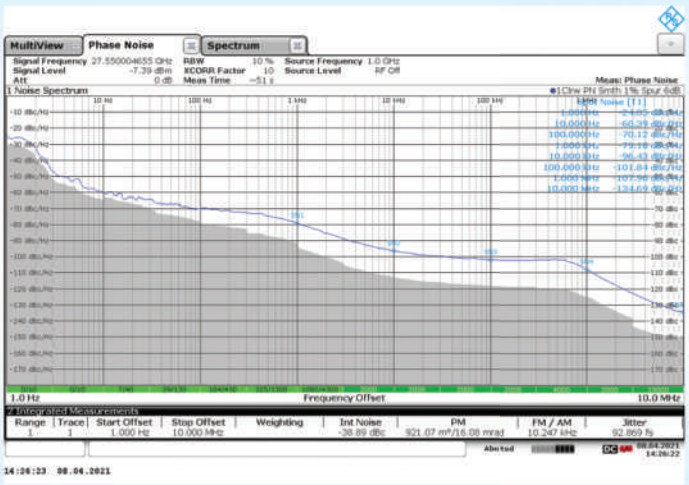


Fo = 27.55 GHz,
Integrated Jitter = 93 fs (1 Hz to 10MHz)



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elements leads to the formulation of distinct bit combinations (see ***Figure 7***). A graphical comparison of the numerically computed and experimentally measured results shows good agreement. Repeating, alternating and random bit sequences from tags on a 0.508 mm thick Rogers RT/duroid 5880 laminate are shown in ***Figure 8***. ***Table 2*** lists the properties of the laminate. Copper with a thickness of 0.035 mm was used as the radiator. The encoding capacity is determined by the number of resonating slot elements to obtain an equal number of resonances in the resulting frequency band. Figure 5a shows 12 octagonal resonating elements in a cobweb shape, corresponding to the RCS response in Figure 8a for a sequence of all 1s.

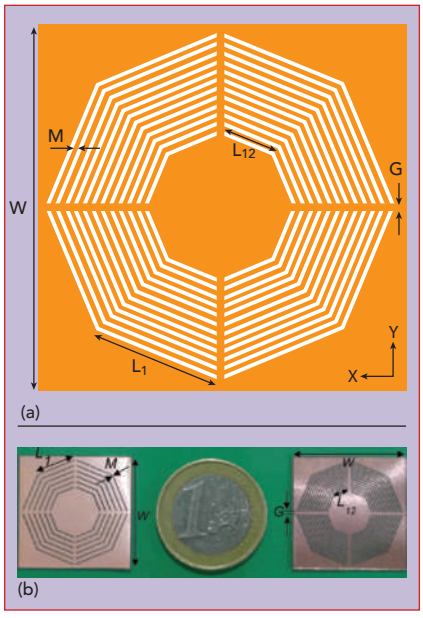

Fig. 5 **Cobwebbed, chipless RFID design concept (a) and two fabricated tags (b).**

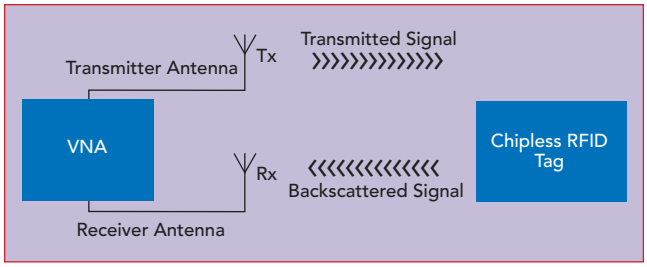

Fig. 6 **RFID tag measurement setup.**

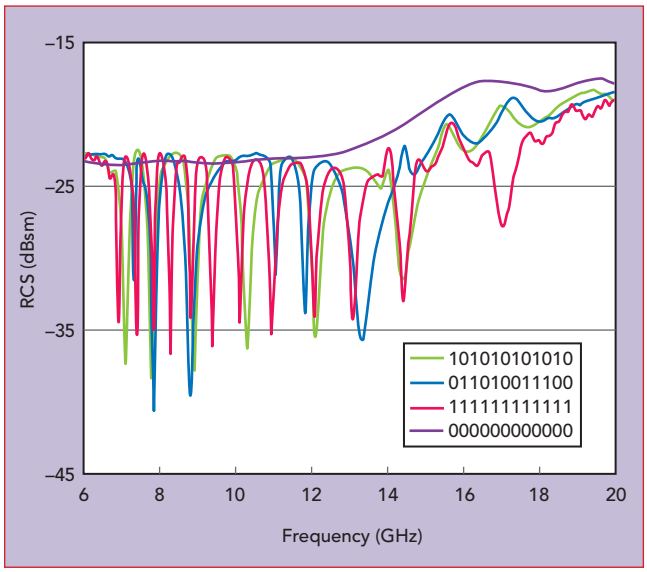

Fig. 7 **RCS responses for various bit sequences created by adding or removing resonating elements.**

Each cobweb shaped resonator represents a bit, resulting in a total capacity of 12 bits. Within the operating band from 6.5 to 18 GHz, there are 12 resonances with a 1:1 resonance-to-slot correspondence. The examples

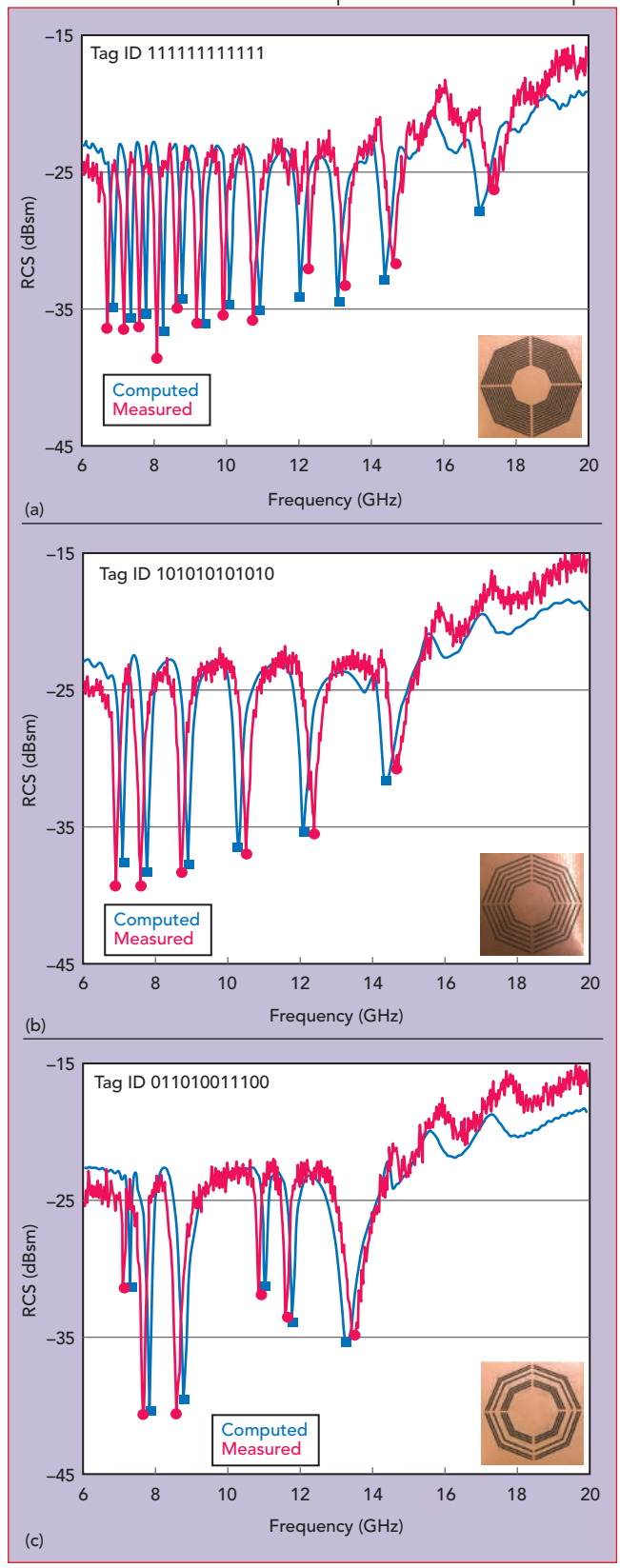

Fig. 8 **Computed vs. measured RCS responses for tags with repeating (a), alternating (b) and random (c) bit sequences.**

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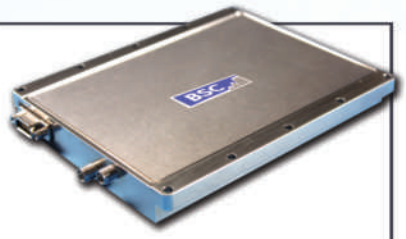

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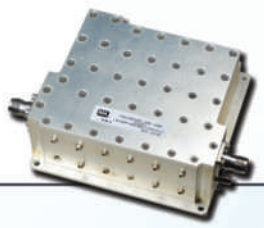

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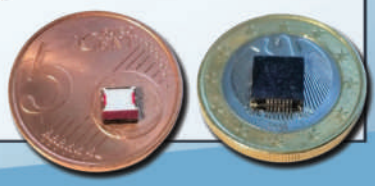

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shown in Figure 8 illustrate the capability of the design to encode any 12-bit sequence. The RFID tag has a small 5.29 cm^2 footprint, achieving a bit density of 2.26 bits/cm^2. It is insensitive to a variety of polarization angles and is viable for use on non-rigid substrates.

A comprehensive comparison of this work with other reported results is summarized in ***Table 3***. The table includes encoding capacity, bit density, polarization insensitivity, the flexible nature of the laminate, spectral bit capacity and spatial bit density. Encoding capacity is the number of bits stored for encoding data, which is 12 in this design. Bit density is the number of bits per unit area, usually measured in bits/cm^2. The readability of the tag at different orientations with reference to the XY plane is indicated by polarization insensitivity. Spectral bit density is the number of bits per GHz, and spatial bit density relates to the number of bits per λ^2, where λ is the wavelength.

TABLE 2
TAG DESIGN CHARACTERISTICS

Characteristic	Design Value
Substrate	Rogers RT/duroid 5880
Thickness	0.508 mm
Permittivity	2.2
Loss Tangent	0.0009
Radiator	Copper
Copper Thickness	0.035 mm
Frequency Band	6.50-18 GHz
Encoding Capacity	12

CONCLUSION

A passive, polarization independent, chipless RFID tag with a compact size of 23 × 23 mm and 12-bit encoding capacity provides a bit density of 2.26 bit/cm^2. The design mitigates high order harmonic components and possesses 1:1 slot-to-bit correspondence, enabling a total of 4096 items to be uniquely tagged.■

ACKNOWLEDGMENTS

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TABLE 3

CHIPLESS RFID TAG COMPARISON

Ref.	Area (mm^2)	Laminate	Encoding Capacity (Bits)	Bit Density ($Bits/cm^2$)	Radiator	Polarization Insensitivity	Flexible Laminate	Spectral Bit Density (Bits/GHz)	Spatial Bit Density ($Bits/\lambda^2$)	Radiator Thickness (mm)
11	2025	FR-4	5	0.55	Copper	✓	✗	1.23	0.04	0.035
12	714	Paper	8	1.12	Silver Nano Ink	✗	✓	2.00	0.04	0.015
13	825	FR-4	10	1.21	Copper	✗	✗	1.42	0.17	0.035
17	1155	FR-4	12	1.03	Copper	✗	✗	2.00	0.22	0.035
18	900	RO4003	19	2.11	Copper	✓	✓	2.53	0.20	0.035
19	4264	Paper	5	0.11	Silver Micro Ink	✓	✓	0.66	0.08	0.005
20	2940	Kapton® HN	16	0.54	Silver Metal	✗	✓	3.40	0.21	0.015
This Work	529	Rogers RT/duroid 5880	12	2.26	Copper	✓	✓	1.19	0.63	0.035

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• Phase Stability over Flexure	≤±6.5° @ 67 GHz	≤±5° @ 50 GHz	≤±4° @ 40 GHz	≤±2.7° @ 26.5 GHz
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Design of Multi-Modulus Programmable Frequency Dividers in 2 µm GaAs HBT Technology

Xinlin Xia, Zhichen Zhao, Fengjun Chen, Xu Cheng, Xianhu Luo and Xianjin Deng
China Academy of Engineering Physics

Two multi-modulus programmable frequency dividers (MMPFDs) with improved performance consist of eight stages of emitter-coupled logic (ECL) dual-modulus prescalers (divide by 2/3 cell). One prescaler is constructed with four master-slave D flip-flops (MS-DFFs) and three OR gates, another uses two MS-DFFs and one XOR gate. To further increase the operating frequency while reducing power consumption, the MS-DFF is modified: the hold circuits and sample circuits are controlled by the same input clock signal so that a single power supply can be used, reducing power consumption. Two frequency divider prototypes were built in 2 µm GaAs HBT technology for verification. Measured results show that the two frequency dividers can operate over a very wide frequency range—50 MHz to 5 GHz and 50 MHz to 8 GHz, respectively—and their division ratios are 256 to 511 with a unit step increment.

Frequency dividers are key components of phase-locked loop (PLL) frequency synthesizers, which are widely used in modern communication and radar systems. High performance frequency dividers with wide operational frequency bandwidths, low-power consumption, wide division ratios and low phase noise are in demand. Various frequency divider topologies have been studied and built using compound semiconductor processes (InGaP, GaAs or GaN) and Si bulk (CMOS or Bi CMOS) in recent years.[1-10]

Most employ Si bulk technology because dividers using this technology are easy to be implemented and have lower power consumption. However, relatively high substrate losses resulting in low-quality factors and noise, such as low frequency flicker noise, restricts use of silicon in applications with demanding high frequency performance requirements. For these applications, compound semiconductors such as InGaP, GaAs and GaN are attractive alternatives; however, MMPFD based on compound semiconductor processes remain difficult to implement due to high-power consumption and the large amount of circuit area required.

Synchronous current mode logic (CML) or ECL architectures are the most popular because of a wide operational frequency range.[1-6] Li et al.[1] describe a 5.5 GHz pulse-swallowing multi-modulus frequency divider with divide ratios from 256 to 511. It is composed of a CML divide by 4/5 prescaler and a digital programmable arbitrary modulus counter. Wang et al.[4] describe a multi-modulus frequency divider using cascaded divide by 2/3 cells. The divide by 2/3 cell consists of four ECL D-latch and three AND gates; however, the fabrication processes are either Si bipolar or CMOS. In recent

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years, several dividers using compound semiconductor processes have been reported.[7-10] Tseng et al.[7] describe a divide by 3 prescaler using GaInP/GaAs HBT technology. Shin, Won et al.[8, 9] describe a semi-dynamic frequency divider with a division ratio of 1.5. In addition, Osafune and Ohwada[10] report on a GaAs MESFET frequency divider. The division ratios of these dividers, however, are limited and cannot be changed. It remains a challenge to design a compound semiconductor frequency divider with a wide division ratio that does not consume high DC power.

In this work, two MMPFDs were designed and implemented using a 2 μm GaAs HBTs process technology. Simulation shows a power reduction of more than 180 and 240 percent, respectively, compared to reported traditional dual-modulus divide by 2/3 prescalers. A considerable decrease in die area was also achieved. To our knowledge, these are the first reported MMPFDs with such a wide operational frequency range and range of division ratios using GaAs HBT technology.

DESIGN

Previous 2/3 Divider Cell

A popular method for PLL realization is hybrid integration, in which the voltage-controlled oscillator is implemented by a compound semiconductor process and the other circuits—the frequency divider and phase frequency detector—are implemented in silicon (CMOS or SiGe). For a fully integrated PLL, nearly all are realized in silicon. Silicon-based frequency dividers are easily fabricated using available foundries and can be integrated with high speed digital and mixed-signal circuits to facilitate system interface designs. Thus, academic and industrial applications are more inclined to use silicon dividers for on-chip system compatibility, ease of integration and low-power consumption; however, the multi-modulus frequency divider still remains difficult to integrate in the same process, since area overhead and power consumption is huge.

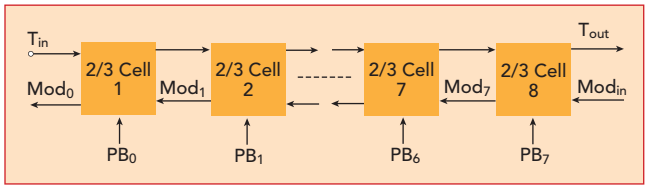

Fig. 1 **Conventional 2/3 divider cell.**

In summary, the main difficulties designing MMPFDs using compound semiconductor processes (GaAs, InP and GaN) are:

- The focus of academia and industry has been on the analysis and optimization of CMOS frequency dividers; however, some of the theoretical analysis and structures are not always available in compound semiconductor design
- For the programmable frequency divider, the larger division ratio means more dual-modulus divider cells, yielding a larger die area and higher power consumption
- The relatively crude process design kit and immature electronic design automation prevent academic researchers from gaining deep insight into the compound semiconductor frequency divider
- With traditional design methods, the frequency divider based on compound semiconductor processes faces difficult problems, such as large chip area, high-power consumption and high design complexity.

A variety of structures and methods have been proposed to realize the 2/3 divider cell, including a commonly used structure[1-5] containing four D-latches and three AND gates (see ***Figure 1***). However, these logic circuits AND gates increase propagation delay, resulting in a lower operating frequency. Also, the latch output is not stable. During the update phase, any input change will be passed to the output, and the transition of the latch output is not synchronized to the edge. The 2/3 divider cell divides the input frequency by 2 or 3 as determined by the control inputs to Mod_{in} and PB. The output frequency is half of the input frequency except when Mod_{in} = 0 and PB = 0; then, the output fre-

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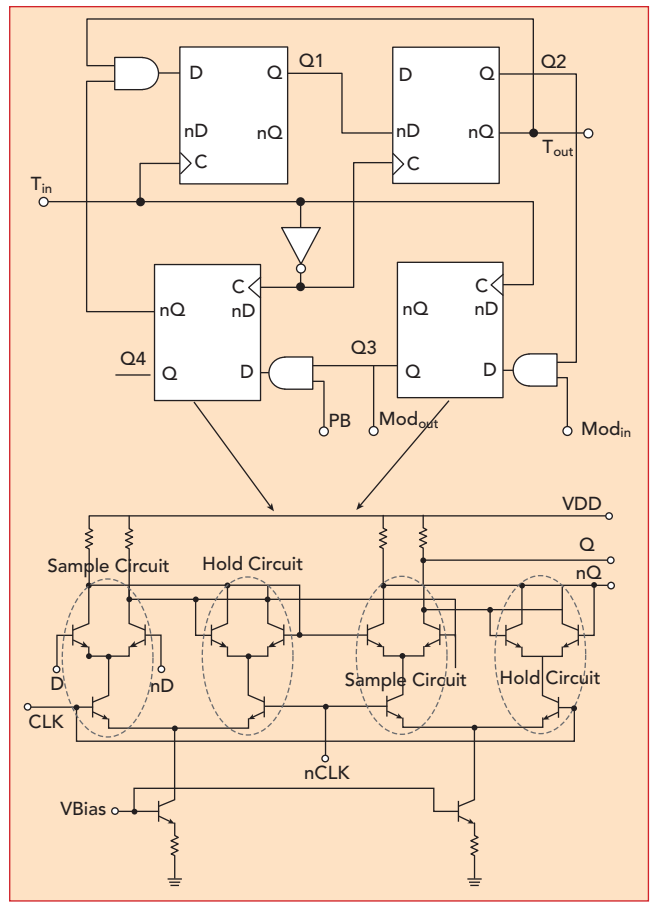

Fig. 2 **MMPFD structure comprising eight stages of dual-modulus, divide by 2/3 prescalers.**

quency is 1/3 the input frequency. Because of the power consumption and die area for a traditional 2/3 divider cell, it is not suitable for a multi-modulus programmable frequency divider with a wide range of division ratios.

2/3 Divider Cell with MS-DFF and Gate (MMPFD-1)

To realize a multi-modulus programmable frequency divider for high frequencies with large division ratios and relatively low-power consumption, some improvements are needed in the structures of the dual-modulus prescaler (i.e., the 2/3 divider cell) and MS-DFF. ***Figure 2*** shows the elementary structure of a frequency divider that consists of eight stages of dual-modulus divide by 2/3 prescalers. The 2/3 divider cell comprises four MS-DFFs and three OR gates (see ***Figure 3a***). The D flip-flops use synchronous ECL D-latches due to their high operating frequencies. In contrast with traditional structures,[1-4] the propagation delay is reduced to yield a higher operating frequency and lower power consumption.

The 2/3 divider cell divides the input frequency by 2 or 3, determined by control inputs Mod_{in} and PB. When PB = 1, Mod_{in} = 1 or PB = 0, Mod_{in} = 1 or PB = 1, Mod_{in} = 0, the 2/3 divider cell works as a divide by 2 cell. Its simplified circuit configuration and state diagram are shown in ***Figure 3b***. When PB = 0, Mod_{in} = 0, the 2/3 divider cell works as a divide by 3 cell. Its simplified circuit configuration and state diagram are shown in ***Figure 3c***. The division ratio of this multi-modulus

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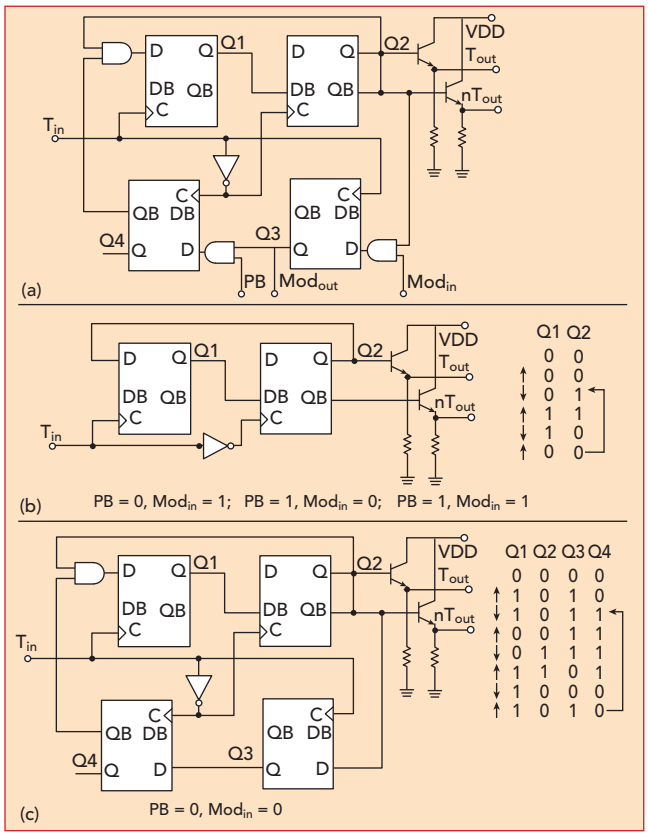

Fig. 3 MMPFD-1 2/3 divider cell (a) and simplified configuration and state diagram when set to divide by 2 (b) or divide by 3 (c).

frequency divider is expressed in Equation 1:

$$T_{out} = 2^n.T_{in} + 2^{n-1}.T_{in}.\overline{PB_{n-1}} + 2^{n-2}.T_{in}.\overline{PB_{n-2}} + \cdots + 2.T_{in}.\overline{PB_1} + T_{in}.\overline{PB_0} = \left(2^n + 2^{n-1}.\overline{PB_{n-1}} + 2^{n-2}.\overline{PB_{n-2}} + \cdots + 2.\overline{PB_1} + \overline{PB_0}\right).T_{in} \quad (1)$$

where T_{out} and T_{in} represent the output and input periods, respectively, and PB0, PB1, … PBn-2, PBn-1 represent the control bits of the MMPFD given to the cells, as shown in Figure 1.

To overcome latch output instability, a MS configuration cascades two latches. Recalling the traditional MS

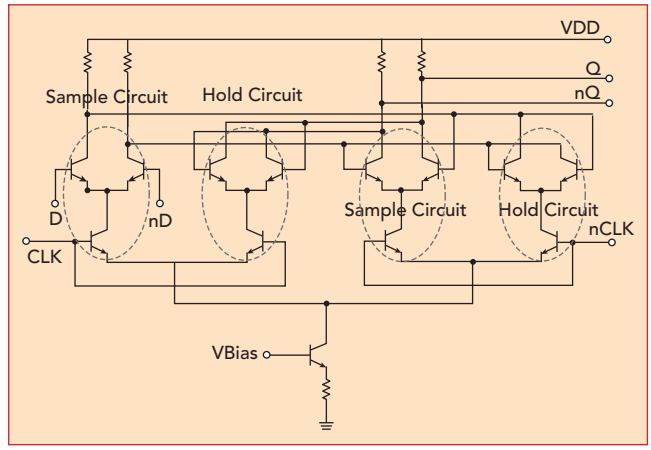

Fig. 4 Sample and hold circuits of the MS-DFF.

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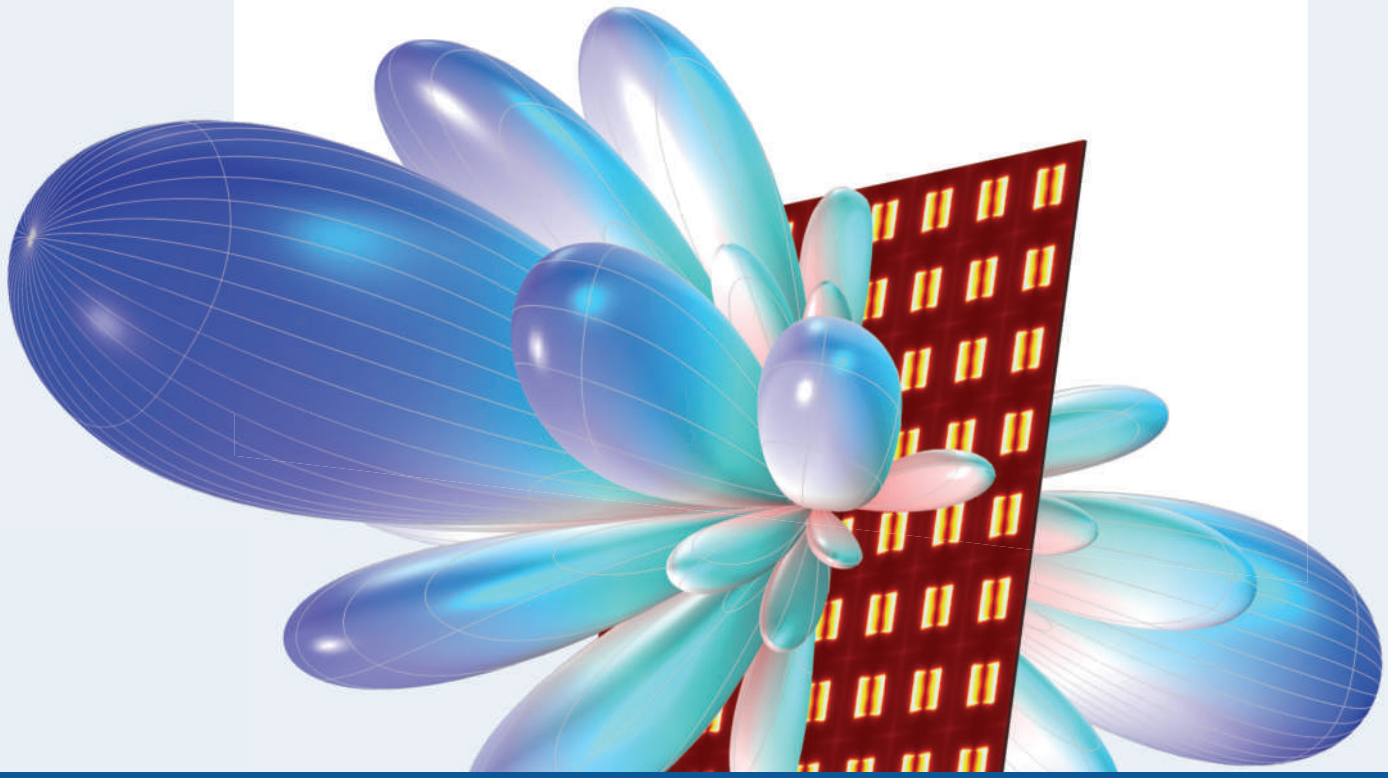

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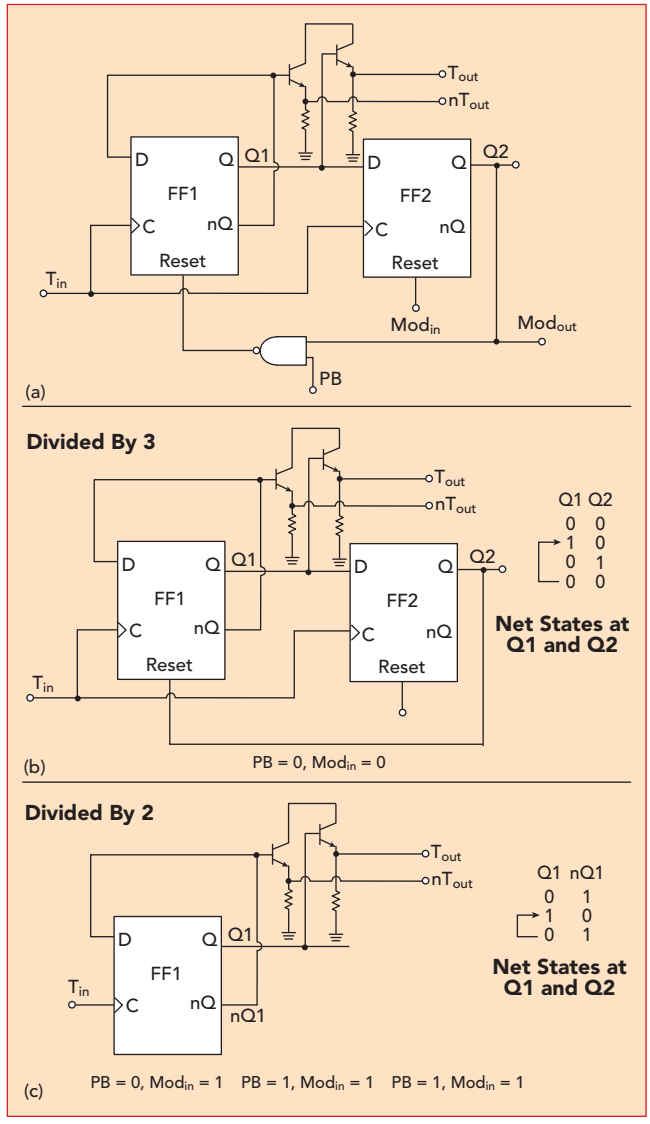
flip-flop shown in Figure 1, it has 14 transistors including two extra transistors used as two tail current sources. As shown in ***Figure 4***, the sample and hold circuits of the MS-DFF are controlled by the same input clock signal, theoretically reducing power consumption by 50 percent. The structure also enables a more compact die area.

2/3 Divider Cell with MS-DFF and XOR Gate (MMPFD-2)

To further decrease power consumption and die size, a 2/3 divider cell comprising two MS flip-flops and an XOR gate are used (see ***Figure 5a***). Compared to MMPFD-1, fewer D flip-flops result in less time delay, lower power consumption and higher operating frequency. When PB = 0 and Mod_{in} = 0, the 2/3 divider cell works as a divide by 3 cell (see ***Figure 5b***). When PB =1 and Mod_{in} = 1 or PB = 0 and Mod_{in} = 1 or PB = 1 and Mod_{in} = 0, the 2/3 divider cell works as a divide by 2 cell (see ***Figure 5c***).



▲ Fig. 5 **MMPFD-2 2/3 divider cell (a) and simplified configuration and state diagram when set to divide by 3 (b) or divide by 2 (c).**

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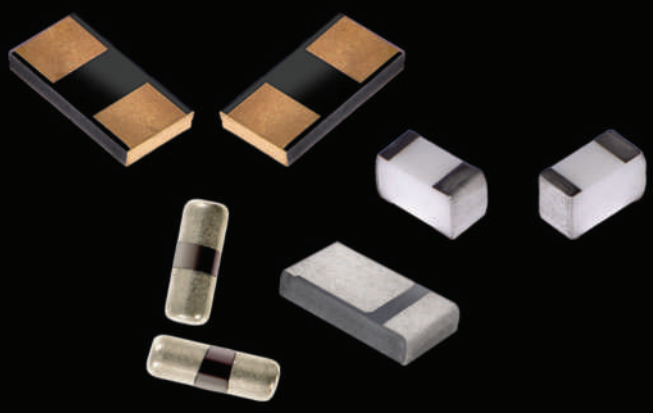

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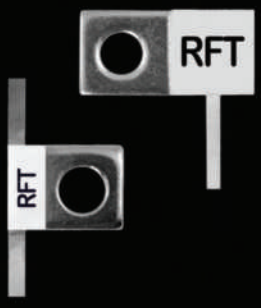

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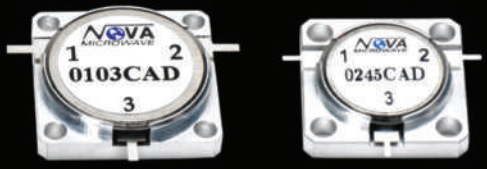

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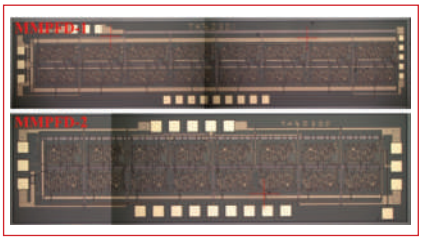
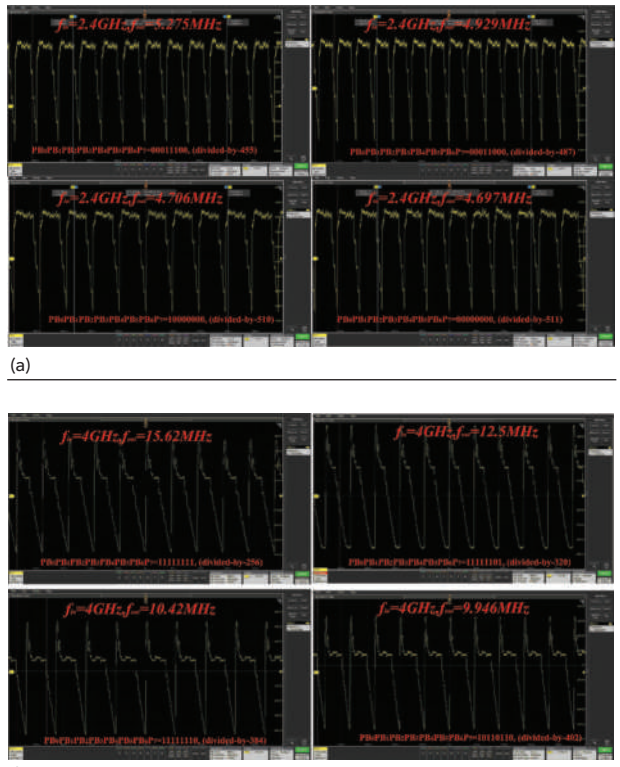
EXPERIMENTAL RESULTS

The frequency dividers were implemented in a 2 μm GaAs HBT process (see ***Figure 6***) and measured with an oscilloscope for verification (see ***Figure 7***). Without bonding pads, the core areas of MMPFD-1 and MMPFD-2 are 0.56 × 4.4 mm and 0.52 × 2.91 mm, respectively. MMPFD-1 draws 175 mA current with a 5 V supply, while MMPFD-2 only draws 112 mA. Figure 7a shows representative output waveforms from each divider. As shown in ***Figure 8***, compared with the traditional prescaler and operating at the same frequencies, the power dissipation of MMPFD-1 is reduced by up to 180 percent while the power dissipation of MMPFD-2 is reduced by 240 percent, and a more compact die is possible.

Table 1 compares this work with other published work when this article was written. In general, frequency dividers designed in Si bulk technologies (i.e., CMOS and BiCMOS)[1,2,6] have lower DC power dissipation, but technology shortcomings may eliminate them from use in applications needing very low phase noise and radiation resistance. Compared to some reported frequency dividers using compound semiconductor process-



▲ Fig. 6 **Fabricated dividers.**



▲ Fig. 7 **Representative output waveforms from the MMPFD-1 (a) and MMPFD-2 (b).**

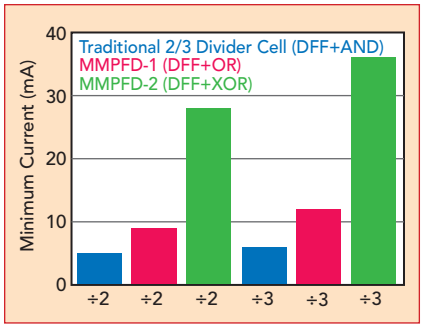


Fig. 8 Comparing minimum current with 3 GHz input.

es,[7-10] these MMPFDs achieve the widest division ratios and they have the largest bandwidths compared with other reported dividers.

CONCLUSION

Two MMPFDs based on 2 µm GaAs HBT technology demonstrated a wide division range with the divide ratio varying continuously from 256 to 511. The MS flip-flop used to construct the 2/3 divider cell was modified so that it is supplied by a single tail current source. As a result, the GaAs HBT structure consumes less power and is more compact. It may be employed in fully integrated PLL applications such as fractional-N frequency synthesizers and agile frequency synthesized sources.■

TABLE 1
FREQUENCY DIVIDER COMPARISON

Reference	Operating Frequency (GHz)	Bandwidth (%)	Division Ratio	DC Power (mW)	Process
1	2.3-5.5	82.1	256-511	20.4	BiCMOS
2	13	0	128-159	24.2	BiCMOS
6	2.2-2.3	40	3/2/1.5	—	CMOS
7	DC-2.6	—	3	85	GaAs HBT
8	4.5-9.2	64	1.5	119	GaAs HBT
9	9.0-9.5	5	1.5	256	GaAs HBT
10	2.1-8.5	120.8	32	540	GaAs MESFET
MMPFD-1	0.05-5	196	256-511	875	GaAs HBT
MMPFD-2	0.05-8	198.6	256-511	560	GaAs HBT

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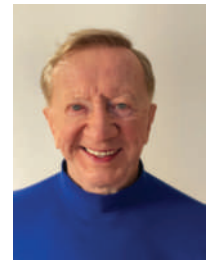
INVITED PAPER

The Birth of Commercial RF/Microwave CAD

Les Besser



Fifty years ago, RF/microwave amplifier design was more art than science. The introduction of S-parameters and the Hewlett Packard (HP) network analyzer provided practical ways to measure circuit performance, but the design phase was still complicated and frustrating "cut and try." A small number of progressive companies and government labs, such as HP, Texas Instruments and the U.S. Army Research Center, had ongoing, in-house computer program development to support RF/microwave design, but microwave engineers elsewhere had no access to those tools.

Early computers were primarily used for business applications, and some of their operating languages, such as BASIC,[1] even lacked scientific features like complex numbers and matrices. Most engineering managers were reluctant to adopt and spend money on techniques that did not start at the workbench. Circuit designers carried out approximate calculations, often with the aid of slide rules or desktop calculators, to create the first prototypes. Products were finalized through time-consuming iterations of tweaking, peaking and shielding—sometimes without reaching the original goals. At the same time, space-age demands required microwave circuits to be smaller and have higher performance. Circuit integration was the desired direction, but that required more accurate simulation.

In this article, I summarize the early-day efforts to have computational power available to design engineers, including those who worked at small companies.

FIRST-GEN CIRCUIT SIMULATORS

In 1971, the University of California, Berkeley, developed a general-purpose, open-source analog circuit simulator called SPICE,[2] but it lacked many of the passive components used in microwave design. For active devices, it required equivalent-circuit models (e.g., Ebers-Moll, Gummel-Poon) instead of measured S-parameters. Additionally, SPICE was only available for large computers.

Gradually, time-shared computer companies introduced affordable access to computational power for engineers,[3] but circuit design programs were rare and often user-unfriendly. The most commonly available computer terminal for engineers was the noisy Teletype machine,[4] with a printing capability of 10 characters per second—requiring several minutes to print a page (see ***Figure 1***). Unlike today, when every engineer has at least one computer within reach,

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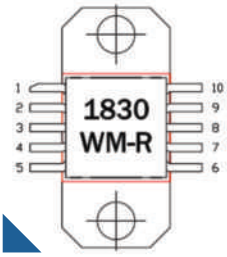
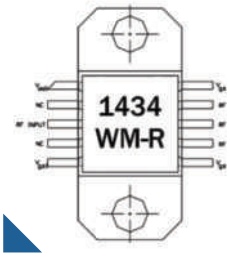
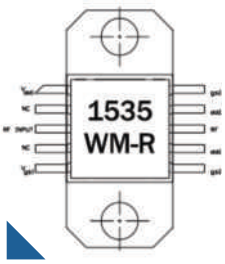


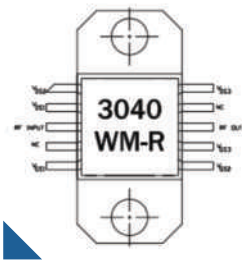
AMCOM's **AM183031WM-EM-R** is part of the GaAs MMIC power amplifier series. It has 30.5dB gain and 31.5dBm output power over the **1.6 to 3.3 GHz** band. This MMIC is in a ceramic package with both RF and DC leads at the lower level of the package to facilitate low-cost SMT assembly to the PC board.



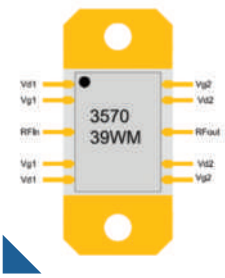
AMCOM's **AM143440WM-EM-R** is part of the GaAs HiFET MMIC power amplifier series. This high efficiency MMIC is a 2-stage GaAs pHEMT power amplifier biased at 10 to 14V. The input and inter-stage matching networks cover **1.4 to 3.4 GHz** with 20 dB of gain and 39 dBm output power.



AMCOM's **AM153540WM-EM-R** is part of the GaAs HiFET MMIC power amplifier series. It is a 2-stage GaAs HIFET PHEMT MMIC power amplifier. It is fully matched to 50-ohm at both input and output, covering **1.5 to 3.5 GHz**. The MMIC has 21dB gain and 38.5dBm output power at 14V.

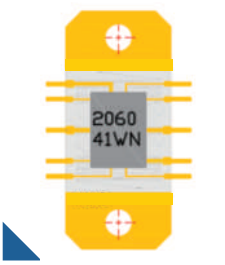


AMCOM's **AM304031WM-EM-R** is part of the GaAs MMIC power amplifier series. It has 31dB gain and 31 dBm saturated output power over the **2.6 to 4.8 GHz** band. This MMIC is in a ceramic package with both RF and DC leads.

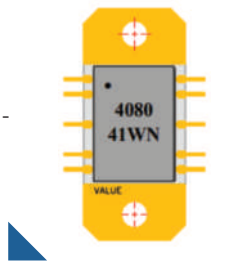


AMCOM's **AM357039WM-SN-R** is a broad-band GaAs MMIC Power Amplifier. It has a nominal CW performance of 21dB small signal gain, and 38.5dBm (7W) saturated output power over the **3.5 to 7 GHz** band.

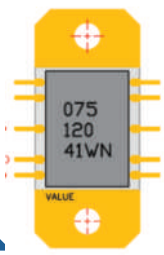
AMCOM's **AM07511542WM-SN-R** is a broadband GaAs MMIC power amplifier. It has 25 dB small signal gain, and 42 dBm output power over the **8 to 11 GHz** band at 8V bias and a 5% pulsed operation.



AMCOM's **AM206041WN-SN-R** is a broad-band GaN MMIC power amplifier. It has > 30 dB gain, and > 41 dBm output power over the **1.75 to 6.5 GHz** band. The AM206041WN-SN-R is in a ceramic package version with a flange and straight RF and DC leads for drop-in assembly.



AMCOM's **AM408041WN-SN-R** is in a ceramic package with a flange and straight RF and DC leads for drop-in assembly. It has 31dB gain, and 41.5 dBm output power over the **3.75 to 8.25 GHz** band. Because of high DC power dissipation, good heat sinking is required.



The **AM07512041WN-SN-R** is in a ceramic package with a flange and straight RF and DC leads for drop-in assembly. It has 27dB gain, and 41dBm output power over the **8.25 to 11.75 GHz** band. Because of high DC power dissipation, good heat sinking is required. The package is RoHS compliant. This MMIC is matched to 50 Ohms.

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those Teletypes were usually shared by several designers. To make things worse, barely any of those designers knew how to type.

Early microwave circuit design programs were generally based on various two-port interconnections using S-, Y-, Z- and ABCD-matrix manipulations.[5] The frequent matrix conversions required significant and expensive CPU time. My graduate degree thesis was a novel, S-parameter-based, two-port technique,[6,7] and I wrote a circuit simulator program on a Santa Clara University IBM computer based on that approach. While working at Fairchild Microwave and Optoelectronics, a division of Fairchild Semiconductors, I converted the program to the General Electric time-share system's GE-635 computers for our engineers. Later, I asked Fairchild's management to make the new program, named SPEEDY, available worldwide to microwave circuit designers. At that point, Fairchild Microwave had the only commercial GaAs FETs in production, and SPEEDY's large database of broadband device S-parameter data proved to be a convenient marketing tool for the company.

SPEEDY was a two-port circuit simulator, requiring engineers to describe their circuits through the interconnection of series, parallel and cascade segments. Compared to today's schematic entry, that method sounds primitive, but until sparse-matrix techniques and faster computers became available, computational speed was crucial, and the two-port approach was speedier—hence the name. I made a special effort to simplify the program's use by supplying a manual with examples of typical circuits.

SECOND-GEN MICROWAVE CAD

By 1972, the semiconductor industry experienced a worldwide slowdown, and I was asked to lay off some of our newly hired engineers—which I refused to do. I found work at Farinon Electric, a stable, well-managed company that produced microwave telecommunications equipment. After learning that none of their circuit designers used computers and hearing about a brand new time-sharing service called NCSS, which operated with far more powerful IBM 370 computers, I offered Farinon a deal: on my own time, I would convert my original IBM school program to the 370 system, enhance it and let all Farinon engineers use it royalty-free—if the company would pay for the related computing charges and let me have ownership of the new product. The proposed new program would also include additional circuit components for Farinon's communications system designers, as well as optimization to find the best per-

(a)

(b)

Fig. 1 **Teletype model 33ASR with telephone modem and punched-tape reader (a). Texas Instruments introduced the Silent 700 portable printer (b) in 1973, a major improvement. *Sources:* Rama & Musée Bolo (a) and Retro-Computing Society of Rhode Island (b) via Wikipedia.**

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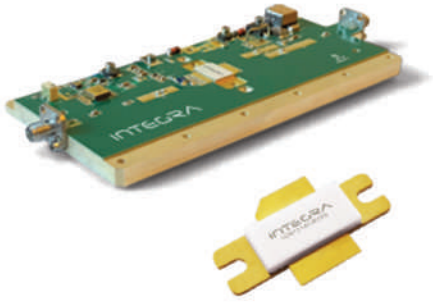

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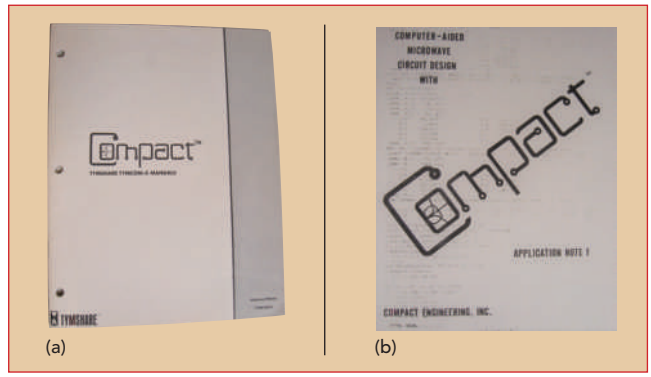
formance.[8,9] The company agreed and for the next six months I had no free time to myself or my family.

Although I initially wrote the program in FORTRAN,[10] transferring it from one time-share company to another required some effort and learning. To make computer access easier, every time-share company developed its own unique, user-friendly operating interface, like the major computer operating systems we have now. These days, we are spoiled with simple ways to store and transfer files, but in the 1970s, punched (Hollerith) cards[11] were the most common way of passing a program from one computer to another. Handling and shipping those paper cards required special precautions, as you might imagine.

The first version of the program contained over 1,200 lines of code, with a 45-page manual. To assist new users, I also released an application note to illustrate the coding of typical microwave circuits and the optional available output formats (see ***Figure 2***). Offering a free lunch to my Farinon colleagues to come up with the best name, one of them suggested COMPACT: **C**omputerized **O**ptimization of **M**icrowave **P**assive and **A**ctive **C**ircui**T**s. Everyone agreed and after I gave a short seminar, our engineers started to use the program in mid-1972. Their feedback helped immensely to clean up the initial bugs.

A few months later, a salesman from a competing time-share company, United Computing System, came by to demo their circuit simulator, called MAGIC. "We have a better program that can also find the optimum performance," I told him and showed how COMPACT worked. Impressed, he left and returned a few days later with several managers. None of them were engineers, but the idea that COMPACT had circuit optimization made them extremely interested. "Please consider adding this program to our library on a royalty basis," their district manager suggested. "We'll give you free unlimited computer access and help you with the conversion to our Control Data 7600 computer, too." I talked it over with Ed Nolan, Farinon vice president of engineering. He had no objections, but he emphasized, "Providing support for other engineers will require extra effort, and we need you here full time!" Within a few weeks, COMPACT was running on their system.



▲ **Fig. 2 COMPACT user manual (a) and application note (b).**

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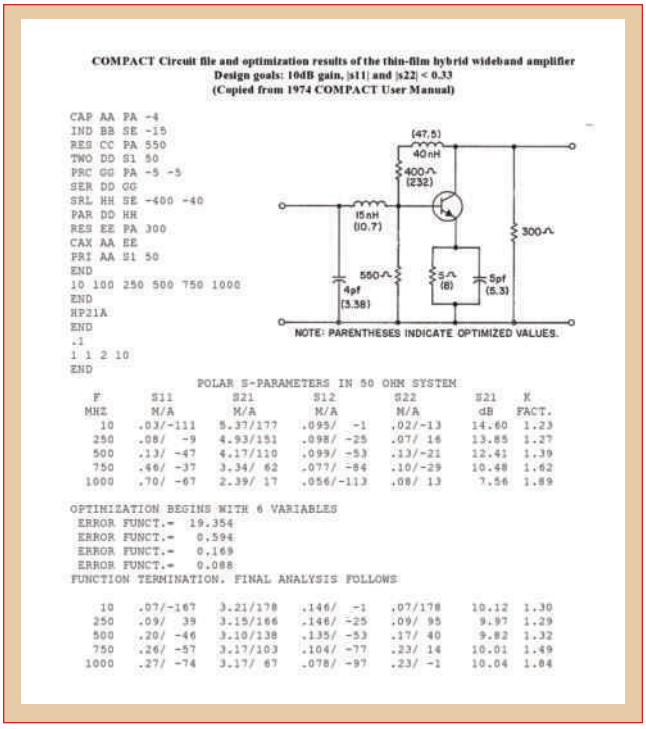

COMPACT Circuit file and optimization results of the thin-film hybrid wideband amplifier
Design goals: 10dB gain, |s11| and |s22| < 0.33
(Copied from 1974 COMPACT User Manual)

```
CAP AA PA -4
IND BB SE -15
RES CC PA 550
TWO DD S1 50
PRC GG PA -5 -5
SER DD GG
SRL HH SE -400 -40
PAR DD HH
RES EE PA 300
CAX AA EE
PRI AA S1 50
END
10 100 250 500 750 1000
END
HP21A
END
.1
1 1 2 10
END
```


POLAR S-PARAMETERS IN 50 OHM SYSTEM

F	S11	S21	S12	S22	S21	K
MHz	M/A	M/A	M/A	M/A	dB	FACT.
10	.03/-111	5.37/177	.095/ -1	.02/-13	14.60	1.23
250	.08/ -9	4.93/151	.098/ -25	.07/ 16	13.85	1.27
500	.13/ -47	4.17/110	.099/ -53	.13/-21	12.41	1.39
750	.46/ -37	3.34/ 62	.077/ -84	.10/-29	10.48	1.62
1000	.70/ -67	2.39/ 17	.056/-113	.08/ 13	7.56	1.89

OPTIMIZATION BEGINS WITH 6 VARIABLES
ERROR FUNCT.= 19.354
ERROR FUNCT.= 0.594
ERROR FUNCT.= 0.169
ERROR FUNCT.= 0.088
FUNCTION TERMINATION. FINAL ANALYSIS FOLLOWS

10	.07/-167	3.21/178	.146/ -1	.07/178	10.12	1.30
250	.09/ 39	3.15/166	.146/ -25	.09/ 95	9.97	1.29
500	.20/ -46	3.10/138	.135/ -53	.17/ 40	9.82	1.32
750	.26/ -57	3.17/103	.104/ -77	.23/ 14	10.01	1.49
1000	.27/ -74	3.17/ 67	.078/ -97	.23/ -1	10.04	1.84

▲ **Fig. 3 10 to 1000 MHz hybrid amplifier design optimized using COMPACT.**

When National CSS learned about the deal, they, too, offered a royalty arrangement. Soon, Cupertino-based Tymshare came along, and we installed the program on their XDX 940 computers.[12] To promote the program, I submitted technical articles to trade journals and presented papers at conferences.[13–16]

Interestingly, not everyone endorsed circuit optimization. A well-known college professor told me, "A good engineer should always be able to find closed-form solutions instead of relying on iterative techniques." While that was true for certain cases, optimization proved to be invaluable for active microwave circuits (see ***Figure 3***), as well as considering the effects parasitic elements and transmission line discontinuities in passive circuits. At the same time, I always recommended using all available analytical tools to obtain the initial circuit instead of immediately jumping to optimization.

By the end of 1974, COMPACT was running on four international time-share systems without any competition. Technical support and bug fixes on the different computer systems required a tremendous effort. My wife took calls at our house, and every night as soon as I arrived home, I settled on my portable Texas Instruments computer terminal, connected it to the phone line and worked long hours. Adding new features required research and getting up early in the morning to talk with East-coast customers became part of my regular routine.

Even though I loved my work at Farinon, eventually I had to admit I was paying more attention to COMPACT and I was not being fair to the company. Still, leaving microwave engineering was too hard to consider. When I discussed the issue with my father-in-law, an oil company executive, he was not happy. "Leaving a steady job with great benefits is not a good idea! Besides, I don't see how anyone can make a good living by selling computer programs," he told me. Although I respected his advice, in late 1975, I announced to Farinon that I wanted to quit my job. The CEO, Bill Farinon, who was also an entrepreneur, sympathized with my situation. "We don't want to lose you, so take a six-month leave of absence," he told me. "We'll maintain your health insurance coverage until then. If you still like what you're doing, then leave us with our blessing. On the other hand, if you change your mind, pass the program support to someone else and come back." Within a few months, I knew I had made the right decision and we parted on friendly terms. My former Farinon colleagues gave me a wonderful farewell party.

After taking a long overdue Hawaiian vacation with my family, at the beginning of 1976 I started full time

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Fig. 4 The author exhibiting at the MTT-S conference in Palo Alto in 1976.

program development and support out of our home. That summer, a booth at the first exhibit of the IEEE International Microwave Symposium in Palo Alto gave me the opportunity to meet with many of my customers in person (see ***Figure 4***). Moving to a "mega house" in Los Altos Hills enabled me to have space for employees and be close to my family.

TEACHING TO MARKET CAD

Selling CAD was a challenging task because many microwave designers were not convinced of its practicality. Technical articles helped, but I found a more personable way to promote the program: short university courses.

While taking a microwave system design short-course at UCLA, I met Bob Wenzel, one of the leading filter design experts in our field. Recalling how impressed I had been with his personable, easy-going teaching style, I asked if he would team up with me to teach a microwave circuit design course. He agreed to teach two days on filter synthesis and I would follow with three days on active circuit design. In 1976, UCLA scheduled the first five-day course, titled Microwave Circuit Design. The school allowed us to use its computer lab for a two-hour, hands-on design session using COMPACT. Our first course was booked to capacity; engineers from TRW, Hughes Aerospace and other defense-oriented business groups were eager to attend. I gradually hired consultants to add new capabilities to the program, including various physical transmission line elements and discontinuity models, Monte Carlo statistical analysis, noise analysis and optimization, among others. Within a few years, other universities—the Universities of Maryland and Santa Clara in the U.S. and Cambridge and Oxford in the U.K.—asked us to teach the course. These presented excellent opportunities to introduce COMPACT to new users. In addition, we were paid well to teach.

The security considerations of defense products became a concern. Government agencies were not happy about designs performed through unsecured telephone lines. They wanted the program running on their own computers. The first company that purchased COMPACT was the Communications Research Centre of Canada, followed by several others. Installing the program on various systems often presented new challenges for us. In 1977, the president of Tokyo System Lab, a Japanese technical marketing company, offered to become our representative in Asia. We signed an agreement, they translated our user documentation and I began to teach short courses in that country, often with the support of interpreters.

THIRD-GEN MICROWAVE CAD

Early in 1979, Communications Satellite Company (COMSAT) approached me with an interesting proposal. COMSAT had been formed by the U.S. Communications Satellite Act of 1962 and had maintained a worldwide monopoly on satellite communications. In 1977,

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the FCC reclassified the company as a utility and began to regulate the rates charged to COMSAT's customers. To make matters worse, the new "Open Skies" policy, which encouraged competition, ended COMSAT's worldwide monopoly on satellite telecommunications the following year. COMSAT's management decided to diversify and look for new business ventures, with one of their ideas automating the engineering design and manufacturing processes of high-tech companies.

The COMSAT representative told me that design engineers from large companies either used outside time-sharing or their own central mainframe computers. The first alternative was expensive and not fully secure. In the second case, engineers were using a computer that was purchased for business instead of scientific applications. He planned to form a group to develop a dedicated design system to automate the engineering departments, which would run on minicomputers. Digital Equipment (DEC) and Prime Computer Company had recently introduced powerful minicomputers that could handle the needs of 30 to 40 engineers simultaneously. Among other tools, such as a spreadsheet and word processor, he wanted COMPACT and a digital circuit simulator to be part of that system and sold to companies in the defense and telecommunications businesses.

The man sounded like a visionary. The more I heard, the more excited I became. I recalled a lengthy article in *Business Week* predicting that office automation would become a $5 billion business within the next five years. If that were true, IBM, General Electric, HP and other giants would enter that business and would squash my small company. Perhaps working with COMSAT would be the safe way to go. (As it turned out, most of today's major software companies, like Microsoft, Adobe and Oracle were started by entrepreneurs.) Our discussion led to a merger agreement and the formation of COMSAT General Integration Systems (CGIS).

Fig. 5 The opening of the CGIS building in Palo Alto hosted a meeting of COMSAT's board of directors.

Instead of my crowded home office, our employees now worked in a fancy new building in Palo Alto (see ***Figure 5***). My children, however, did not like the change. My daughter Nanci had just begun preschool and cried in class. "My daddy started to work and he's

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- **Low additive phase noise**
- **High channel-to-channel isolation**
- **High return loss**

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The FS730 and FS735 10 MHz distribution amplifiers from SRS provide state-of-the-art solutions to challenging signal distribution tasks.

These distribution amplifiers use an input limiter design, which removes amplitude modulation from the signal, provides fixed amplitude outputs and blocks input noise. Virtually any 10 MHz waveform with a duty cycle near 50% may be used as an input.

The FS735 model provides fourteen 10 MHz output BNC connectors on the rear panel, with status indicators on the front panel. The half-rack sized FS730 model gives seven 10 MHz outputs and is available in both bench-top and rack-mount forms.

With mix and match capability, the FS735 can also be configured with 10 MHz, 5 MHz, Broadband, and CMOS Logic distribution amplifiers side-by-side for other applications. Multiple units can be daisy-chained for easy expansion.

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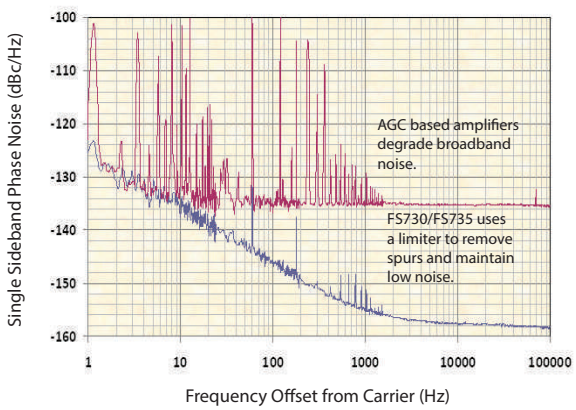

Additive phase noise in 10 MHz Distribution Amplifiers: Limiter vs. AGC Designs

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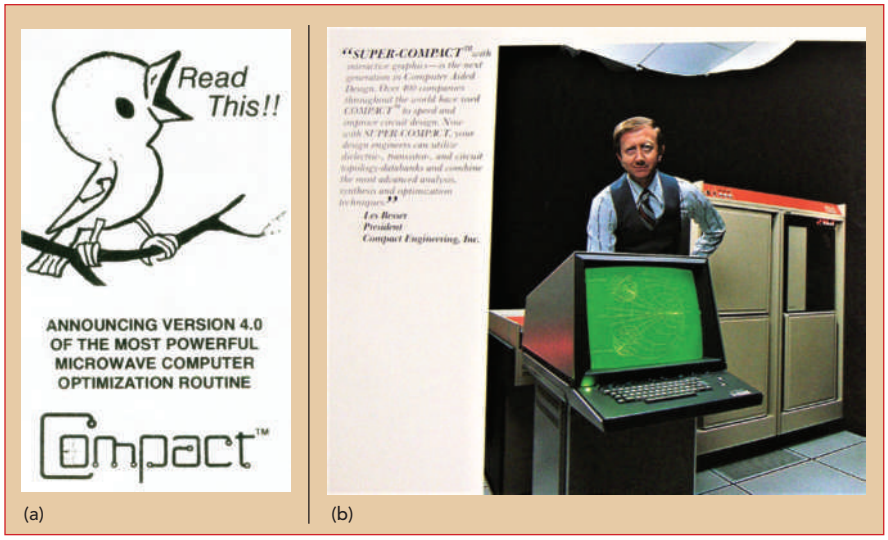

Fig. 6 Early ad for COMPACT (a) vs. later ad promoting SUPER-COMPACT on Prime minicomputers (b).

not home anymore during the day," she told the teacher. When the teacher asked her how long I had been out of work, she said, "He's never worked." A few days later, I met the teacher. "I'm so glad to hear that you've finally found a job," she told me. "But apparently Nanci does not like the change." I was confused. "I've been working full time since I turned 18. Where did you hear that I did not have a job?" "Nanci said that you're no longer at home during the day," she replied. When I finally understood, I explained that I began my home business the year Nanci was born. To her, a dad who was at home during the day could not possibly be "at work" at the same time.

With the help of new technical experts and professional programmers, COMPACT was vastly expanded, nearly 3x the size of the code. A new name, SUPER-COMPACT, and a new logo followed.[17–18] In early 1980, we released the program for VAX PDP-10 and Prime minicomputers (see ***Figure 6***). Our plan was for the program to only run on those systems. However, within a week, one of our major customer's vice presidents called. "We're the most important U.S. defense contractor, and I am not going to bypass our multimillion-dollar large-scale computer system. Please make your new program run on that!" he demanded. I decided to make an exception. Soon after, other major companies followed; again, I caved by converting SUPER-COMPACT for their CDC and Cray computers. Our dream of simple, two computer system technical support vanished.

At the peak, CGIS had over 200 employees. Unfortunately, within a year, I faced a major family problem that forced me to resign from CGIS. My non-compete agreement kept me away from CAD-related activity, so my next technical career several years later shifted to continuing education.

MAINFRAME TO PC

Although the end of the Cold War and the disintegration of the Soviet Union in 1991 led to a significant reduction in defense activities, personal wireless communications offered a wide range of new product developments. Interestingly, for the next three years, SUPER-COMPACT still had no significant competitors. A few smaller programs—such as Circuit Busters which became Eagleware—were offered for PCs, and HP released its in-house program, Microwave Design System (MDS) on UNIX-based workstations.

Finally, in 1984, a new company, EEsof, entered the market with Touchstone,[19] running on the IBM PC and dropping the price of microwave CAD from the $60,000 to $100,000 range down to $10,000. One of the unique features of

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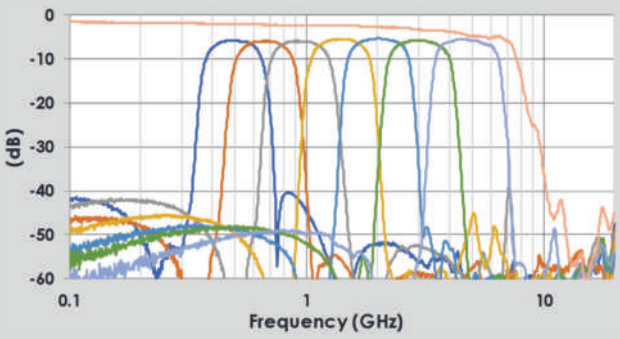

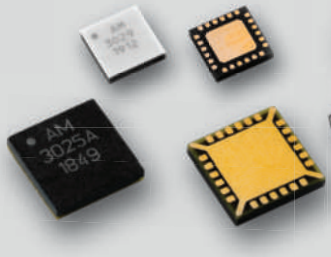

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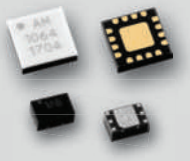

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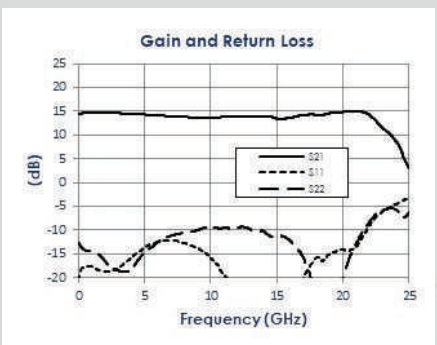

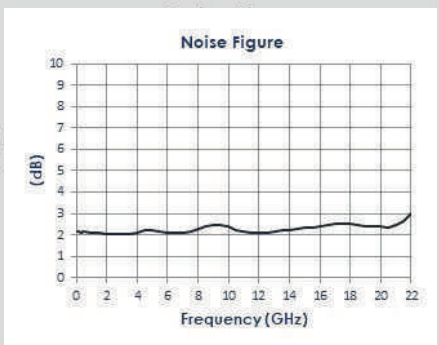

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Touchstone was its "tune mode," enabling designers to watch how the circuit's performance changed with component tweaking. Managers of small companies were more willing to buy PCs with Touchstone, shared by several engineers, rather than installing and maintaining a minicomputer. The new program soon became a favorite among designers, opening the door to true competition for RF/microwave CAD.[20] Touchstone was enhanced with harmonic balance and became Libra. HP acquired EEsof and out of the combination of Libra and MDS, ADS emerged.

COMSAT sold SUPER-COMPACT to Ulrich Rohde in 1985, and the software's computational approach shifted to EM-based models, validated by Raytheon and Texas Instruments as part of DARPA's MIMIC program. Compact Software merged with Ansoft in 1997, and later with Ansys.

In 1994, Applied Wave Research (AWR) formed to provide computer-aided design tools for RF and microwave designers. In 1998, at the International Microwave Symposium in Baltimore, AWR demonstrated Microwave Office, which combined circuit simulation, EM analysis and schematic capture in a single package. AWR's portfolio expanded to offer additional capabilities, including Visual System Simulator and AXIEM. The company was acquired by National Instruments in 2011, then sold to Cadence in 2020.

With the wide adoption of the PC and new companies forming to tap the processing power available to every design engineer, computerized RF/microwave design became an industry.[21,22] Communication circuit and system designers now have the luxury of conveniently accessing linear and nonlinear, analog and digital circuit and system simulation and optimization, as well as 3D EM simulation with interactive graphics.

Sometimes, I wish I had started my career decades later, so I'd be able to use all these new design tools.■

ACKNOWLEDGMENT

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INVITED PAPER

6G: Innovating the Future of Wireless Communications

Jessy Cavazos
Keysight Technologies, Santa Rosa, Calif.

It seems like 5G is just starting, so why talk about 6G? Because cellular technologies take more than a decade to go from vision to deployment. Take 5G as an example. Work on the technology started well before the first specification emerged in 2018, as the International Telecommunication Union (ITU) started developing the vision for 5G in 2012. Each new generation of cellular technology represents a step-function increase in complexity. 5G leverages new spectrum for commercial mobile communications, among other new concepts. With consumers and businesses accustomed to getting new capabilities with each generation, 6G needs to deliver much higher performance than 5G. Early 6G targets in key performance indicators represent a 10x to 100x increase over 5G. The 6G vision, ITU's "Network 2030," includes peak data rates to 1 Tbps, lowering latency to 0.1 ms and increasing density to 10 units/m².

Delivering 6G in time while meeting consumer expectations for never-before-seen, sci-fi-like capabilities requires the industry to increase research on 6G. Several universities are running research programs to advance 6G: The University of Oulu in Finland launched the first 6G program, 6G Flagship, in May 2018; the University of Surrey in England launched the 6G Innovation Centre in November 2020. The Wireless Internet of Things Institute at Northeastern University in

TABLE 1
5G/6G SPECTRUM BANDS (SOURCE: 6G FLAGSHIP)

Frequency Band	0.3-3 GHz	3-30 GHz	30-300 GHz	0.3-3 THz	3-30 THz
Wavelength	100-10 cm	10-1 cm	10-1 mm	1000-100 µm	100-10 µm
Dominant Propagation Mechanism	LOS, Reflection, Diffraction, Scattering, Penetration	LOS, Reflection, Diffraction, Scattering	LOS, Reflection	LOS, Reflection	LOS, Reflection
Dominant Attenuation Effects	Free Space Loss	Free Space Loss Transmission Loss Through Materials High at Upper Band	Free Space Loss/ Molecular Absorption O_2@60 GHz H_2O> 24 GHz	Free Space Loss/Molecular Absorption High H_2O Peaks	Free Space Loss/Molecular Absorption High H_2O Peaks
Supported Link Distances	10 km	1000 m	100 m	< 10 m	< 1 m
TX Power Limiting Factor	Regulation	Regulation	Technology	Technology	Technology
Approximate System Bandwidth	Up to 100 MHz	400 (or 800) MHz	Up to 30 GHz	Up to 300 GHz	> 100 GHz

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1998
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2000
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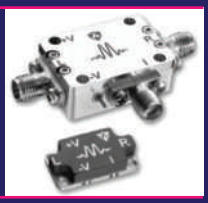
2002
4-lag correlator for ASIAA to detect "big bang" radiation

2004
Introduction of the T3 Mixer – Still the best mixer on the planet



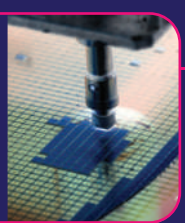
2007
Dr. Christopher Marki joins to develop new and complementary product lines

2013
Introduction of the Microlithic mixer – solving the mixer paradox

2016
- Dr. Christopher Marki becomes CEO
- 10,000 square foot expansion to support unprecedented growth
- Release of MMIC IQ Mixers, Nonlinear Transmission lines, Equalizers & Diode Limiters

2017
- Company grows past 100 employees
- Accelerating the innovation in MMIC mixers with the world's first MMIC T3 mixer, broadband triple-balanced MMIC mixer and multi-octave MMIC mixer

2018
Release of over 50 new products including Marki's first space-grade MMIC product



2020
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2021
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the U.S. is also working on 6G technology; it hosted a virtual event on 6G in October 2020, with plans to repeat it annually. Also, many countries have started to invest in 6G. In November 2020, China launched a satellite to test the Earth-to-space radio channel for frequency bands above 100 GHz, which are above the mmWave 5G bands (i.e., FR2). In the U.S., the Next G Alliance launched in October 2020 with the mission to advance North American leadership in 6G. Japan recently announced investments of almost $500 million for 6G research.

6G will bring new and exciting use cases beyond those introduced with 5G. One area of focus is to combine sensing, imaging and precise timing with mobility and leverage artificial intelligence to create innovative applications. Some of these will require wider bandwidths—thus, the move from mmWave to sub-THz frequencies (see ***Table 1***). Studying sub-THz frequencies is critical to advance 6G development. Among other aspects, researchers need to determine the error vector magnitude (EVM) performance while using these frequency bands and higher modulation bandwidths.

MEASUREMENT CHALLENGES

With sub-THz systems, good EVM performance is critical to achieve higher-order modulation for high data throughput. To avoid masking the device being tested, the test system must also deliver better EVM performance, which requires a low signal-to-noise ratio (SNR). While maximizing signal power helps increase the SNR, reducing the signal power is necessary to avoid compressing the components along the signal chain. The noise contributions to SNR can also be problematic for wideband applications because the noise power is integrated over the wider signal bandwidths.

Phase noise is another issue to contend with. Up- and down-converting between the IF and sub-THz frequencies requires a local oscillator signal source and frequency converter. Frequency multipliers are often used in the local oscillator (LO) path rather than the signal path to avoid impacting the signal modulation characteristics. However, frequency multipliers increase the phase noise and can introduce additive phase noise, further degrading the multiplied LO phase noise.

Impairments provide additional challenges. While filters can remove the undesired image products, LO feedthrough, out-of-band spurious and other undesired artifacts from nonlinear mixing, these components can introduce linear amplitude and phase errors over the wide signal bandwidths. Adaptive equalization in the receiver of a wide bandwidth test system can remove linear amplitude and phase impairments across the signal bandwidth. However, the adaptive equalizer only addresses linear amplitude and phase error; it cannot remove any nonlinear impairments from compressed amplifiers in the test system signal path nor LO phase noise. Noise and nonlinear impairments will remain and degrade the residual EVM of the test system.

The test system requires flexibility to handle candidate waveforms for 6G, since the physical layer standards are not yet defined. Including design simulation will aid the evaluation of system performance under various simulated scenarios.

SUB-THZ MEASUREMENTS

Figure 1 shows an example testbed meeting the performance demands of 6G research. The transmit chain includes a multichannel arbitrary waveform generator (AWG) to generate wide bandwidth modulated IF signals, a signal generator to provide a low phase noise LO for the up-converter and an up-converter to convert the IF signal from the AWG to a sub-THz frequency. The receive chain includes a down-converter to convert the sub-THz signal back to IF using the same signal generator LO and a multichannel, high performance oscilloscope to digitize it. Software is used to generate and analyze 6G candidate waveforms.

Using this setup, single carrier, quadrature amplitude modulation measurements were performed using varying modulation bandwidths. Because 6G waveforms are not defined, preliminary 802.11ay test software was used for signal genera-

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tion and analysis, as 802.11ay is an emerging wideband standard with optional bandwidths similar to those planned for 6G. ***Figure 2a*** shows the performance of a two-channel bonded (CB2) signal centered at 144 GHz and a channel bandwidth of 4.32 GHz, using D-Band (i.e., 140 to 170 GHz) up/down-converters (left) and G-Band (i.e., 140 to 220 GHz) up/down-converters (right). ***Figure 2b*** shows a four-channel bonded (CB4) signal centered at 144 GHz and a channel bandwidth of 8.64 GHz, using the same D- and G-Band up/down-converters. The modulation bandwidth shown in Figure 2b is double that of Figure 2a, which increases the integrated noise power within the signal bandwidth. There

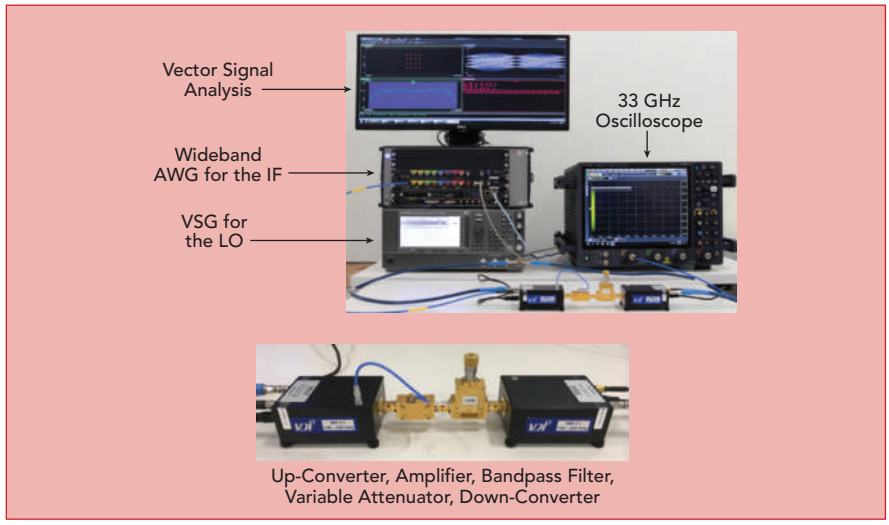

Fig. 1 Sub-THz testbed.

Fig. 2 144 GHz, 802.11ay CB2 (a) and CB4 (b) measurements using D-Band (left) and G-Band (right) up- and down-converters.

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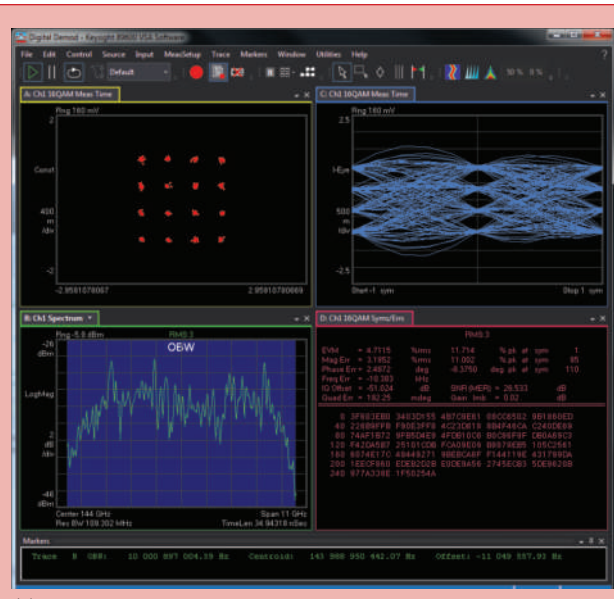

(a)

(b)

▲ **Fig. 3 Performance of a 16 QAM, 10 GHz occupied bandwidth signal at 144 GHz in a conducted test setup (a). OTA setup (b). Both conducted and OTA tests used the G-Band up/down-converters.**

is also greater linear amplitude and phase variation as the signal bandwidth is increased. These factors degrade the EVM performance, which goes from approximately 2.1 to 3.4 percent using the D-Band converters and from 2.2 to 3.5 percent using the G-Band converters.

The same test setup can perform measurements for "extreme" bandwidth cases, such as an occupied bandwidth of 10 GHz (see ***Figure 3***). With a conducted test, the baseband waveform is pre-corrected before being downloaded into the AWG and the adaptive equalizer is disabled. The resulting EVM is 4.7 percent. Repeating the test over-the-air (OTA), the baseband waveform is pre-corrected for the channel and signal path before being downloaded to the AWG. In this case, the adaptive equalizer is enabled to compensate for OTA channel impairments. The OTA EVM performance degrades slightly, increasing from 4.71 to 4.75 percent.

INNOVATION AND FLEXIBILITY

6G will further integrate communications technologies into society and human life, bringing mixed reality experiences and telepresence, while playing an important role helping move to global sustainability, a better society and increasing productivity across industries. Like its predecessors, 6G comes with new challenges, particularly the wider bandwidths and higher frequencies to support new use cases. To develop the potential of 6G, researchers need test solutions with better EVM performance, so the test system does not mask the true performance of devices and systems.■

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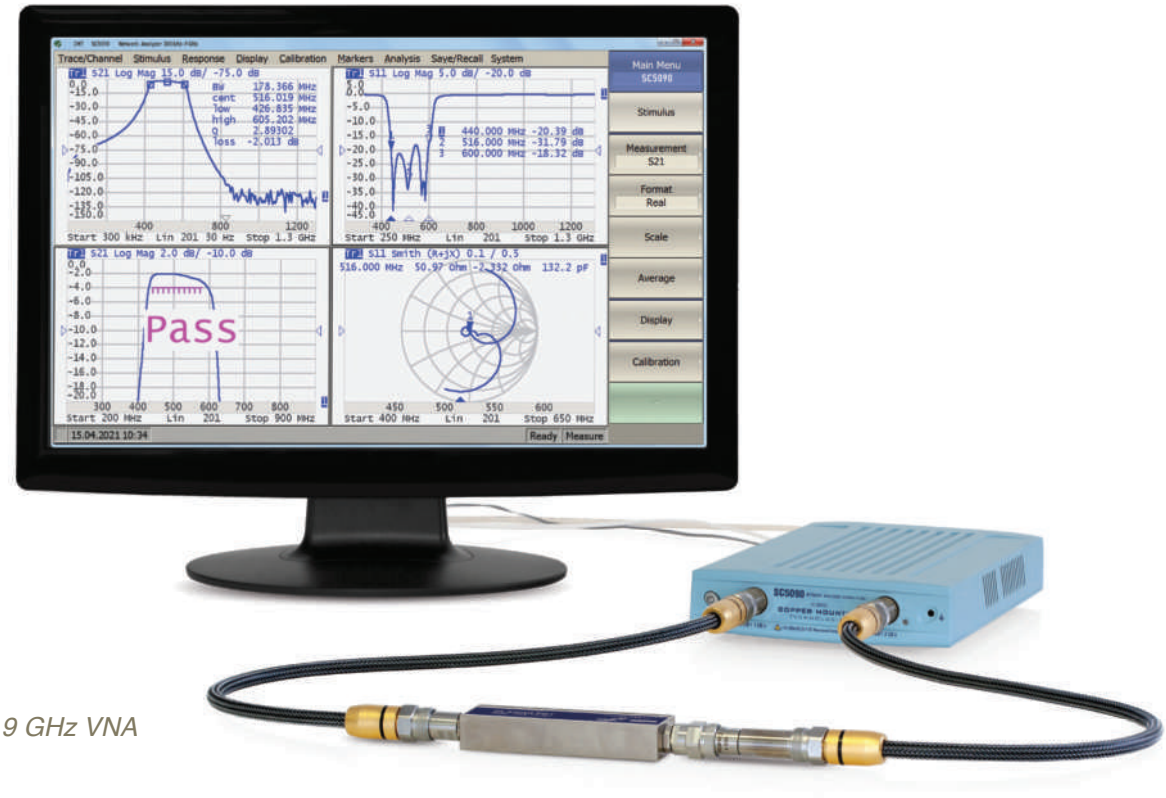

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A seemingly endless variety of antennas are available for 5G applications. Selecting from this range of options typically involves a complex set of choices among competing performance objectives. A new antenna from Eravant strikes a good balance for many applications that require ultra-wide bandwidth, moderate beamwidth and polarization diversity.

Model SAV-0634431050-2F-S1-QR is a quad-ridged horn antenna with dual coaxial feeds that covers 6 to 44 GHz. For each port, the typical E-plane beamwidth is 45 degrees while the H-plane beamwidth is 55 degrees (see ***Figure 1***). Sidelobe suppression is 15 dB or better, the cross-polarization is better than -15 dB, with -20 dB or less at most frequencies and port-to-port isolation above 30 dB across most of the operating spectrum (see ***Figure 2***).

Over the operating frequency range, the gain increases from 4 dBi at 6 GHz to 12 dBi at 44 GHz (see ***Figure 3***). Reduced gain at lower frequencies is partially from the smaller effective aperture relative to the wavelength. Loading effects related to the antenna's compact structure are also a factor limiting the low frequency gain, which is reflected by the lower return loss (see ***Figure 4***).

The feed ports have 2.4 mm coaxial connectors, with return loss typically around 15 dB. Power handling capability is 10 W. The antenna occupies a small volume, measuring 1.6 × 1.4 × 1.4 in. (4.1 × 3.7 × 3.7 cm), and the assembly includes a ¼-20 threaded hole for easy attachment to a standard mount.

APPLICATIONS

As a development tool, the dual polarized antenna is useful in a variety of test scenarios. In an antenna test range, the radiation patterns of a test antenna can be evaluated for vertical and horizontal polarization without requiring the operator to adjust antenna position. Adding a quadrature hybrid network, such as Eravant's SCZ-

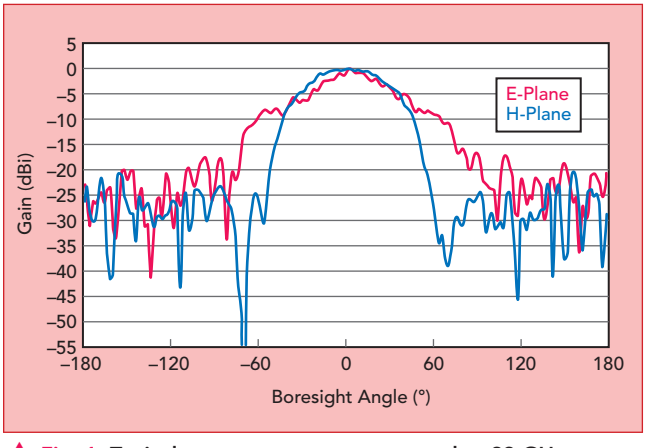

Fig. 1 Typical antenna patterns measured at 23 GHz.

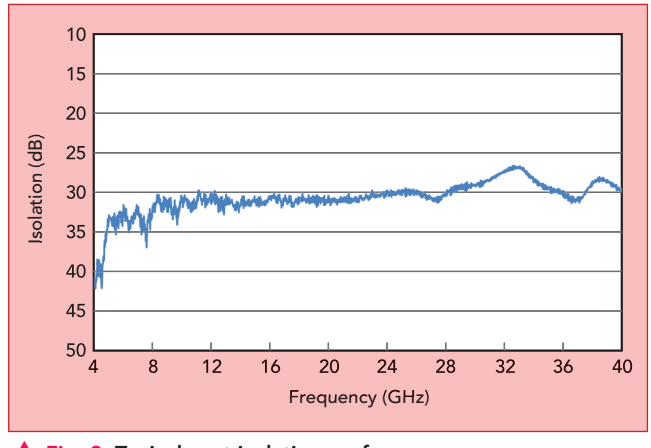

Fig. 2 Typical port isolation vs. frequency.

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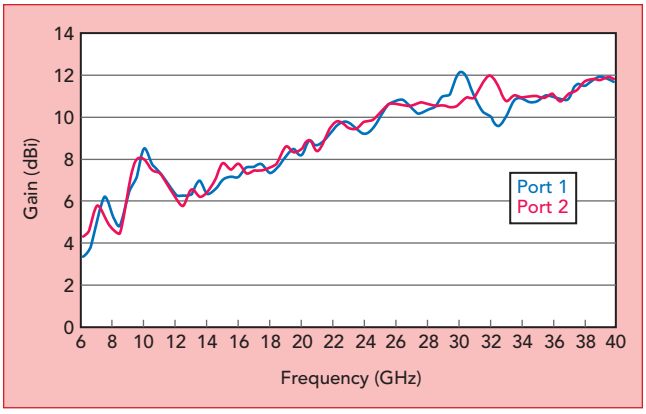

Fig. 3 **Typical antenna gain vs. frequency.**

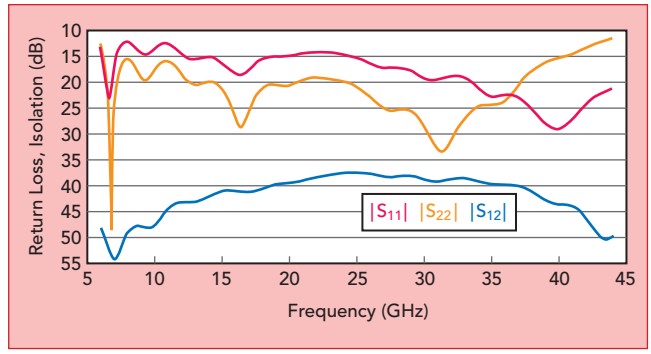

Fig. 4 **Simulated return loss and isolation vs. frequency.**

0234031009-KFKF-43, yields a circularly polarized antenna with both right-hand circularly polarized (RHCP) and left-hand circularly polarized (LHCP) ports (see ***Figure 5***). Arrays of antennas with this configuration can support MIMO communication systems that use environments rich in multipath propagation channels.

Dual polarized antennas can also contribute to the development of advanced radar sensors. When electrically reciprocal materials and components are used in an antenna that transmits a given polarization, the antenna is sensitive to received signals with the same polarization. This rule applies to any reciprocal antenna, regardless of polarization. To suppress co-polarized reflections, a cross-polarized (two-port) antenna system is required. Distances in confined spaces are commonly measured using a dual-port antenna that transmits and receives circularly polarized signals with orthogonal polarizations. Sidelobe responses that involve an even number of signal bounces, such as caused by container walls, are generally co-polarized relative to the transmitted signal and are suppressed by a receiver that is more sensitive to cross-polarized signals.

A radar system with cross-polarized transmit and receive channels can effectively suppress reflections from many types of background clutter that reflect co-polarized signals. Reflections from structures such as flat surfaces and trihedral corner reflectors exhibit an odd number of radar bounces, usually having adequate cross-

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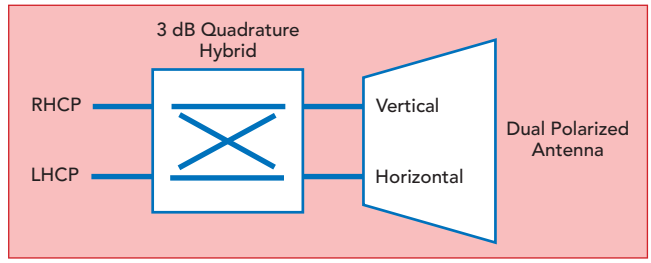

▲ Fig. 5 **Dual mode, circularly polarized antenna configuration.**

▲ Fig. 6 **OMT-based, circularly polarized antenna.**

polarized radar cross-sections. Objects having complex shapes often exhibit similar responses for both co-polarized and cross-polarized antenna configurations, making clutter identification and suppression possible. Separate transmit and receive antennas are often used to coherently receive both co-polarized and cross-polarized radar signals in various combinations. Both RHCP and LHCP signals are transmitted and received, yielding four distinct radar measurements. This arrangement enables advanced signal processing to dynamically suppress clutter-generated signals while enhancing target responses.

Although quad-ridge horn antennas often provide low-cost solutions adequate for many situations, some applications require antennas tailored to specific levels of performance. Eravant offers hundreds of antennas, enabling system developers to find the best match for unique requirements. Many communication links depend on dual polarized antennas having high gain with low sidelobes and low levels of cross-polarization. Eravant's family of lens-corrected and Gaussian optical, dual polarized antennas are often suitable. Offerings include at least 60 models covering the waveguide bands from 17 to 170 GHz, with gain from 22 to 48 dBi. Cross-polarization is typically better than -25 dB. Cassegrain antennas offer high gain, typically 50 dBi at frequencies from 33 to 50 GHz using reflectors with diameters of 48 in. (128 cm). They are well-suited for many long-distance communication links and radar sensors. For applications requiring exceptional cross-polarization, low sidelobes and flat gain, Eravant has many dual polarized, waveguide horn antennas fed using orthomode transducers (OMT). Cross-polarization and port isolation are typically 40 dB or better, with gain from 10 to 50 dBi (see ***Figure 6***).

Eravant carries a comprehensive selection of antennas to serve many applications in instrumentation, communication, radar and remote sensing, with frequency coverage spanning the entire 5G spectrum, well into THz.

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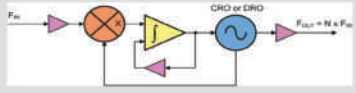

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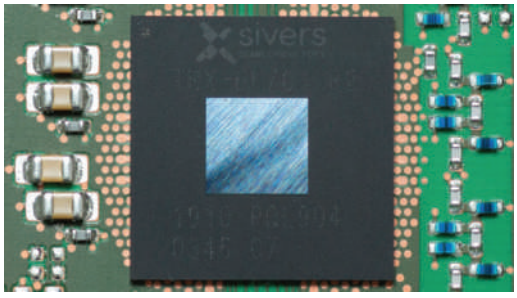
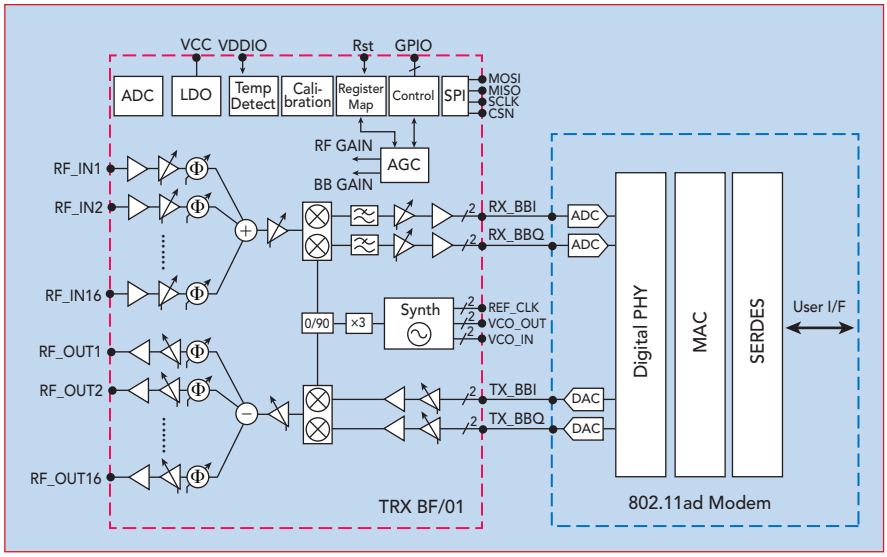


16 Channel Beamforming Transceiver RFIC Covers the Full 57 to 71 GHz Unlicensed Band

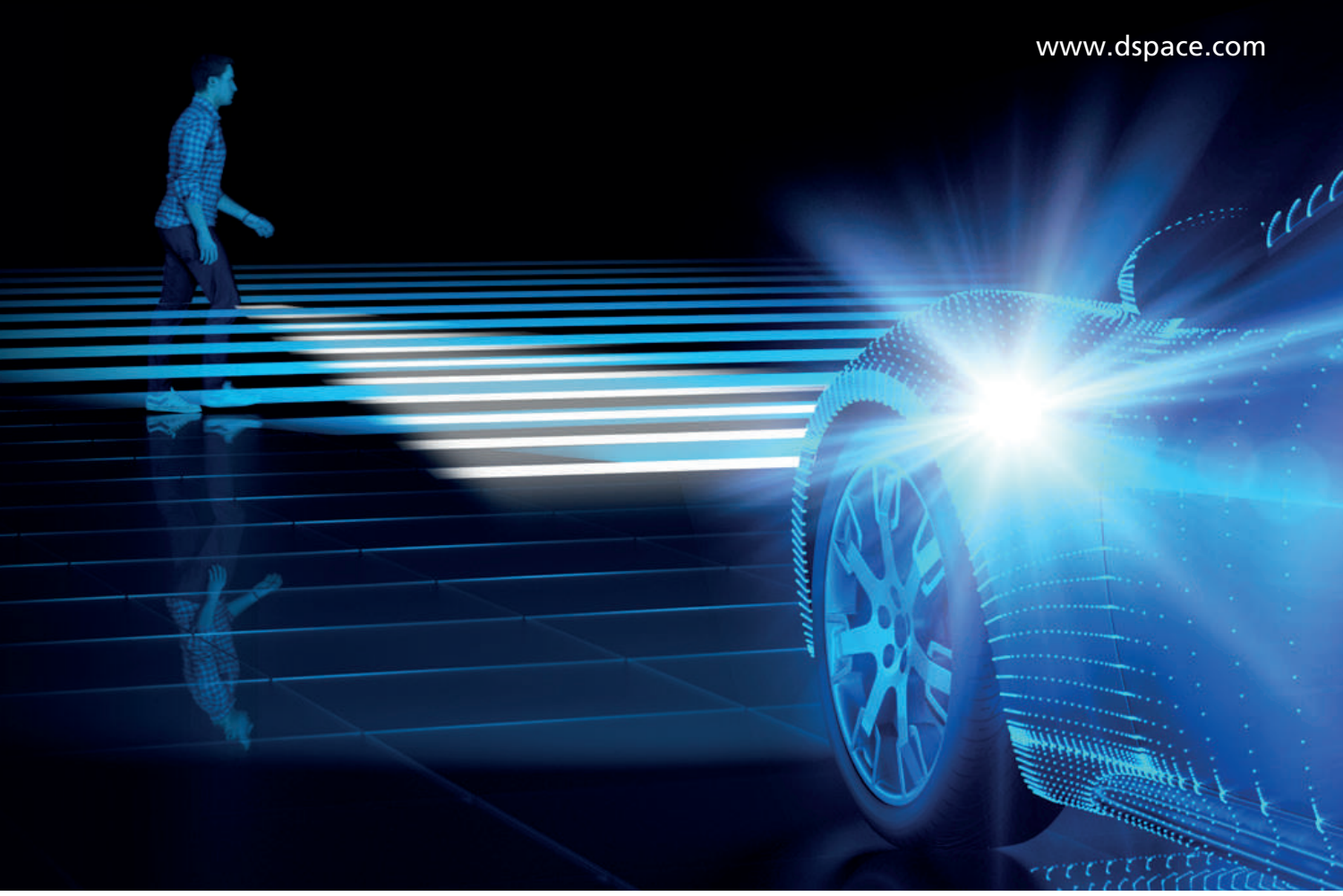
Sivers Semiconductors
Kista, Sweden



▲ **Fig. 1 802.11ad transceiver combining the TRX BF/01 RFIC with a separate modem.**

Sivers Semiconductor's TRX BF/01 transceiver RFIC targets applications using the unlicensed 60 GHz band, primarily fixed wireless access (FWA) systems using the 802.11ad and 5G NR-U, TDD standards (see ***Figure 1***). The transceiver was developed based on robust requirements for the product to be used outdoors, the typical FWA deployment, with consistent performance across the full temperature range, -40°C to +85°C.

The TRX BF/01 uniquely supports the full 60 GHz unlicensed band, from 57 to 71 GHz. Combining flat performance across this 14 GHz bandwidth, including high output power and excellent linearity, the TRX BF/01 is well-



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suited for current broadband applications and future unlicensed 5G NR use cases (see ***Table 1***). The EVM and integrated synthesizer's phase noise are good examples of the excellent performance: with > 10 dB better phase noise than any comparable RFIC currently on the market, the TRX BF/01 supports 256 QAM, which enables 10 Gbps over-the-air links using a single channel.

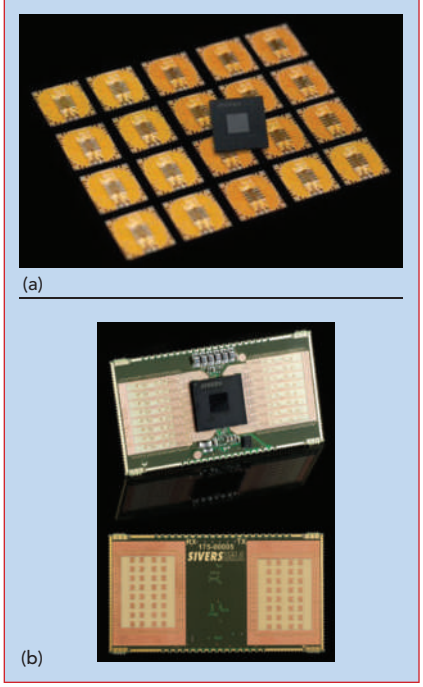
802.11ad compliant, the TRX BF/01 RFIC is highly integrated, including all necessary building blocks from the baseband interface to the 16 RF transmit and receive channels, including control signaling and beam handling capabilities. Comparing the TRX BF/01 with other RFICs, the TRX BF/01 was designed to operate with any available baseband solution having a zero IF or low IF interface. Because of this approach, most calibration routines are executed without needing baseband resources. It also shows Sivers' experience and capability to integrate the RFIC with baseband alternatives.

In a FWA system with a point-to-multipoint (PmP) configuration, the cost and resources of the central node or access point (AP) should be shared among as many users or customers as possible. The number

TABLE 1

TRX BF/01 PERFORMANCE SUMMARY

Parameter	Typical
Frequency Range	57–71 GHz
P_{out}	> 10 dBm per path > 22 dBm, 16 Combined Paths
Channel Spacing	2.16 GHz
Noise Figure	7 dB
EVM (Rx and Tx)	-27 dB
Power Dissipation - Low-Power Mode - High-Power Mode	Rx: 3.6 W, Tx: 4.6 W Rx: 4.3 W Tx: 5.9 W
Power Supply	Analog: 3.1–3.3 V Digital I/O:1.65–2.0 V
Tx EIRP	> 42 dBm with 20 dBi Gain Antenna



▲ Fig. 2 The TRX BF/01 can be supplied as individually packaged ICs (a) or integrated with antennas on a board, such as the BFM06009 (b).

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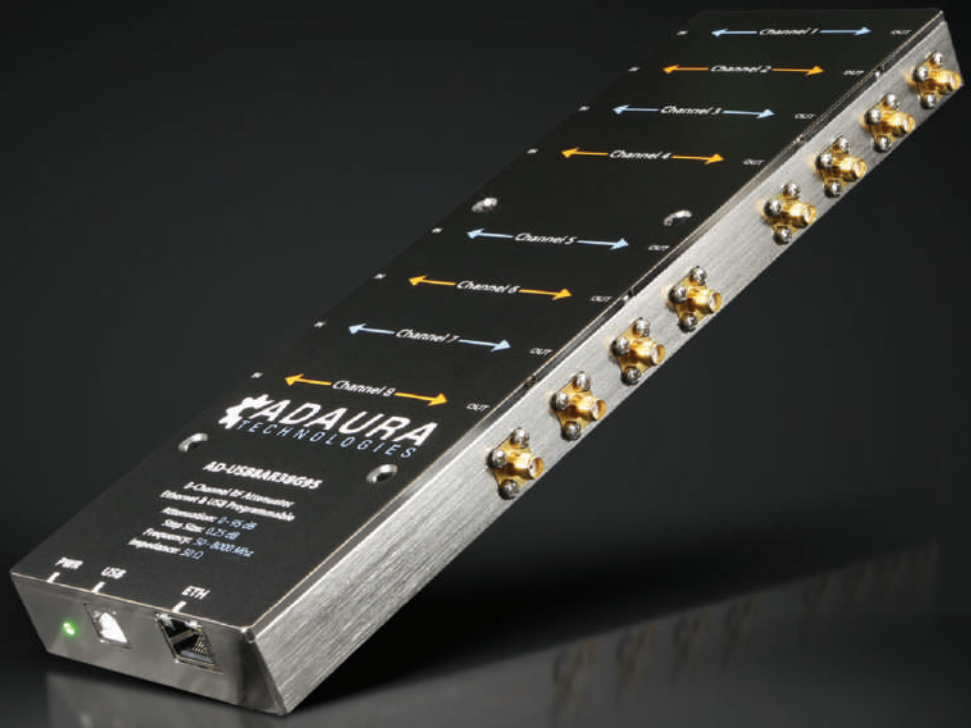

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of connected customer units (CPEs) in a PmP system is often limited by the size of the "beam book" and the capabilities of the baseband modem. To reduce system cost, Sivers designed the beam book of the TRX BF/01 to support up to 30 CPEs connected to the same AP.

Today, the most mature and advanced commercial baseband is the Renesas RWM6050/6051 modem IC. It has unique features such as interference mitigation and support for ½ and ¼ channels for enhanced deployment flexibility. A system combining the Renesas or comparable modem with Sivers high performance transceiver RFIC will be differentiated by its performance, flexibility and robustness.

Sivers provides system developers with two options for using the TRX BF/01, either as a standalone packaged IC or integrated with antennas in a board-level module optimized for large FWA deployments, like the BFM06009 (see ***Figure 2***). Sivers will design custom antenna modules for specific applications, so system designers can use the capabilities of the TRX BF/01 and tailor the antenna performance to their own requirements. This flexibility combined with the consistent performance of the TRX BF/01 adds value to system implementations. For example, the integrated synthesizer on the RFIC can be disabled to use an external VCO, which can be used when tiling several RFICs into larger arrays or using the RFIC in a radar application using a frequency sweep waveform.

The TRX BF/01 is in mass production and used in several applications, including FWA, broadband "track-to-train" links, indoor backhaul for Wi-Fi APs and transmission of multi-Gbps uncompressed medical data.

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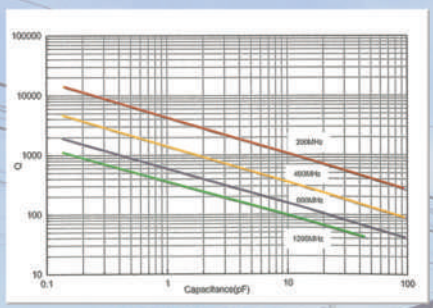
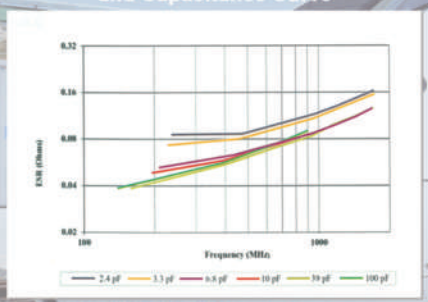


DLC70A(0505) Q Value and Capacitance Curve



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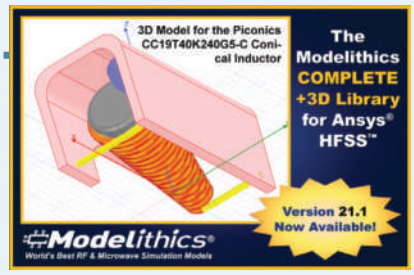

Modelithics Expands COMPLETE+3D Library for Ansys HFSS

The recent update to the Modelithics® COMPLETE+ 3D Library for Ansys® HFSS™ contains an extensive number of measurement-based models for components from many popular vendors. Version v21.1 now includes over 325 highly scalable Microwave Global Models™ for capacitor, inductor and resistor families, with a collection of nearly 400 3D models for inductors, capacitors, resistors, filters, packages and connectors—totaling more than 22,000 individual components in the library.

Developed by Modelithics, the Microwave Global Models are advanced circuit models that are part value scalable, i.e., a single model covers the full range of part values for a vendor component series, making the models well-suited for tuning and optimization during simulation. The Microwave Global Models also scale with respect to the solder pads and substrate used for the next level of assembly.

Several of the new Microwave Global Models in v21.1 of the Modelithics COMPLETE+3D Library are the 1) AVX 1206xC capacitor series, validated to 20 GHz; 2) Taiyo Yuden HKQ0603S, HKQ0603U and HKQ0603W inductor families, with each model validated to 50 GHz; and 3) TDK CGA1A2C0G, CGA1A2X7R and CGB1T3X5R-0J104M capacitor families, each validated to 50 GHz.

Another benefit of the Modelithics COMPLETE+3D Library is the collection of full-wave, 3D electromagnetic (EM) models. In v21.1, 3D EM models were added for the QFN4424-0522 package from Barry Industries and three conical inductors from Piconics. These models are validated to mmWave frequencies, enabling them to be designed into 5G, satellite ground terminal, point-to-point radio and other high frequency systems.

Request a trial of the full Modelithics COMPLETE+3D Library or a vendor trial at the Modelithics website.

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For applications requiring more channels, Spectrum offers the StarHub clock and trigger distribution system. This option enables up to 16 different M2p-series cards—digitizers, arbitrary waveform generators or digital I/O cards—to share a common clock and trigger. A single system with 512 fully synchronized digital I/O channels is possible, and synchronization to other devices is realizable using a direct external clock or the reference inputs.

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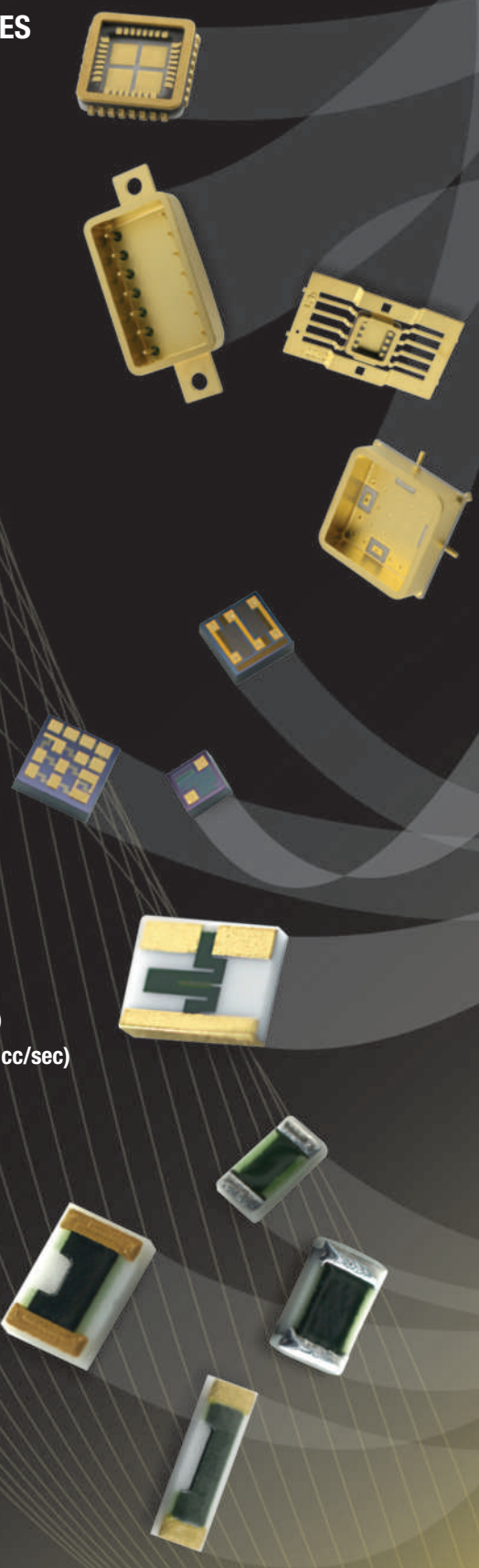

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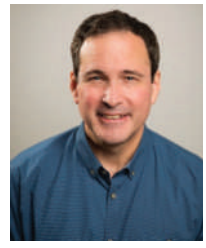

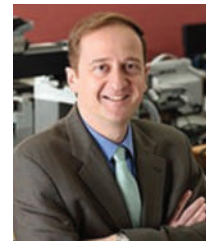

IMS2021 will certainly be a different experience than in past years. Our theme, "Connecting for a Smarter, Safer World," could not be more appropriate. First, we should explain that IMS2021 is really two events: live, in-person in Atlanta, 7-10 June at the Georgia World Convention Center (GWCC), and virtual 20-25 June. Attendance is expected to be somewhat down in Atlanta due to travel restrictions, vaccine schedules and other difficulties. But we applaud the ~200 companies who will be exhibiting this year live in Atlanta. Many of our non-U.S. authors and exhibitors cannot make it to live event, and we have consolidated our technical sessions to include a mix of live and virtual presenters. However, we have a full program planned for the virtual event!

For those able to attend the live event it is business as usual, except for an abundance of caution and safety measures that will be in place to minimize the risk of exposure. The IMS2021 GWCC venue in Atlanta (see ***Figure 1***) was the first facility in the U.S. to achieve the Global BioRisk Advisory Council's GBAC Star™ Accreditation, which recognizes facilities that implement the industry's highest standards of cleaning for COVID-19. Session rooms will be limited to about one forth capacity, and we have worked with Horizon House to layout the exhibition floorplan to allow wider aisles for proper social distancing (see https://ims-ieee.org/exhibition). We will follow all State of Georgia, City of Atlanta and Center for Disease Control and Prevention guidelines for facemasks and social distancing. Room layout will accommodate social distancing and will be sanitized between sessions. There will be contactless registration and hand sanitizer stations as well.

Fig. 1 **Georgia World Congress Center.**

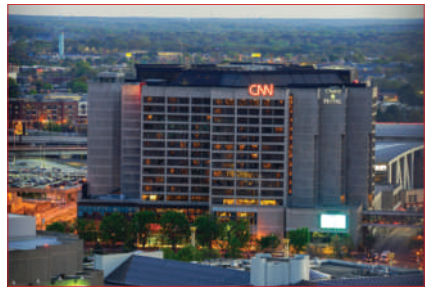

Fig. 2 **Omni Hotel, Atlanta, Ga.**

All Social Events will be held either at the Omni Hotel (see ***Figure 2***), headquarters hotel, or the GWCC to avoid transportation on crowded buses. Hand sanitizing stations will be located in all event rooms and distributed throughout the Omni, the GWCC and other event hotels. We have also confirmed Chief Technology Officer and Senior Vice President at Texas Instruments Dr. Ahmad Bahai and Chief Technology Officer of Honeywell Suresh Venkatarayalu to present their thoughts in the future of wireless sensing, connectivity and control at the plenary session in the Sydney Marcus ballroom that will be a joint IMS and RFIC plenary session.

In planning the virtual event, we have certainly benefited from the knowledge gained by the IMS2020 Virtual symposium, and the heroic efforts of that year's steering committee led by Tim Lee. However, we are expanding our investment in the virtual event experience by contracting vFairs and will use their

virtual platform that is tailored for large events. The vFairs platform will enable virtual attendees to view and hear pre-recorded papers. It will also allow interaction with the authors via a chat room, as well as networking between individuals and small groups via chat and video conferencing. Exhibition attendees will be able to enter a virtual booth and interact live with exhibitors to hear about the latest microwave products and technologies.

We are planning six parallel technical sessions, 35 workshops, three technical lectures, as well as MicroApps and Industry Workshops. Except for the plenary session and select other sessions to be live-streamed, the virtual event will follow the live event by two weeks. This is done out of the logistical necessity of managing the two events separately. But it allows attendees from all over the world to have on demand access to any Microwave Week event in which they are registered. Attendees at the live event are also eligible to attend the virtual event for free to see all of the sessions and workshops they might have missed.

The MTT Society has also recognized that things will not go back to "normal" after the COVID pandemic is under control. It is expected that the "new normal" will include a virtual component for future symposiums, and this is already under planning within an MTT-S Ad Hoc committee chaired by Nuno Borges Carvalho. So, in a way, IMS2021 serves as a pilot for future Microwave Week events that will include a virtual component.

We hope to see many of you here in Atlanta for IMS2021! We urge you to take advantage of the low early bird prices for the live event by June 4. For those not able to travel, we understand and hope to see you at the IMS2021 virtual event following the live event. It will certainly be a memorable event as some of us gather for the first time in more than a year. Please visit the IMS2021 website (https://ims-ieee.org) for more details and updates.

Stay safe!
Steve and John

THE HYBRID 2021 RFIC SYMPOSIUM

Brian Floyd, Osama Shana'a and Donald Y.C. Lie, RFIC2021 General Chairs

The IEEE RFIC Symposium (RFIC) is the premier annual forum focused exclusively on presenting the latest research results in RF, mmWave and wireless integrated circuits. RFIC is part of Microwave Week, the world's largest RF and microwave technical symposium. This year, to maximize our community's ability to participate, we are organizing the symposium as a first-ever hybrid event with both in-person and virtual symposiums, the same as IMS2021. Our plans for both events continue to evolve, where our goal is to ensure safe, informative, interactive and effective events for all participants.

The in-person RFIC Symposium has been merged with the in-person International Microwave Symposium (IMS). They will take place in Atlanta, Ga. at the Georgia World Congress Center on Monday through Wednesday, 7-9 June 2021. The event starts with a complimentary workshop program on Monday covering key topics in RF and mmWave technology. On Monday night, there will be a plenary session followed by a welcome reception at the Omni Hotel. Two outstanding industry leaders will give the plenary talks—Dr. Ahmad Bahai, the chief technology officer from Texas Instruments, will discuss "New Horizons for Millimeter-wave Sensing" and Mr. Suresh Venkatarayalu, the chief technology officer from Honeywell, will discuss new directions for his industry. Technical sessions will be held on Tuesday and Wednesday in parallel tracks featuring RFIC and IMS authors who elect to attend in person. Finally, the IMS technical exhibition opens on Tuesday and runs through Wednesday.

All RFIC technical sessions will be held on Tuesday in parallel tracks. Since some authors will only participate in the virtual event, the RFIC presentations will include a mixture of in-person and pre-recorded talks. The schedule for the live talks will be optimized to maximize attendees' ability to see in-person content and updates will be communicated to attendees over the IMS app. During lunch on Tuesday, live and remote panelists will debate the topic "Are RFIC Startups a Dead Horse in the Era of Software Unicorns and Pandemics?" This should help both students and aspiring entrepreneurs understand the evolving RF startup landscape in today's economy. Finally, RFIC attendees are encouraged to also attend the IMS exhibition on Tuesday and Wednesday, along with the technical sessions.

The virtual RFIC Symposium will be open to both in-person and virtual registrants, the virtual event will start two weeks after the in-person event, running from Sunday, 20 June through Friday, 25 June as with IMS. Attendees will use the same online platform, vFairs, to access all content and interact with others. All presentations, workshops, lectures and panels will be live-streamed by presenters throughout the week and then available on demand afterward. Most sessions are scheduled to begin at 10 am EDT to maximize the ability for attendee participation from around the world. A separate joint RFIC/IMS plenary is planned for the virtual event on Monday, 21 June 2021, again featuring two prominent speakers—Dr. Bram Nauta, distinguished professor from the University of Twente, the Netherlands, presenting his "Transceiver Roadmap for 2035 and Beyond" and a second talk from IMS still to be confirmed.

The core RFIC technical sessions will be held on Tuesday, Wednesday and Thursday, 22-24 June, in parallel tracks. For each live-streamed session online, there will be time devoted to real-time questions and answers. Virtual educational offerings include a technical lecture and multiple workshops. The technical lecture is a tutorial intended for newcomers and practicing designers alike. This year's lecture is from Dr. Peter Asbeck, professor at the University of California, San Diego and member of the U.S. National Academy of Engineers. He will teach "A Quick Tour Through the World of Si IC Power Amplifiers." Live-streamed RFIC workshops

are scheduled for Friday, 25 June, covering a variety of topics ranging from mmWave phased arrays to power amplifiers, low-power radios and quantum computing. Additionally, we will have two live-streamed panels, the first on the topic "Are RFIC Startups a Dead Horse in the Era of Software Unicorns and Pandemics?" and the other on the topic, "Automotive Radars and Artificial Intelligence (AI): Is My Car Really Safe?" This will provide an interesting debate related to the roles of RF circuits and AI in enabling autonomous driving. Finally, we will feature a new systems and application forum at the virtual event to highlight short videos of RFIC authors' circuit and system demonstrations.

On behalf of the RFIC Steering and Executive Committees, we welcome you to join us at the hybrid 2021 RFIC Symposium either in-person at Atlanta or online in our virtual platform. If you are a student, we encourage you to consider the student super pass for accessing all events throughout the week. Please visit the RFIC 2021 website (http://rfic-ieee.org/) for more details and updates.

ARFTG AT IMS2021 MICROWAVE WEEK

Marco Spirito, Basim Noori, Jeffrey Jargon and Jon Martens, ARFTG General Chairs

ARFTG, the microwave measurements conference, once again joins IMS and RFIC for an instructive and interesting Microwave Week. ARFTG also participates in a number of co-sponsored and other activities during the event to further cover the area of high frequency measurements. As with the other conferences, ARFTG is planning on a hybrid event with a combination of in-person and virtual content and will adapt accordingly with other changes in Microwave Week.

For the in-person event, ARFTG's more relaxed schedule gives attendees more opportunities to interact directly with colleagues, experts and vendors from the RF and microwave test and measurement community. Whether your interests include high-throughput production or specialized metrology, complex systems or simple circuit modeling, small-signal S-parameter or large signal nonlinear measurements, simpler passive measurements or complex integrated converter analysis, DC or near-optical frequencies, you will find colleagues interested in similar areas and there is often an expert attending the ARFTG conference (see ***Figure 3***).

The extended breaks at every ARFTG conference allow for detailed technical discussions with others facing similar test and measurement challenges. On Thursday, 10 June, ARFTG plans to host a separate, supplier exhibit focused on the measurement industry in a more congenial setting (see ***Figure 4***). Given the informal and friendly atmosphere, ARFTG attendees often find these interactions to be an excellent source of ideas and information for their projects. Often, someone at ARFTG has already worked through and solved the same problem you are having.

Among the other ARFTG-related events, ARFTG is co-sponsoring a workshop with IMS2021 entitled "Calibrated Testbeds for the Characterization, Optimization and Linearization of Multi-Input Power Amplifiers," which is scheduled to be held on Monday, 7 June and with online availability of the content. There will also be a joint IMS/ARFTG technical session that covers additional important results. See the full IMS technical program for more details. As with IMS and RFIC, the majority of the technical program, including all of the conference talks, will be available in a virtual form two weeks after the in-person event.

Additionally, ARFTG hosts several users' forums that are open to all. For IMS2021, there will be a nonlinear VNA users' forum that discusses the latest techniques and advances in nonlinear measurements and large signal network analysis and an on-wafer users' forum that deals with issues related to high frequency on-wafer measurement techniques, calibration and theory. Both events are planned to be held on the afternoon of Thursday, 10 June and, at this time, are planned on being available virtually.

Fig. 3 **An ARFTG conference technical session (courtesy of Lyle Photos).**

Fig. 4 **A combined vendor exhibit and interactive forum session allows for discussions on many relevant measurement topics (courtesy of Lyle Photos).**

The main one-day ARFTG conference, where four oral technical sessions take place in a single-track format, is planned for Thursday, 10 June. The theme of the conference is "Conducted and OTA Measurement Challenges for Urban, Rural & SatCom Connectivity." Papers on topics related to a number of connectivity-related activities will be presented. Also included will be papers in other areas such as nonlinear studies, calibration and de-embedding, on-wafer analysis and mmWave/THz characterization. A series of invited talks will highlight areas related to the theme and will open many of the sessions.

Integrated within the technical program is a student paper competition to recognize outstanding work in the measurement arena. As last year, ARFTG is a part of the Three Minute Thesis (3MT®) competition along with IMS and RFIC. 3MT® finalists are selected from eligible students and young professionals following acceptance of their papers and subsequent video submissions.

If you are interested in measurements from kHz to THz and beyond, be sure to add the 2021 ARFTG con-

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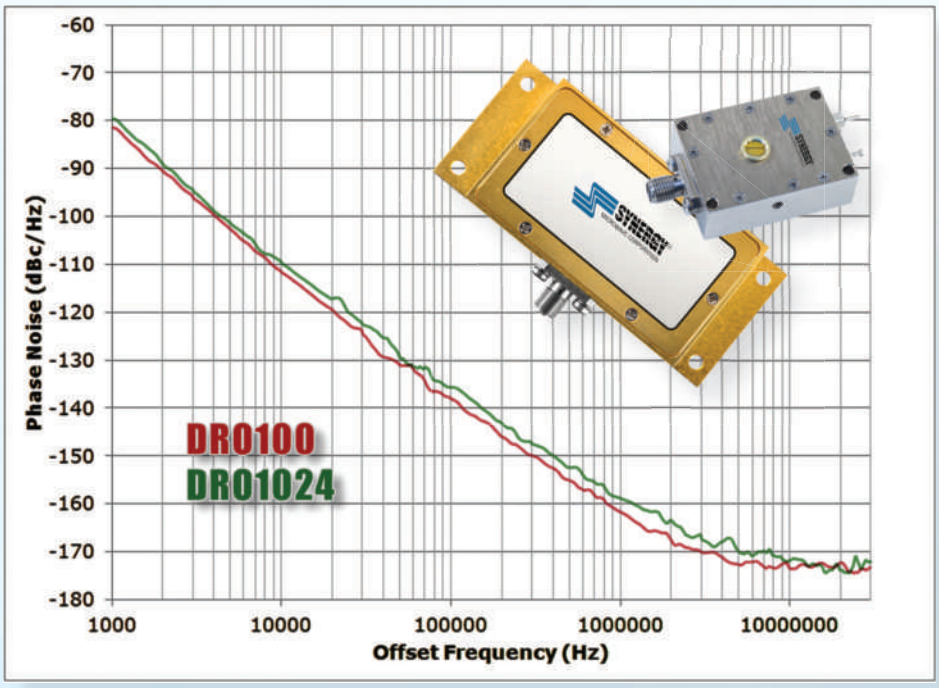

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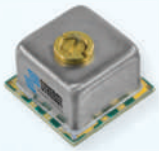

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SDRO900-8	9.000	1 - 10	+8.0 @ 25 mA	-112
SDRO1000-8	10.000	1 - 15	+8.0 @ 25 mA	-107
SDRO1024-8	10.240	1 - 15	+8.0 @ 25 mA	-105
SDRO1118-7	11.180	1 - 12	+5.5 - +7.5 @ 25 mA	-104
SDRO1121-7	11.217	1 - 12	+5.5 - +7.5 @ 25 mA	-106
SDRO1130-7	11.303	1 - 12	+5.5 - +7.5 @ 25 mA	-106
SDRO1134-7	11.340	1 - 12	+5.5 - +7.5 @ 25 mA	-107
SDRO1250-8	12.500	1 - 15	+8.0 @ 25 mA	-104
Connectorized Models				
DRO80	8.000	1 - 15	+7.0 - +10 @ 70 mA	-114
DRO8R95	8.950	1 - 10	+7.0 - +10 @ 38 mA	-109
DRO100	10.000	1 - 15	+7.0 - +10 @ 70 mA	-111
DRO1024	10.240	1 - 15	+7.0 - +10 @ 70 mA	-109
DRO1024H	10.240	1 - 15	+7.0 - +10 @ 70 mA	-115
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ference to your plans in Atlanta, or virtually thereafter, in June. You will find our atmosphere informal and friendly, which enhances interactions and provides opportunities for you to learn new ideas and discuss your own ideas with colleagues. For more information about these programs, see the ARFTG website (www.arftg.org).

CONNECTED FUTURE SUMMIT AT IMS2021

Debabani Choudhury, Connected Future Summit Committee Member

The 5G Summit event has been held during IMS since its inception at IMS2017 in collaboration with IEEE Communications Society (Comsoc). The event provides a platform for academic and industrial communities to interact and exchange technology ideas related to technologies of 5G and beyond. The 5G Summit committee is part of the IMS Technical Program Committee and is responsible for selecting timely topics and inviting speakers to create an agenda. This event has been getting sponsorships from industry with encouraging attendance every year ranging from about 300 to 400 attendees.

In addition to the technology advancements with 5G and beyond (toward 6G), the wireless connectivity landscape is changing rapidly with the evolution of Wi-Fi and the broadband wireless satellite network based on Low-Earth Orbit satellite constellations. The 5G standardization, deployment and R&D of next generations are impacting the future directions of connectivity in coordination with beyond Wi-Fi 7 technologies, broadband satellite networks like Space-X Starlink and Amazon Kuiper as well as autonomous vehicle-to-everything (V2X) networks (see ***Figure 5***). As the 5G deployments are being planned, IMS2021 will host the "Connected Future Summit," replacing the "5G Summit" to create a new platform that discusses various connectivity technologies and applications, as well as the coexistence of different wireless standards to enable a safer and smarter world.

As IMS2021 is a hybrid event, the technical program committee is planning for a virtual program in addition to the usual live in-person sessions at the GWCC in Atlanta. The "Connected Future Summit" will be held virtually in June. The planned Connected Future Summit at IMS2021 will review core technologies for future wireless networks along with their human and societal impacts. The day-long program will feature experts from industry and academia sharing technical knowledge and strategies with the summit attendees. The topics will include future trends of 5G and beyond; standardization of both cellular (3GPP) and Wi-Fi Alliance; broadband wireless with satellite constellations; V2X technology with beyond 5G; semiconductor technologies, front ends, system architectures, test and measurement challenges impacting

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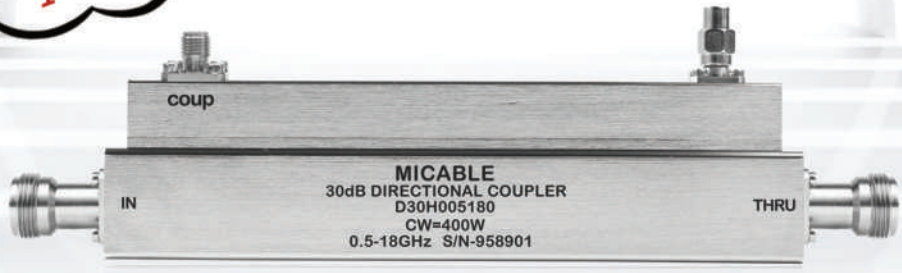
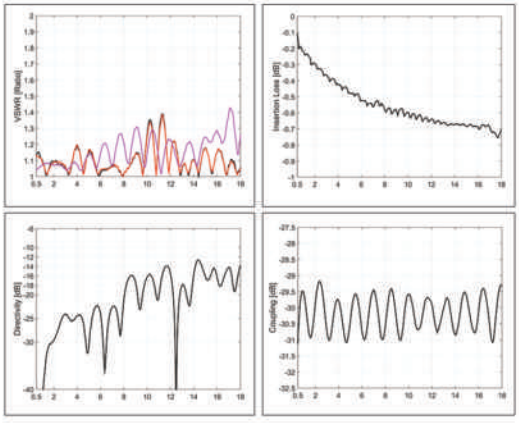


Test Curve of D30H010180



Frequency Range (GHz)	P/N	Coupling Max.(dB)	Main Line VSWR Max.(:1)	Coupling VSWR Max.(:1)	Insertion Loss* Max.(dB)	Flatness Max.(dB)	Directivity Min.(dB)	Power Max.(W)	Unit Price** (USD)
0.5-6	D30H005060	30±0.7	1.3	1.3	0.6	±1	15	600	1276
	D40H005060	40±0.8	1.3	1.3	0.6	±1.1	15	600	1276
0.5-18	D30H005180	30±1.2	1.5	1.6	1	±1.2	10	400	1899
	D40H005180	40±1.2	1.5	1.6	1	±1.4	10	400	1899
0.7-6	D30H007060	30±0.7	1.3	1.3	0.5	±0.9	15	600	1195
	D40H007060	40±0.7	1.3	1.3	0.5	±0.9	15	600	1195
1-6	D30H010060	30±0.7	1.3	1.3	0.5	±0.9	15	600	1073
	D40H010060	40±0.7	1.3	1.3	0.5	±0.9	15	600	1073
1-18	D30H010180	30±1.2	1.5	1.6	0.8	±1	10	400	1417
	D40H010180	40±1.2	1.5	1.6	0.8	±1	10	400	1417
2-6	D30H020060	30±0.7	1.3	1.3	0.4	±0.7	15	600	931
	D40H020060	40±0.7	1.3	1.3	0.4	±0.7	15	600	931
2-8	D30H020080	30±0.8	1.4	1.4	0.4	±0.7	14	600	1033
	D40H020080	40±0.8	1.4	1.4	0.4	±0.7	14	600	1033
2-18	D30H020180	30±1.0	1.5	1.6	0.6	±0.8	10	400	1215
	D40H020180	40±1.0	1.5	1.6	0.6	±0.8	10	400	1215
6-18	D30H060180	30±1.0	1.5	1.6	0.5	±0.7	10	400	972
	D40H060180	40±1.0	1.5	1.6	0.5	±0.7	10	400	972

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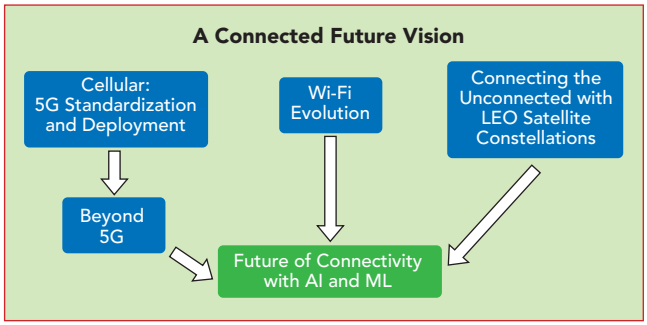

next-generation connectivity evolution. Please join the Connected Future Summit to learn about the future of connectivity!

◀ Fig. 5 **The future of connectivity.**

WOMEN IN MICROWAVES – CELEBRATING CONNECTIVITY AT IMS2021

Rhonda Franklin, IMS2021 WIM Event Chair

The IEEE MTT-S's Women in Engineering invites all women working in high technology and/or attending educational programs or interested in the field to attend the virtual 2021 Women in Microwaves (WIM) event. It will be held during the virtual IMS2021 event to provide the broadest access. The conference will be presented in a hybrid form with an in-person meeting on 7-10 June in Atlanta and a virtual meeting starting 20 June (https://ims-ieee.org/FAQs). See https://ims-ieee.org/ under "Menu" for evolving development of details and speakers.

Over 25 years ago, about 15 women and men gathered in a small hotel conference room to meet and commune. Before COVID, over 100 people gathered annually at receptions and panels to catch up and discuss critical topics to support, develop and advance the careers of WIM. Women at all stages of their careers come together to bond and support one another, interact with other supportive members of the microwave community and talk to women leaders from academia, business, industry and government from around the world.

This year we will highlight women's contributions to the advancement of connectivity as technologists, researchers, leaders and educators. There will also be conversations with women leaders on their vision for addressing emerging societal problems around connectivity and important emerging fields that will enhance connectivity. We will wrap-up with recommendations of best practices to support the careers of WIM members, to grow WIM membership and to engage WIM members in the leadership roles in the profession and IEEE MTT Society. If time permits, a few questions from the audience will be taken. All are welcome to join our event. If you are interested in getting more information about the event, go to https://forms.gle/VYnvm4f2NcZ3gFmF9.

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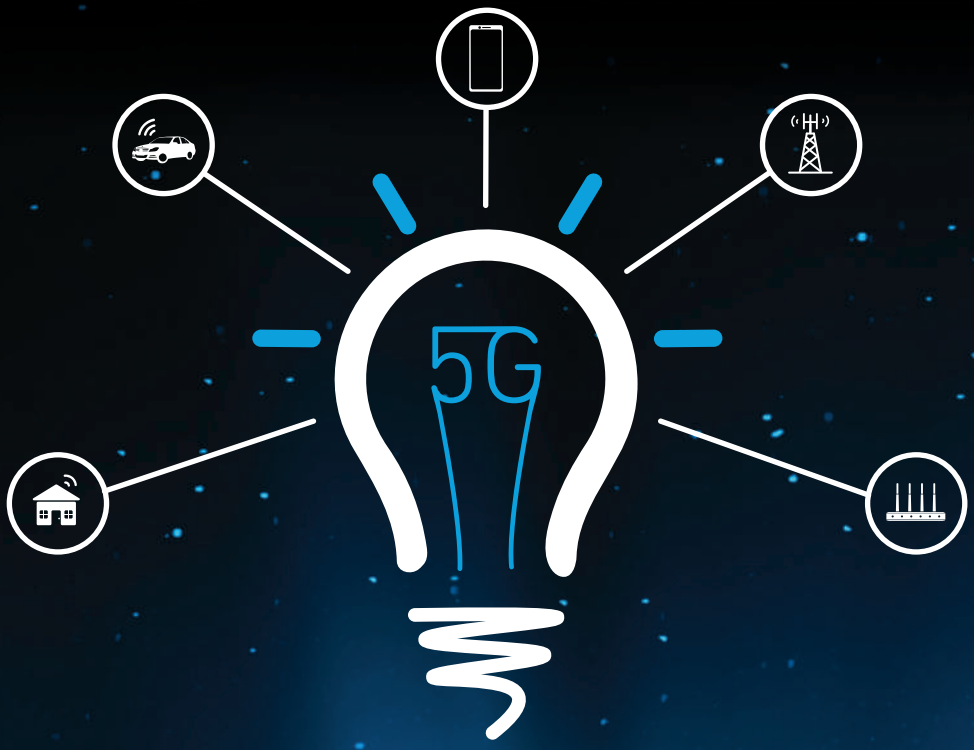

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IMS2021 EXHIBITION

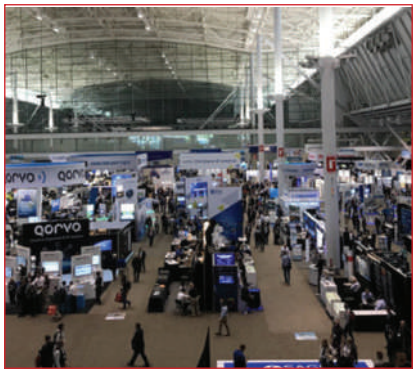
Horizon House, Exhibition Management Company

The IMS2021 exhibition in Atlanta will feature approximately 200 companies from the RF and microwave industry showing off the latest product and service innovations (see ***Figure 6***). The exhibition will take place in-person at the GWCC and online during the virtual event two weeks later. The in-person exhibition will be Tuesday and Wednesday, 8-9 June, starting at 09:30 each day closing at 17:00 and 18:00, respectively.

The virtual exhibition will take place in parallel to the technical sessions with separate halls for different categories of products so they will be easy to navigate through, depending on your products/services of interest. Newly added this year will be exhibitor sessions covering various technical topics given by industry experts. Please be sure to check out the virtual booths and exhibitor presentations to learn about new products and service offerings in our industry.

The IMS2021 committee and event management teams are doing everything they can to make IMS2021 the best event possible and are committed to presenting a conference and exhibition that addresses the health and safety considerations so essential in our current environment. The IMS2021 venue in Atlanta, the Georgia World Congress Center, (GWCC), was the first facility in the U.S. to achieve the Global BioRisk Advisory Council's GBAC Star™ Accreditation, which recognizes facilities that implement the industry's highest standards of cleaning for COVID-19. The organizers are working closely with the GWCC, their partners and event consultants to adhere to currently advised health and safety precautions. Special precautions are being taken from special cleaning procedures to extended spacing of booths in the exhibition hall to reduced capacity in the conference rooms to keep all in-person attendees safe.

Remember that if you register by 4 June and attend in-person, you will get the same level of registration in the virtual event at no addition cost. We hope to see as many people in-person as possible at IMS2021 but if we do not see you there, we will virtually see you two weeks later.



▲ Fig. 6 **IMS2019 exhibition floor.**

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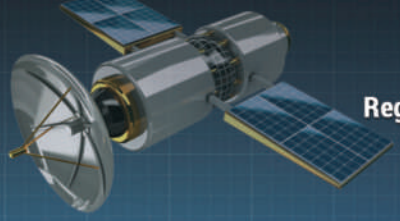

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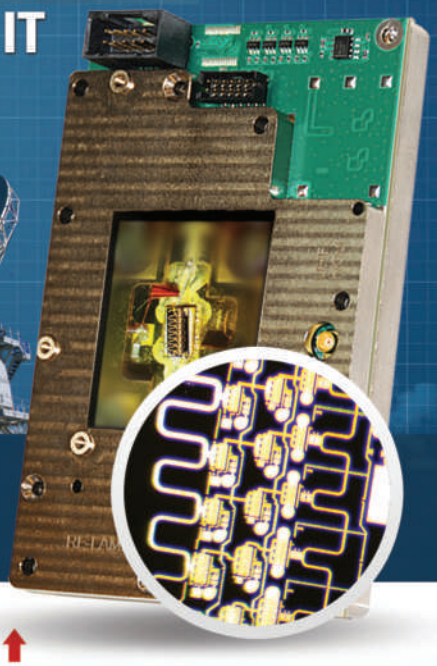

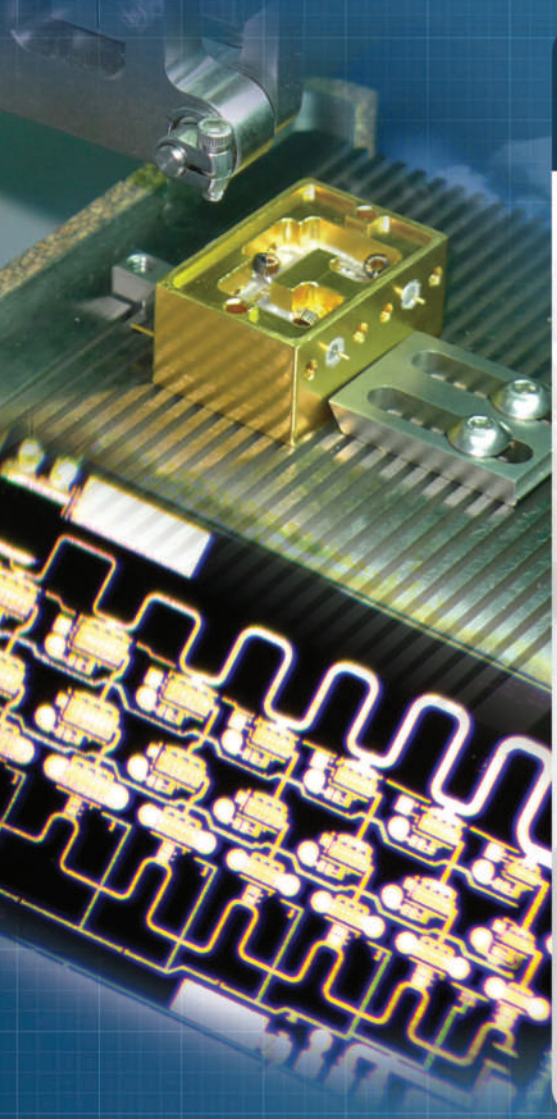

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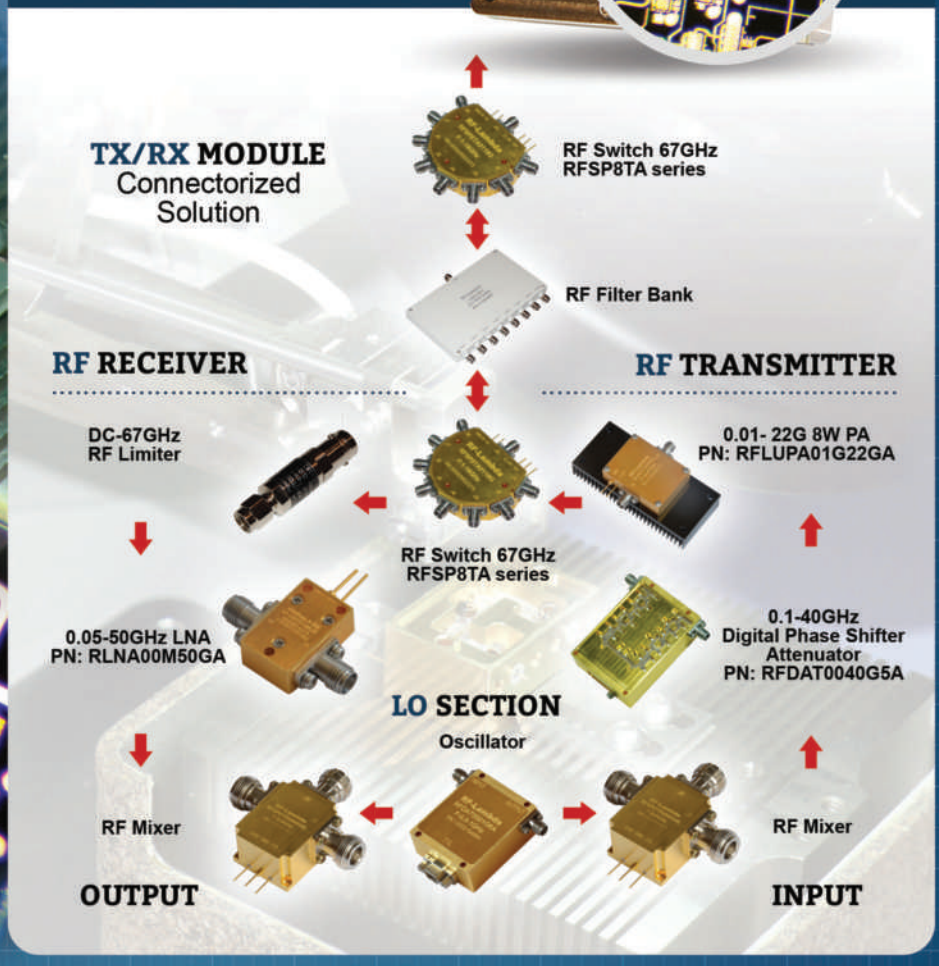

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All information is current as of 4-20-2021

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For an up-to-date exhibitor list, please visit https://ims-ieee.org/.
The virtual IMS event will take place 20-25 June.

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- Joint IMS/RFIC Plenary Session
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- Three-day exhibition
- IMS and RFIC Workshops and Technical Lectures
- Panel Sessions, including RFIC and IMS Panels
- Special focused highlights, including WIM Panel Session; Mobility Closing Panel with Competition results and 3MT Competition
- Industry workshops and MicroApps
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- Connected Future Summit (formerly 5G Summit)
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Agile Microwave
Power Amplifier

Agile Microwave's new power amplifier AMT-A0560 features 27 to 31 GHz, 10 W, 40 dB gain, +48 V single supply, linear and saturated output power and a compact size with 2.92 mm connectors. It is ideal for 5G and satellite communications. Check out our full collection of power amplifiers.
www.agilemwt.com

Altum RF
Linear Power Amplifier

Altum RF's ARF1010Q4 is a 22 to 30 GHz linear power amplifier designed for high data-rate applications. Delivering 28 dB of linear gain and 38 dBm OIP3, it is well-suited for demanding, high-order modulation schemes such as mmWave 5G or satcom. The ARF1010Q4 draws 600 mA from a 4 V DC supply with positive gate voltage. This RoHS compliant part is internally matched to 50 Ω with ESD protection in a 4 × 4 mm QFN package.
www.altumrf.com

American Microwave Corp.
Hermetically Sealed Switch

VENDORVIEW

Presenting the latest product development from American Microwave Corp., AMC Model No: MSN-0518-25T-30DB-HERM-1JV. This is an absorptive/non-reflective SP25T hermetically sealed switch. This product has an integral 30 dB coupler on its common port and uses a combination of suspended and strip line substrate design. Switch control configuration is via encoded 5-bit TTL inputs and latched by the use of dual rail strobe. For more information, please contact American Microwave Corp. by phone at 301-662-4700 or by email at sales@americanmic.com.
www.americanmic.com

AmpliTech Inc.
Ultra-Low Noise Figure LNA

AmpliTech introduces an ultra-low noise figure LNA for 5G and quantum computing applications. It is a 7 × 7 mm QFN package and features an unparalleled noise figure of 45 K typical at 296 K. It has a wide operating frequency of 5.5 GHz to 9.5 GHz optimized for use below 4 GHz with low DC power dissipation. The QFN LNA can be cryogenically cooled to 4 K, perfect for 5G MIMO phased array antennas, quantum computing and space qualified LEO satellite front ends.
www.amplitechinc.com

AnaPico AG
APVSG Series VSGs

AnaPico launched its APVSG series VSGs, with frequency ranging from 10 MHz to 40 GHz and a modulation bandwidth of 400 MHz. The APVSG has very low phase noise (-125 dBc/Hz at 10 GHz and 20 kHz offset), high harmonic, subharmonic and spurious suppression (> 50 dBc), short switching time (200 ns), etc. The AnaPico proprietary Fast Control Port allows for high speed inter-operation between the APVSG engine and external instruments. The multi-channel APVSGs feature excellent phase coherence and relative frequency stability.
www.anapico.com

API Technologies Corp.
RF & Microwave Amplifiers

Guaranteed high performance in a low-cost package. RF and microwave amplifiers from APITech, a leader in amplifier technology, and your full service partner for high performance amplification requirements. APITech has a broad range of amplifier solutions of high frequency designs, high-power models, low-cost selections and lower phase noise amplifiers. API offers both standard and custom high-volume designs, with both exceptional value and outstanding performance. Explore the full product line and ask for your copy of API's amplifier selection guide.
www.apitech.com

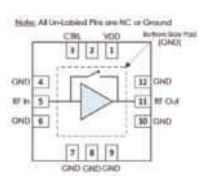
AR RF/Microwave Instrumentation
Solid-State Amplifiers

VENDORVIEW

The 60S1G6 provides a minimum of 60 W across its full operational band. The low spurious signals and high linearity levels make the 60S1G6 ideal for use as a driver amplifier in testing wireless and communication components and sub-systems. It is also suitable for EMC test applications where class A amplifiers are desired.
www.arworld.us

Atlanta Micro
Bypassable Gain Block

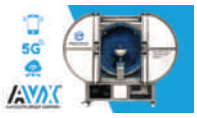
VENDORVIEW



Atlanta Micro has introduced the AM1101, a wideband bypassable

amplifier covering the 2 to 26.5 GHz frequency range. The device exhibits low noise figure and flat gain across the entire frequency range while drawing only 100 mW of power. Packaged in a 3 mm QFN with an integrated amplifier bypass path and internal 50 Ω matching, the AM1101 represents a dramatic size reduction over a discrete implementation of a bypassable amplifier.
www.atlantamicro.com

AVX
mmWave Measurement System

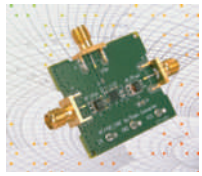


The AVX mmWave measurement system uses a maximum RF wave guide instead of RF cables to minimize the RF losses; therefore, maximizing the native pure dynamic (without amplifier) of the measurement system. Many interfaces and accessories are available and can be changed in a few seconds allowing several users to share the chamber. Passive (efficiency, radiation patterns) and active (TRP/TIS) measurements for several protocols, including 5G, are available. The mmWave measurement testing chamber's cost-effective design and speed make it an excellent tool for device development.
www.avx.com

BSC
Filter Bank Technology

This 2 to 18 GHz example with 8 simultaneously selectable equal bandwidth filters allows up to 256 different filter states be generated covering lowpass, highpass, bandpass and notch responses. Sub 100 nsecs switching speed make this ideal for high speed electronic warfare (EW) preselector applications to reject on-platform or external interferes on a dynamic pulse by pulse basis. With nominal 0 dB gain and low NF the technology can be modified for channel count and channel bandwidths, please enquire.
www.bscfilters.com

Cadence
IC Through System Level Design



Cadence equips engineers developing wireless products for 5G, radar and automotive applications with high-capacity simulation, multi-physics analysis and design interoperability with the Virtuoso, AWR Design Environment® and Allegro® PCB platforms. Cadence's booth will showcase its latest innovations that address IC through system level design (chip, package and board) inclusive of EM and thermal analysis, specifically Clarity™ 3D Solver, Celsius® Thermal Solver and EMX® Planar 3D Solver, for large-scale systems.
www.cadence.com

CAES
Advanced Electronics

VENDORVIEW

Visit the CAES booth to learn more about the company's pioneering advanced electronics for the most technologically challenging systems. As the largest provider of mixed-signal and radiation-hardened technology to the U.S. aerospace and defense industry, CAES delivers high-reliability RF, microwave and mmWave, microelectronic and digital solutions that enable a safer, more secure planet. On land, at sea, in the air, space and cyberspace, CAES' electronics and enhanced manufacturing capabilities are at the forefront of mission-critical innovation.
www.cobhamaes.com

Cernexwave
Waveguide Circulators

VENDORVIEW

Cernexwave's CWC Series high-power waveguide circulators are a great solution for directing signals of any strength. They are made to fit your project requirements with small to very large frequency bands and power levels into the kilowatts. The precision internals provide low insertion loss low and high isolation while the robust aluminum construction keeps temperature levels manageable.
www.cernexwave.com

Charter Engineering Inc.
5G RF Switches

CEI introduces a new series of RF switches operating from DC to 40 GHz utilizing 2.92 mm female connectors. The switches feature outstanding characteristics in insertion loss of 0.6 dB maximum and return loss of 1.50:1 maximum. The highly repeatable RF switches are targeted to 5G applications and are available in a variety of configurations including failsafe, latching and normally open.
www.ceiswitches.com

Ciao Wireless Inc.
Amplifiers

Standard models include units with instantaneous bandwidths covering 10 MHz to 6.0 GHz and 24 to 43 GHz (designs for 52 GHz available), to support both the uplink/downlink bands for 5G NR. Designs are available with O/P levels up to +33 dBm P1 dBPT and functions including detectors, switched/RF

bypass (TTL), variable gain (digital and VVA) or full rack mount with Ethernet control. Multiple gain levels from 10 dB and up are available, typical noise figures in the 3 to 5 dB range.
www.ciaowireless.com

CTT
GaN-Based 630 Watt SSPA

The SSPA operates at 9.4 to 9.9 GHz, within 8 to 12 GHz (X-Band). With 630 W of pulse power output in a compact package, this SSPA is designed for—and currently operating in—multifunctional LEO small satellite and airborne synthetic aperture radar systems. Model AGN/099-5860-P offers small signal gain of 60 dB minimum and noise figure is +10 dB. The amplifier measures 6.17 (L) × 6.35 (W) × 0.82 in. (H) and weighs less than 2 lbs.
www.cttinc.com

Dow-Key Microwave
SPDT PCB Mount Switches

Dow-Key Microwave produces many compact SPDT PCB mount switches. The 409 series unit, which can be mounted directly on an electronic board, is ideal for military, ATE and commercial applications that require higher power handling and proven capability in severe environmental conditions 0.1 to 6 GHz. Its compact packaging occupies only 310 mm² of printed circuit board area to meet high density mounting requirements.
www.dowkey.com

dSpace
Radar Target Simulator

4D radars provide detailed images of the radar's surroundings with a wide view, including elevation, distance and speed information. Tests of these radar sensors place high demands on the capabilities and bandwidth of the radar target simulator (RTS) used. The dSPACE automotive radar test system (DARTS) 9040-G is the first RTS to successfully meet these challenges. DARTS 9040-G is designed and optimized for all next-generation automotive radars (e.g., imaging radars, 4D radars).
www.dspaceinc.com

Empower RF
Solid-State Tri-Band Amplifier
VENDORVIEW

Empower RF Model 2198 is a solid-state tri-band amplifier in a single 3U chassis and is ideal for general purpose lab and production line test applications. With user selectable modulation and power output modes this amplifier integrates easily into any test system and simplifies test setups with selectable AGC and ALC modes. The amplifier is ready to go out of the box with its built in browser GUI so there's no software to install for PC or LAN control.
www.EmpowerRF.com

Eravant
VNA Frequency Extender
VENDORVIEW

STO-10203-U6 is a W-Band vector network analyzer (VNA) frequency extender that extends VNA frequency range to 75 to 110 GHz for full two-port, S-parameter testing. It is compatible with modern VNAs such as the Anritsu VectorStar, Rohde & Schwarz ZVA24, Copper Mountain CobaltFx C4220 and Keysight PNA-X Series. Meantime, the companion high performance calibration kit, STQ-TO-10-S1-CKIT1, is offered to complete the W-Band VNA test set.

Analyzer Calibration Kit

STQ-TO-10-S1-CKIT1 is a metrology grade, W-Band calibration kit designed for industry standard network analyzers. It consists of one fixed short, one fixed matching load, three waveguide shims (1/8 λg, ¼ λg, 3/8 λg offsets), two waveguide quick-connects, 10 waveguide screws, one waveguide screwdriver and one calibration data USB drive. NIST calibration traceable certs can be offered with additional fee. The kits to cover 26.5 to 325 GHz are also available under various models.

Coaxial Attenuator

SCA-03-1M1F-S1 is a 1 mm connectorized 3 dB coaxial attenuator to cover the frequency range of DC to 110 GHz. The attenuator has a typical attenuation value of 3 dB with a flatness of ±1.5 dB. The power handling of the attenuator is +27 dBm and typical return loss is 10 dB. Other attenuation values, such as 6, 9 and 12 dB are offered under different model numbers, respectively.

Connectorized Amplifier

SBB-5039532510-1M1M-S1 is a broadband amplifier with a typical small signal gain of 25 dB, a nominal P1dB of +10 dBm and a typical noise figure of 7 dB across the frequency range of 50 to 95 GHz. The 1 mm connector offers wideband performance across multiple waveguide bands. Wider bandwidth and different gain etc. are offered under various model numbers.

Waveguide Quick-Connect

The Waveguide Quick-Connect is designed and manufactured for quickly connecting and disconnecting the standard round flanges by implementing the use of easy turning hand screws. It is also designed for setups where tight spaces do not allow for the use of standard waveguide screw connections. Two models, SWH-QC-0750C-R2 and SWH-QC-1125C-R2, are offered to make any WR-22 and higher standard waveguide flange quick connections.

Phase Locked Oscillator

SOP-24310113-KF-BB is a high performance DRVCO based oscillator that generates a clean high-quality signal at 24 GHz with +13 dBm output power. The oscillator works on 100 MHz internal reference and has an option to synchronize with 10 MHz external reference source. The oscillator is hermetically sealed to offer the maximum environmental performance. Various models are offered to cover 1 to 32 GHz range.

www.eravant.com

Exodus Advanced Communications

AMP6034-Suite with Synthesizer

VENDORVIEW

Exodus AMP6034 series is unique. Exodus Innovation now provides optionally integrated synthesizer and calibrated power metering functions with a new attractive 7" color-touchscreen. These features are ideal for 5G, communications testing, EMI-Lab and other applications. The AMP6034's are robust Class A/AB designs providing excellent gain flatness, low noise figure and low harmonics for all modulations and industry standards.

www.exoduscomm.com

Gowanda Components Group

Broadband Conicals

Gowanda's newest broadband conical series—surface-mount C070SM and flying lead C070FL—offer inductance from 0.165 µH to 1.050 µH, DCR ohms from 0.08 to 1.50, current rating mA DC from 150 to 625, and they meet TML requirement of 1.0 percent maximum per ASTM E595 outgassing test. The C070FL coil is just 0.07" long. These conicals are designed for use in broadband communication: bias T's, high frequency, microwave circuitry, RF test setups, test and measurement and transmission amplifiers. Visit us at the GCG booth #1129.

www.GowandaComponentsGroup.com

HASCO Inc.

Adapter Kit

VENDORVIEW

HASCO, Inc., a global supplier of RF components, announces their new 1.85 mm adapter kit as part of their growing line of adapters and kits. The 185ADPK features 30 high performance adapters, available in both in-series and between series. The new 1.85 mm adapter kit offers a convenient and reliable solution for RF test engineers and system designers. HASCO's full line of adapter kits, including the 1.85, 2.4, 2.92 and 3.5 mm kits are available in-stock, ready to ship daily.

www.hasco-inc.com

HYPERLABS INC.

Ultra-Broadband Bias Tees

HYPERLABS INC. has expanded its line of ultra-broadband bias tees having bandwidths extending from 35 kHz to over 67 GHz. These devices can be used to apply or monitor a DC voltage on a high speed data or RF signaling. The models HL9447, HL9547 and HL9647 offer current ratings of 175, 400 and 1,000 mA, respectively. The devices show consistent performance over all current operating ranges. The insertion loss across models is between 1.25 to 2 dB across band. Demos available upon request.

www.hyperlabsinc.com

JQL Technologies Corp.

MINI-SMT Circulators

VENDORVIEW

JQL Electronics introduces the new series of MINI-SMT circulators for both 5G and radar applications. The industry's smallest SMT X-Band circulator with 0.205" (5.2 mm) diameter delivers impressive up to 200 W pulse power handling. It is an ideal component for high-power radar. JQL's MINI-SMT family also includes the smallest 0.276" (7 mm) circulator for 3.4 to 3.6 GHz tailored for 5G MIMO antenna. Custom design MINI-SMT isolators/circulator is available from 800 MHz to 40 GHz.

www.jqltechnologies.com

K&L Microwave

Space Qualified Cavity Filter K&L Microwave's 5CSP-1703/X6-T/T-FLT is a space qualified cavity filter specifically designed for satellite applications. Low passband insertion loss of 0.75 dB from 1700.5 to 1705.5 MHz contributes to the power handling capability. Rejection at 1,600 and 2,000 MHz reaches 85 dB minimum. CST and Spark 3D were used to verify the multipaction performance at 28 watts input power and 1X10-5 TORR, actual testing confirmed the multipaction requirement. The compact package measures just 4.9 (L) x 3.22 (W) x 1.9 in. (H), plus TNC connectors.

www.klmicrowave.com

KRYTAR

Dual Directional Coupler

VENDORVIEW

This directional coupler lends itself to wireless designs and many test and measurement applications for emerging mmWave and 5G markets. Model 510046010 exhibit excellent 10 dB coupling within a broadband frequency range of 10 to 46 GHz (X- through Q-Bands). KRYTAR couplers offer solutions for many applications including EW, commercial wireless, satcom, radar, signal monitoring and measurement, antenna beam forming and EMC testing environments. The compact package measures 2.24 (L) × 0.40 (W) × 0.62 in. (H) and weighs 2.0 ounces.

www.krytar.com

LadyBug Technologies

RF & Microwave Power Sensor

VENDORVIEW

On display for demonstration at IMS 2021, booth 1649 is LadyBug's fully self-contained, thermally stable, LB5944A True-RMS power sensor. The sensor offers 44 GHz frequency coverage with an 86 dB dynamic range. Options 50 GHz. Optional autonomous mode has non-volatile storage for over 50 million measurements. Once setup, the sensor only requires power to make and store accurate NIST traceable measurements with no power meter or computer. Ask for a demonstration of our exclusive Unattended Operation at IMS2021.

www.ladybug-tech.com

LPKF

PCB Development Systems

LPKF's first ever desktop model with the compact tabletop format, the LPKF Proto-Laser ST, can be used in any laboratory for processing materials from FR4 to sensitive RF substrates. The laser system achieves exact geometries on almost any material and is ideal for creating single or double-sided circuit boards, antennas, filters and many applications where precise, steep sidewalls are required.
www.lpkfusa.com

Micro Lambda Wireless

Programmable Attenuators

Micro Lambda Wireless offers new programmable attenuators. Standard frequency models are available covering 10 MHz to 21 GHz and provide either 31.5 or 63 dB of attenuation over the full frequency range. Model MLAT-1000A 10 MHz to 21 GHz/31.5 dB attenuation. Model MLAT-1000B 10 MHz to 21 GHz/63 dB attenuation. Applications include wideband receivers, automated test systems, telecom, satcom, UAVs and drones and a variety of military and commercial test applications.
www.microlambdawireless.com

Milliwave Silicon Solutions

Phase Array Antenna Positioner

VENDORVIEW

MilliBox unveils GIM04: 4D mmWave and THz phase array antenna positioner. GIM04 features a unique three axis of 360-degree motions in azimuth, elevation and polarization planes. This positioner has a DUT capacity of 3 kg with a width of 27 cm. Equipped with four smart actuators and resolution as low as 0.01 degree, it is controlled by a simple USB interface and a software interface in python delivered in source for universal integration into any existing tool chain.
www.MilliBox.org

Mini-Circuits

Super-Wideband MMIC Mixer

VENDORVIEW

Mini-Circuits' MDB-653H-D+ is a MMIC double-balanced mixer die fabricated using InGaP HBT technology. This model functions as both an upconverter and downconverter for LO and RF frequencies from 20 to 65 GHz with an IF bandwidth from DC to 20 GHz. The mixer operates with +15 dBm LO power and provides 11 dB conversion loss, 45 dB L-R isolation and +20 dBm input IP3.

LTCC Filters

Mini-Circuits continues to innovate LTCC products to support mmWave applications. Recent releases include LTCC low pass filters with frequency cut-offs up to 32 GHz. These models use a proprietary material system with advanced distributed circuit topologies to offer outstanding high frequency performance with the ruggedness, repeatability and low-cost that have made LTCC parts so popular in lower frequency apps.

Mesh Network Simulation Racks

Mini-Circuits has developed a range of test racks that simulate mesh networks of 3 to N interconnected devices with independently variable attenuation on every path. This concept allows simulation of "real-world" mesh communication networks in the confined space of a production environment. Path loss can be varied independently between any pair of devices, simulating the effects of distance and interference without affecting any other paths. Number of ports, operating frequency range (up 40 GHz) and path attenuation range (up to 120 dB) can be tailored to specific test requirements.

Wideband Dual Directional Couplers

Mini-Circuits has expanded its product line with the ZDDC series of 2.92 mm connectorized dual directional couplers. The 13 new models provide wide bandwidths up to 40 GHz with coupling values of 10, 20 and 30 dB and excellent flatness vs. frequency. The couplers offer up to 20 W of power handling, low mainline loss and excellent in/out/coupled VSWR.

www.minicircuits.com

Morion

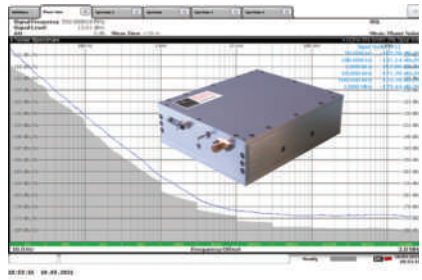
Dual Output Frequency OCXO

Morion's MV359 dual output frequency OCXO module MV359 is now available. The distinctive features of the MV359 include two frequency outputs: at 10 and 100 MHz, high temperature stability: up to ± $1E^{-9}$, a wide range of operating temperatures: -40°C to +80°C and an ultra-low level of phase noise (dBc/Hz).

www.morion-us.com

NEL

500 MHz Reference OCXO



Nel's 500 MHz reference OCXO features extraordinarily low phase noise and can be internally locked to precision 10 MHz with excellent temperatures stability and low aging. External reference is optional. Use this device for radar, advanced computing, instrumentation and COTS/dual use.

www.nelfc.com

Networks International

Thin Film Filters

Network's engineering expertise in high-reliability RF products and integrated assemblies includes a specialty in thin film filters that span from 1 to 20 GHz. These high performance filters are built on industry-standard substrates such as alumina and titanate, offering a compact package size with low profile of < 0.08 in. The filters also offer high selectivity and out of band rejection of > 60 dB. These filters can be customized to meet passband requirements from 1 to 60 percent and meet a wide range of environmental requirements as well.

www.nickc.com

Norden Millimeter

Custom Transceivers

VENDORVIEW

Norden designs custom transceivers for military and commercial applications including airborne, UAV and EW.

The "catalog" models provide wideband RF and up to 1.5 GHz IF with low phase noise. Norden can provide custom designs which incorporate temperature compensation, variable gain and meet military environmental requirements. Norden also offers models in a low-SWaP 3U VPX module which includes a built in LO. Norden engineers utilize proven designs to provide low risk, cost-effective solutions.
www.nordengroup.com

NSI-MI Technologies

Vector Field Analyzer Performance Suite

VENDORVIEW

NSI-MI Technologies introduces the vector field analyzer (VFA) Performance Suite. Using leading-edge technology, they have combined the best RF performance, fastest measurement speed and most advanced features available in the industry to create the foundation of a state-of-the-art measurement system. Measuring frequencies from 10 MHz to 1 THz at 16 million measurements per second, coupled with superior dynamic range and sensitivity, the VFA Suite significantly enhances flexibility and productivity for any RF measurement application.
www.nsi-mi.com

Passive Plus Inc.

PPI Hi-Q/Low ESR MLCC

PPI manufactures high performance RF/microwave passive components specializing in high-Q, low ESR/ESL multi-layer, broadband, single layer and trimmer capacitors, and non-magnetic thin film resistors for the medical, semiconductor, military, broadcast and telecommunications industries. PPI engineering team has extensive experience working with customers determining correct PPI components for their requirements. Known for their outstanding customer service, high-quality product line, competitive pricing, quick delivery times and strong technical support, PPI is committed to delivering their quality components as quickly as possible.
www.passiveplus.com

Planar Monolithics Industries (PMI)

Limiters

VENDORVIEW

PMI's limiters are available in a wide variety of models covering the DC to 62 GHz frequency range. These limiters offer low loss, high speed along with low leakage levels and high peak power handling. Key features/options include fast recovery; small size and standardized packaging; surface-mount or connectorized; form, fit and function designs; various connector options; hermetic sealing available and military, aerospace and space screened and qualified available. With every delivery, Swept Data is supplied with each unit.
www.pmi-rf.com

Pole/Zero

Tunable Bandpass Filters

Designed for handheld and manpack software defined radios, Pole/Zero's reduced SWaP-C next-generation MINI-ERF® tunable bandpass filters offer frequency coverage of 30 to 520 MHz, with +30 dBm in-band power handling, in a 1.0 × 1.0 × 0.5 in. (25.4 × 25.4 × 12.7 mm) package. The 7 percent 3 dB bandwidth configuration provides selectivity of 12 dBc at f_O ± 10 percent, +40 dBm IIP3 and 5 dB insertion loss, with tuning speeds of 20 µsec via SPI tuning control (all specifications are "typical").
www.polezero.com

Qorvo

Ultra-Low Noise Amplifier

VENDORVIEW

The QPL9058 is a high linearity, ultra-low noise amplifier in a small 2 × 2 mm surface-mount package. At 3.6 GHz, the amplifier typically provides 18 dB gain, +36 dBm OIP3 at a 55 mA bias setting and 0.6 dB noise figure. The LNA can be biased from a single positive supply ranging from 3.3 to 5 V. The device is housed in a green/RoHS compliant industry-standard 2 × 2 mm package. The QPL9058 is bias adjustable and requires minimal external components to operate.

www.qorvo.com

RelComm Technologies Inc.

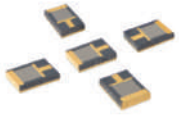
1P4T Coaxial Relay

RelComm Technologies, Inc. introduces 1P4T coaxial relay configured with '7-16 DIN' type connectors providing excellent RF performance to 3 GHz. Power rating is 4,000 W CW to 250 MHz, 1,400 W CW to 1 GHz, 1,100 W CW to 2 GHz and 900 W CW to 3 GHz. The relay measures 4.75 in.^{2} x 4 in. tall and weighs under 3.5 lbs. The relay is RoHS compliant with a standard DE9P or DB15P. It is available in failsafe or latching configurations with 12 and 28 V DC operation.

www.relcommtech.com

Res-Net Microwave Inc.

Diamond Power for Space



The CVD series of resistors, termination and thermal jumpers offers excellent power handling capabilities and frequency response to 30 GHz. The superior thermal properties of CVD diamond (high conductivity and low expansion) make these components ideal for pulsed power applications. The mechanical and electrical characteristics of these chips provide a robust solution for many aerospace and military applications, while its standardized production process keeps the cost competitive for commercial use.

www.resnetmicrowave.com

RFMW

Doherty MMIC Solution

VENDORVIEW

The Ampleon-BLM10D3438-70ABG is a three-stage, fully integrated Doherty MMIC solution for 3.4 to 3.8 GHz power amplifier designs. The Doherty configuration performs well with DPD, making it perfectly suited for mMIMO 5G applications in the N78 band. Using Ampleon state-of-the-art GEN10 LDMOS technology, it delivers > 30 dB of gain and 10 W average power from a 28 V supply. Carrier and peaking device, input splitter and output combiner are integrated in a 10 × 10 mm plastic package.

Minimize Radar Size and Weight

The QPA0007 reconfigurable MMIC power amplifier offers 35 W for 3.1 to 3.5 GHz, S-Band radar and 30 W for 9 to 11 GHz, X-Band radar applications. Offered in a 7 × 6 mm package, large signal gain is 21 dB in both bands. Dual band operation is time duplexed via control lines. Dual band operation along with small size and light weight, due to GaN technology, enables next-generation radar platforms for SWaP-C initiatives in ships, aircraft, space, mobile and portable systems. 24 to 28 V bias.

www.rfmw.com

Rohde & Schwarz GmbH & Co. KG

Vector Signal Generator

VENDORVIEW

The R&S SMM100A is the only vector signal generator with mmWave testing capabilities in the midrange class. It shows excellent RF characteristics across the entire frequency range from 100 kHz to 44 GHz, covering all bands used in LTE, 5G NR FR1, FR2 and the latest WLAN standards. The instrument offers a maximum RF modulation bandwidth of 1 GHz and a maximum output power of +18 dBm. Its excellent modulation frequency response, EVM and ACPR performance result in reliable, repeatable and accurate tests.

www.rohde-schwarz.com

Rosenberger

Aerospace, Security & Defence

Rosenberger provides a comprehensive product portfolio of high-reliable interconnect components and devices which is in accordance with the stringent requirements of MIL-PRF 39012, DIN EN 9100 or ESCC Certification of the European Space Agency. The wide product portfolio qualified for aerospace, security and defence applications includes: RF coaxial components, microwave components and cable assemblies, RF test and measurement products and fiber optic interconnect components. A brochure is available for download from the Rosenberger website.

www.rosenberger.com

Samtec

SMPM Solutions

Samtec has released a family of SMPM products designed to support demands

of emerging technologies where space is limited and a high operating frequency up to 65 GHz is required. Samtec offers ganged, multi-port solutions in both cable-to-board and board-to-board applications. Standard SMPM connectors with bullet adaptors, and cable assemblies using .047" and .086" cable, are also available and offer a maximum VSWR of 1.40 or better.
www.samtec.com

SignalCore Inc.
40 GHz Signal Source

The SC5520A and SC5521A are part of the ultra-high frequency synthesizer series of signal sources. They boast a frequency tuning range of 160 MHz to 40 GHz stepping at 1 Hz resolution, and an amplitude range of -10 dBm to +15 dBm typ with phase noise among the lowest in the market. These compact modules are ideal for system integration and appropriate for applications in communication transceivers, automotive radar, optics and as clocks in modern day digital data converters.
www.signalcore.com

Signal Hound
Spectrum Analyzer

Coming soon, Signal Hound's SM435B is a high performance spectrum analyzer and monitoring receiver tuning from 100 kHz to 43.5 GHz. This next-generation SM-series analyzer can capture a two second, I/Q block of 160 MHz instantaneous bandwidth, which is sent to the PC via an eight-second block transfer or continuous 40 MHz I/Q stream. Featuring 110 dB of dynamic range, 1 THz/sec sweep speed, ultra-low phase noise and PC-connection via USB3.0—the SM435B continues the Signal Hound tradition of unrivaled value.
www.signalhound.com

Signal Microwave
Edge Launch Connector

Signal Microwave's new line of higher performance edge launch connectors is designed for the thinner substrates used today. 1.15:1 maximum connector VSWR through 40 GHz (23 dB return loss). The data shown is for two connectors on a 1 in., 8 mil RO4003 substrate with an FR-4 backer. The new design of the connector is intended for substrate thicknesses

between 5 to 10 mil (0.005 to 0.010 in.), (0.127 to 0.254 mm).
www.signalmicrowave.com

Southwest Microwave

SuperMini Board-to-Board (SSBB)

Southwest Microwave's SuperMini board-to-board (SSBB) solutions are ultra-high frequency, miniaturized push-on blindmate connectors for high density PCB interface. The SSBB product line features advanced bullet and receptacle designs, accommodating misalignment of up to 10 mils axial or ± 10 degree radial with no performance degradation. The unique construction of the bullets extends mating and de-mating cycles and enables board-to-board spacing as close as 3 mm. Configurations include stacking, edge-mount, backplane and front panel applications.
www.southwestmicrowave.com

SV Microwave

Keyed SMA Cable Assemblies

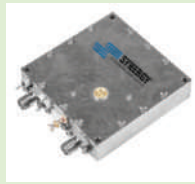
SV Microwave just released fixed length Keyed SMA cable assemblies that offer an ideal solution when polarization is required. These new Keyed SMA connectors are available in four unique keying configurations and are cabled to standard Ø.085" RF cables. This new self-aligning design offers more space savings than other bayonet style connectors.
www.svmicrowave.com

Synergy Microwave Corp.

Frequency Translator/Jitter Attenuators

The VFCTS series of frequency translator/jitter attenuator products combine phase locked loop circuitry with a stable low noise VCXO output signal, to significantly reduce jitter of the input reference and provide phase and frequency coherency to the external master reference. The product series is ideal for applications in higher frequency primary master reference signal or clock and multi-loop synthesizers used for higher frequency translation.

Phase Locked Dielectric Resonator Oscillators



The KSFLOD series of phase locked dielectric resonator oscillators deliver ultra-low noise signal purity with reduced power consumption and small size. A variety of frequency options is available for phase locking applications to the available external master reference and output signals. The series covers single CW output frequency starting at 6 GHz through 15 GHz fundamental, and up to 45 GHz multiplied.
www.synergymwave.com

Wenzel Associates Inc.

Card Assembly Frequency Sources

Wenzel Associates' offers card assemblies in several standard and custom form factors (VPX, VME, VXI, etc.) to provide low phase noise performance at frequencies up to 16 GHz for operation in static and dynamic environments. Each card assembly is comprised of an industry-leading ultra-low noise ovenized crystal oscillator (hard mounted or vibration isolated), frequency conversion circuits and other hardware mounted or integrated on a specified card assembly to provide a high performance frequency source with unparalleled phase noise performance.
www.wenzel.com

West Bond

Convertible Manual Wire Bonder

The West Bond ESD protected model 7KE convertible manual wire bonder interconnects aluminum, gold or copper wire leads to various semiconductor devices such as RF, microwave products, hybrids-MCMs, discrete devices-lasers chip-on-board, optoelectronic modules, sensors and more. Includes one convertible tool assembly to bond 45-degree feed wedge round wire, 90-degree feed wedge for round wire and flat ribbon and ball bond methods with a mechanical advantage using West Bond's 8/1 Ratio X-Y-Z Micromanipulator and pure orthogonal travel in X-Y-Z axis.
www.westbond.com

XMA Corp.

65 GHz Attenuators

XMA's 1.85 mm, 65 GHz attenuators equipped to withstand cryogenic temperatures and fully space qualified, XMA's 65 GHz attenuator family is the ideal solution for all high frequency needs. This attenuator has options for a gold-plated copper or stainless steel outer conductor, providing you with high-grade options regardless of your application. XMA's 1.85 mm attenuators have industry-leading VSWR values and come in all standard attenuation values. Contact sales@xmacorp.com for more details.
www.xmacorp.com

ERAVANT
FORMERLY SAGE MILLIMETER

MILLIMETERWAVE
PASSIVE CAMERA RADIOMETRIC RECEIVER

COMPACT | LOW NOISE FIGURE | HIGH GAIN | LOW COST | 75 to 110 GHz

SAGE Millimeter is now Eravant, a change that renews our commitment to the millimeterwave industry. Since 2011, we have been delivering quality products and energizing the customer experience to meet the needs of RF engineers working on the technology of the future.

SSR-9333534040-10-M4 is a low cost, compact W-Band radiometric receiver that can be used to measure the average physical temperature of any objects in the frequency range of 75 to 110 GHz. By averaging a large number of independent samples, this radiometric receiver can determine the average noise power with a fractional uncertainty. The receiver LNA has a typical gain of 40 dB with a typical noise figure of 4 dB. The receiver includes a high sensitivity Schottky diode detector with a 23 dB typical gain video amplifier.

The receiver is designed and manufactured for **passive image camera applications**. The RF port of the receiver is a WR-10 waveguide with a UG-387/U-M anti-cocking flange and the video output is a LEMO connector for high EM isolation. With various Eravant standard and custom antenna selections, many radiometric receivers can be formed and readily available.

NEW PRODUCTS

FOR MORE NEW PRODUCTS, VISIT WWW.MWJOURNAL.COM/BUYERSGUIDE
FEATURING VENDORVIEW STOREFRONTS

Adaura Technologies

Handover Test System AD-HTS8X8

The AD-HTS8X8 is a rack-mountable RF handover test system that can be controlled via USB or Ethernet. It features a total of 64 attenuation channels across eight inputs and eight outputs using common SMA or N-type connectors. With a robust attenuation range of 0 to 95 dB, a step size of just 0.25 dB, a wide operating frequency of 500 to 6,000 MHz and Ethernet POE, the AD-HTS8X8 is ideal for many RF testing applications.
www.adauratech.com

Amplical

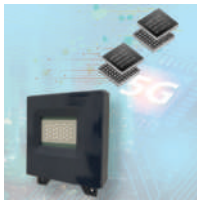
PIN Diode Switch

Amplical's SW8A004 SP8T 100 MHz to 20 GHz ultra-broadband absorptive PIN diode switch features low insertion loss, low VSWR, high isolation and fast switching speed. The switch operates from +5 V DC and a negative DC supply ranging from -12 to -20 V. The compact design incorporates field replaceable SMA female connectors which can be removed for drop-in microstrip or stripline applications used for 5G communications, radar and EW systems, as well as test equipment and simulators.
www.amplical.com

Anokiwave

5G Active Antenna Innovator Kits

VENDORVIEW



A complete 28 GHz mmWave to IF active antenna platform using Anokiwave's latest generation of ICs. The Innovator Kits provide an out-of-the-box starting platform to prototype, demo and proof of concept mmWave 5G radios, easily scale and develop new systems for any use case and evaluate array level performance of Anokiwave's ICs. The kits were 100 percent designed, developed and tested by Anokiwave and provide a tool to help customers accelerate their mmWave 5G radio developments.
www.anokiwave.com

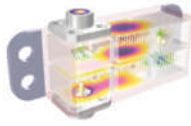
Besser Associates Inc.

RF Technology Certification

RF Technology Certification is an online course designed for professionals who need a solid background in RF and wireless technology and products. The four-part program provides the student with a thorough understanding of RF analytical tools, communication signals, RF devices and test instruments. The program was developed by Besser Associates, a worldwide leader in RF and wireless training.
www.besserassociates.com

COMSOL Inc.

RF Modeling Software



The latest advances in RF and microwave simulation are now available in the RF Module and Wave Optics Module add-on products to the COMSOL Multiphysics® software. New capabilities include port sweeps that enable faster computations of full S-parameter, transmission and reflection coefficient matrices. For periodic structures within metamaterials and plasmonic devices, a powerful new polarization plot tool makes the evaluation and visualization of transmitted and reflected waves significantly easier.
www.comsol.com

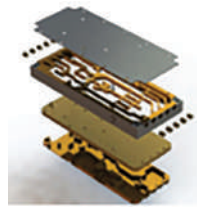
Comtech PST

Solid-State Power Amplifier Module

COMTECH PST has integrated a unique programable power control (ALC) feature into a custom designed solid-state power amplifier (SSPA) module. Normally found in larger systems, the ALC feature was redesigned for use in a SSPA module, supporting programable 1 dB step accuracy. The ALC depicted here in their 2 to 6 GHz, 75 W linear SSPA module is used for S- and C-Band datalink applications on UAV, fixed wing or rotary wing platforms where power accuracy is vital for mission success.
www.ComtechPST.com

Crane Aerospace & Electronics

RF Converter Miniaturization Using Multi-Mix®



This wideband RF converter assembly's package is less than 5" × 2" × 0.5". Offers 5x to 10x reduction over traditional converters, multi-layer multi-mix motherboard with double-sided SMT populated in a lightweight housing frame that provides excellent RF channelization and isolation, four integrated coherent wideband synthesizers, embedded pre-select frequency filters, fast tuning and settling times and low phase noise.
www.craneae.com

Custom Microwave

8 × 8 Non-Blocking Matrix

A 20 to 40 GHz frequency range makes model CMCI1150 switch matrix 5G ready. This solid-state non-blocking 8 × 8 matrix enables the connection of any of eight inputs to any combination of eight outputs. Intuitive browser graphical user interface, integral embedded processing unit server, easy to network, repeatable and reliable performance of solid-state. Applications include Ku- and Ka-Band RF signal routing and 5G system performance testing.
www.customwave.com

Exceed Microwave

WR10 Low Pass Filters

VENDORVIEW

Exceed Microwave now provides WR10 waveguide filters. LPF-W-95000-20000-12-10

passes 75 to 95 GHz with typical insertion loss of 0.6 dB, 15 dB return loss and 60 dB rejection at 110 GHz.
www.exceedmicrowave.com

Fairview Microwave

Double Ridge Waveguide Components

VENDORVIEW

Fairview Microwave's double ridge waveguide components consist of 28 models that include WRD-180, WRD-650 and WRD-750 sizes. These transmission line components deliver superior RF performance, cover wider frequency bands and offer lower cut-off frequencies compared to conventional rectangular waveguide sizes. The product options include double ridge straight sections, bends and twist configurations as well as a series of double ridge waveguide-to-coax adapters. Fairview's double ridge waveguide components are in-stock and are available for same-day shipping.

www.fairviewmicrowave.com

Fujian MIcable Electronic Technology Group Co. Ltd

High-Power Directional Coupler

Model D30H002005 is a 30 dB high-power directional coupler, it has 1.2:1 maximum main line VSWR, 1.2:1 maximum coupling VSWR, 0.2 dB maximum insertion loss, 30 ± 0.8 dB maximum coupling, ±0.8 dB maximum flatness, 20 dB minimum directivity. The CW power is 500 W average. The size is 177.3 × 20 × 61 mm.

Circular Multi-Coax Cable Assemblies

MIcable DC-40 GHz 19-Pin D38999 circular multi-coax cable assemblies are high density, blind mated 19-coax phase matched cable assemblies. They are integrated, high performance easily connected solution. They have 4.92 dB/m at 40 GHz typical cable attenuation, 1.35:1 at 40 GHz maximum VSWR, 75 dB minimum isolation and it is available for phase-match on request. The diameter of the plug circular connector is 48 mm, working temperature is -55°C to +85°C. The applications include base station, antenna, switch matrices test and equipment connection.

www.micable.cn

GeoSync Microwave Inc.

Frequency Synthesizers

GeoSync Microwave's GFSX-0118 offers exceptionally low phase noise (-135 dBc at 10 MHz offset) and high spurious free dynamic range for up to 16 arbitrarily selected frequency sources over the 1 to 18 GHz bands. Either 4, 8, 12 or 16 sources can be provided in the 2RU size. Integrated jitter is < 70 fS over 100 Hz to 1 MHz offset. A separate +23 dBm output power option is available.

www.geosyncmicrowave.com

Herotek

26 to 40 GHz Amplifier

Herotek offers a wideband mmWave amplifier. Model A2640205010A operates from 26 to 40 GHz and matched for low VSWR. It has gain of 20 dB with maximum gain variation of ±2.5 dB, noise figure of 5 dB, P1dB output of +10 dBm and current draw of 180 mA at +12 V bias. This amplifier comes in a hermetically sealed package with removable connectors for drop-in assemble and designed for both military and commercial applications.

www.herotek.com

New**Products**

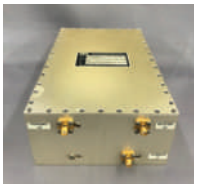
Integra Technologies Inc.
GaN/SiC RF Power Transistors

Integra Technologies Inc. offers an extensive portfolio of high performance GaN/SiC RF power transistors and pallets from P- through X-Band. The IGN1214CW425, designed using Integra's patented thermally enhanced GaN/SiC technology, operates instantaneously from 1.2 to 1.4 GHz delivering 400 W at 40 V with > 15 dB of power gain at 70 percent efficiency under CW conditions. This product is industry leading for CW efficiency and performance, enabling the next generation of multi-mode radar performance.
www.integratech.com

Marki Microwave
Surface Mount IQ Mixer

The MMIQ-1867SM is the best mmWave surface mount IQ mixer yet! The MMIQ-1867SM features an astounding 48 dB of L-to-R isolation across a wide 18 to 67 GHz frequency range. Combined with 23 GHz of IF bandwidth, this MMIC mixer is the ideal solution for wideband IQ and vector modulation, band shifting and much more at K-, Ka- and V-Bands. Excellent amplitude and phase matching result in 32 dB of image rejection.
www.markimicrowave.com

Metropole
Upgrade with MUOS



Upgrade your legacy UHF SATCOM to include MUOS, with the FMA-123. This compact unit has performance compatible with MUOS requirements, proven both in field and shipboard operations. Metropole also offers a host of other MUOS compatible units, to include low noise amplifiers, bandpass filters and diplexer/preamplifiers, just to name a few. Metropole products can help you incorporate MUOS into your system.
www.metropoleproducts.com

NoiseWave
Broadband Calibrated Noise Source

NoiseWave's NW346 series is a broadband calibrated noise source available in standard output levels 6, 15 and 25 dB ENR. These units are designed for noise figure test and are compatible with standard noise figure meters as well as spectrum analyzers and networks analyzers. They are supplied in rugged standard packaging and are economically priced with delivery typically from stock. Excellent noise flatness is featured over wide bandwidths ideal for a variety of applications such as 5G testing, radar and component characterization.
www.noisewave.com

Pasternack
Yagi Antennas

VENDORVIEW

Pasternack's 400 MHz and 900 MHz yagi antennas are the high-quality solution needed for utilities and land, mobile and radio applications. These new antennas provide 7 to 13 dBi of gain for superior performance and allow easy connections to the network. They feature aluminum powder coating for durability in the toughest environments. They are built to withstand up to 200 mph winds and resist corrosive elements. All antennas are in-stock and available for same-day shipping.

SMT Switches

Pasternack's new series of surface mount, electromechanical relay switches with latching actuators, is designed for high performance relay switching such as military communications. Working with broad frequency coverage from DC to 26 GHz and designed for 5 million lifecycles, their switches are an excellent choice for your next higher-power switching applications in space-limited designs. As always, the items are in-stock and ready to ship today.
www.pasternack.com

Pixus Technologies
Versatile Development Enclosures

Pixus Technologies, a provider enclosure and backplane solutions for OpenVPX and RF systems, now offers versatile configurations geared for 3U and 6U OpenVPX and SOSA development. Backplane designs speeds to 100 GbE speeds are available along with various implementations of VITA 66 (optical) and VITA 67 (RF) interfaces. Development enclosures are available in open frame and 19" rackmount options.
www.pixustechnologies.com

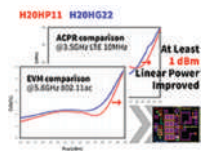
RFHIC
Solid-State Microwave Generator System

RFHIC's RIU093K0-50TG is a 3 kW, GaN solid-state microwave generator system designed ideally for microwave heating, drying and sterilization applications. The RIU093K0-50TG is a stand-alone type equipped with a 380 to 400 VAC power supply unit, a remote-control unit and an IP-protected internal waveguide. With its pre-built internal waveguide, users can connect it directly to the horn antenna without the need for external waveguides, simplifying integration and lowering overall costs.
www.rfhic.com

Richardson RFPD
Multi-Function Transceiver

Analog Devices' ADRV9029 includes an integrated DPD and CFR engine, which enables the use of lower power, lower cost FPGAs. With quad-channel integration, the radio provides the lowest power, smallest size, common platform solution for 4G/5G applications. The IC is part of the RadioVerse™ technology and design ecosystem. RadioVerse accelerates advanced radio design and development and includes market-leading integrated radio platforms, software tools, evaluation and prototyping platforms, reference designs and full radio solutions.
www.richardsonrfpd.com

Sanan-IC
GaAs HBT Technology



Sanan-IC has released its latest GaAs HBT technology called the H20HP11 process, which can meet high linearity requirements in wireless communication applications such as 5G NR HPUE. Excellent PA performance can be obtained together with outstanding harmonic suppression and higher delivered linear power. Its epitaxial structure, developed and manufactured in-house, exhibits lower VCE (offset) and lower knee in its I-V curve.
www.sanan-ic.com

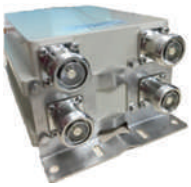
Spacek Labs
Ka-Band Transceiver

Ka-Band transceiver, model TRKa-10, is a custom assembly featuring a transmit and a receive channel sharing a phase-locked LO chain with a 100 MHz reference supplied by the user

New**Products**

at a power level of -3 to +3 dBm. Spacek Labs specializes in custom RF assemblies in bandwidths from 10 to 110 GHz and which are built to our customer's unique electrical and mechanical specifications.
www.spaceklabs.com

Tamagawa Electronics
Sub-6 Antenna Combiners



Tamagawa Electronics announced the Sub-6 antenna combiners for the 5G wireless network systems. The combiners enable easy implementation of 5G Sub-6 (3,400 to 3,600 MHz) system into existing 4G/LTE systems such as WCS2300/IMT2600 (2305 to 2673 MHz) bands and LTE/PCS/AWS(600/700/800/1800/1700/2100/2300 MHz) bands. Minimum isolation between existing bands and Sub-6 (3.6 GHz) is 60 dB minimum PIMD -153 dBc CW 2 × 43 dBm. Quadruplexer, three bands multiplexer are also available for each telecom carrier.
www.tmeleus.com

TotalTemp Technologies
SD450-N Thermal Platform

New SD450-N thermal platform offers 450 square inches (18" × 25") of even, wide range, precise thermal testing from 200°C to -100°C. Extended range options, safety features, alternate cooling methods and customization available. New design allows more accessibility, custom fixturing and clamping choices. Great for larger devices with a flat thermally conductive surface. Advanced programmable synergy nano temperature controller can monitor and log one or many points on the device(s) allowing advanced temperature control optimization.
www.TotalTempTech.com

Wenteq Microwave
Broadband Low Noise Amplifier

Model ABL1800-01-3330 is a two-stage MMIC based low noise amplifier (LNA) with input limiter over drive protection. It offers 33 dB linear gain and 3.0 dB noise figure with excellent gain flatness and input/output return loss. The unit has a built-in voltage regulator and operates with a single DC power supply voltage. The package size of the amplifier is 1.5 × 1.0 × 0.4".
www.wenteq.com

Wright Technologies
Amplifiers

The newly released ASL18B series amplifiers feature extended frequency operation. The ASL18B series LNA consists of gain blocks with +20, +30 and +40 dB. The noise figure levels are +2.0 dB typical, and +2.5 dB maximum 1 to 18 GHz. The output P1dB is +15 dBm typical and +12 dBm minimum 1 to 18 GHz. Like all Wright Tech products, these ASL18B series amplifiers are battle tested and backed with the four-year warranty program.
www.wrighttec.com

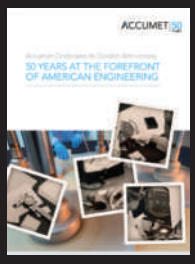
Z-Communications
Phase-Locked Oscillator

VENDORVIEW

The SFS16000H-LF is an ideal plug and play solution for radar, SATCOM and T&M applications. It provides a 16 GHz output, when locked to an external 100 MHz source. Excellent phase noise performance at 1 Khz offset of -90 dBc/Hz cascades to -116 dBc/Hz at 100 Khz. Power output is -3 dBm into a 50 ohm load, while operating from 3 and 5 Vcc sources. The SFS16000H-LF is offered in the ZCOMM SFS-L1 package. Measuring just 1 × 1 × 0.215" this compact PLO is well suited for automated surface mount applications.
www.zcomm.com

MICRO-ADS

MAKING WAVES



50 Years of Accumet

Accumet, an industry-leading advanced processing manufacturer for new and legacy materials fabrication, precision laser services, lapping, polishing and critical component assembly, celebrated its 50-year anniversary.

Accumet
Accumet.com

Educational Test Blog

Anritsu Company has launched an educational blog, Test Talk, that discusses industry trends and emerging technologies, as well as how to test them most effectively.

Anritsu Company
https://anritsu.typepad.com/testtalk/

Test Talk

RF and Microwave Amplifiers Video

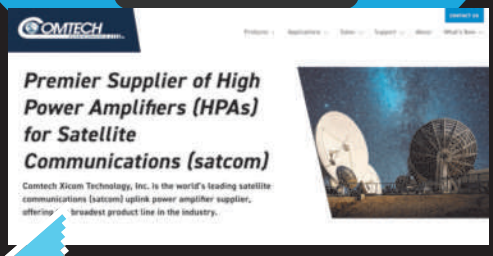
APITech, a leader in amplifier technology, provides higher frequency designs, higher-power models and lower phase noise amplifiers. Check out their products in this video.

APITech
https://bit.ly/30QGnQF

New Comtech Website

Comtech Xicom Technology has launched a newly redesigned website. The website highlights the company, leadership in Ka-, Q- and V-Band SATCOM HPAs and targets solutions for many new commercial and military/government applications.

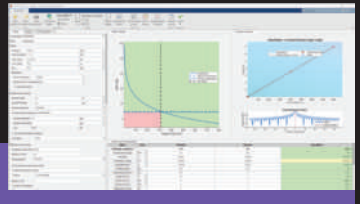
Comtech Xicom Technology
www.xicomtech.com



Interactive Calibration Video

Interact with Copper Mountain Technologies' VNA software in this video to complete a simulated calibration of a two-port VNA without the instrument.

Copper Mountain Technologies
https://bit.ly/32rxJc9



R2021a Release Highlights

MathWorks announced updates to MATLAB and Simulink tools as part of its semi-annual refresh, Release 2021a, offering hundreds of new features and functions and introduces new products in the areas of SATCOM, radar and DDS applications.

MathWorks
https://bit.ly/3tvmqMk

Mini-Circuits Opens Netherlands Office

Mini-Circuits has established a new office in Nijmegen, co-located at the Novio Tech Campus, to expand its corporate service and support presence for European customers.

Mini-Circuits
www.minicircuits.com

Courtesy of Novio Tech Campus

The COMPLETE+3D Library, v21.1 Released

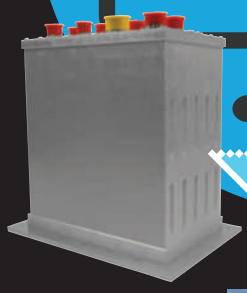
Modelithics announced the release of version 21.1 of the COMPLETE+3D Library for use with Ansys HFSS, containing over 325 highly scalable Microwave Global Models.

Modelithics
www.modelithics.com

ATR Enclosure Section Update

Pixus Technologies, a provider of OpenVPX/SOSA and RF enclosure solutions, has updated its website's ATR enclosure section for new configurations.

Pixus Technologies
https://bit.ly/3x366ob



Timing is Everything: Alternate Solutions for TCXO Shortages

This blog post offers alternatives to TCXO shortages caused by the AKM factory fire in Japan, including MEMS technology from SiTime and Rakon.

RFMW
https://rfmwblog.com/2021/03/30/timing-is-everything/

20+ Years of GaN on SiC

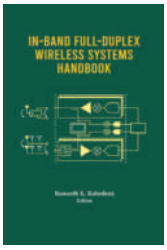
Wolfspeed is powering the future of RF systems as the only vertically integrated manufacturer of GaN on SiC technology. Enabling 5G, improving radar systems and providing higher efficiency at lower costs.

Wolfspeed
www.youtube.com watch?v=rLgLhZ2XIa8

A New Video from Skyworks!

Skyworks introduces the SKY67181-396LF, a high gain, low noise amplifier designed to meet the challenging requirements of cellular LTE and 5G NR infrastructure applications.

Skyworks
www.youtube.com/watch?v=h7su2wd8vKU



In-Band Full-Duplex Wireless Systems Handbook

Kenneth E. Kolodziej

Many wireless systems could benefit from the ability to transmit and receive on the same frequency at the same time, which is known as in-band full-duplex (IBFD). This technology could lead to enhanced spectral efficiency for future wireless networks, such as 5G new radio and beyond, and could enable capabilities and applications that were previously considered impossible, such as IBFD with phased array systems. In this exciting new book, experts from industry, academic and federal research institutions discuss the various approaches that can be taken to suppress the inherent self-interference that is generated in IBFD systems. Both static and adaptive techniques that span across the propagation, analog and digital domains are presented.

Details and measured results that encompass high isolation antenna designs, RF and photonic cancellation as well as signal processing approaches, which include beamforming and linear/non-linear equalization are detailed. Throughout this book, state-of-the-art IBFD systems that utilize these technologies will be provided as practical examples for various applications. Expert IBFD perspectives from multiple research organizations and companies, which provides readers with the most accurate state-of-the-art approaches. This is the first book that dives into both the techniques that make IBFD systems possible as well as several different applications that use IBFD technology.

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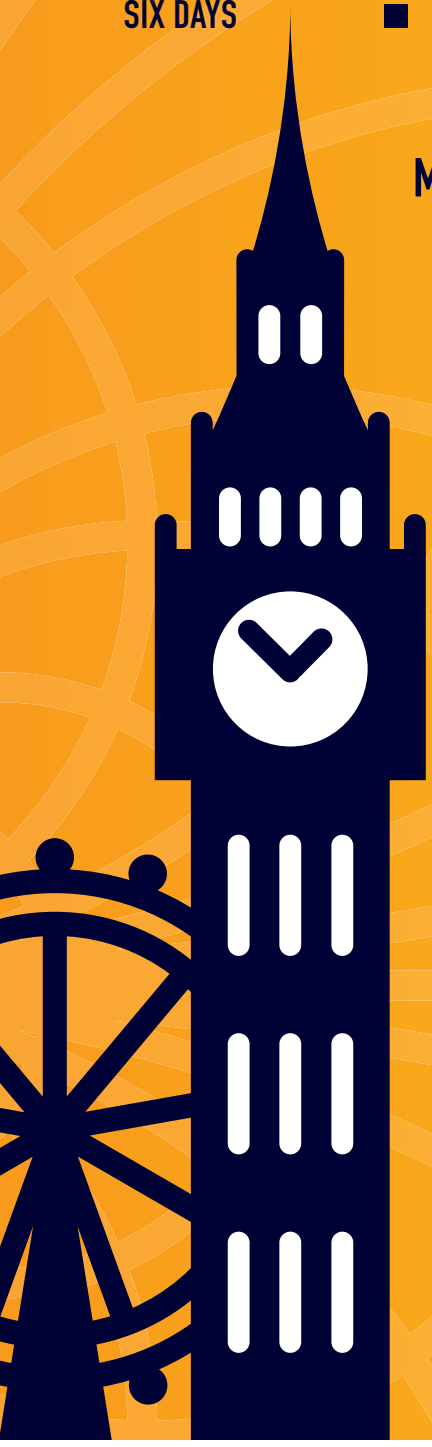

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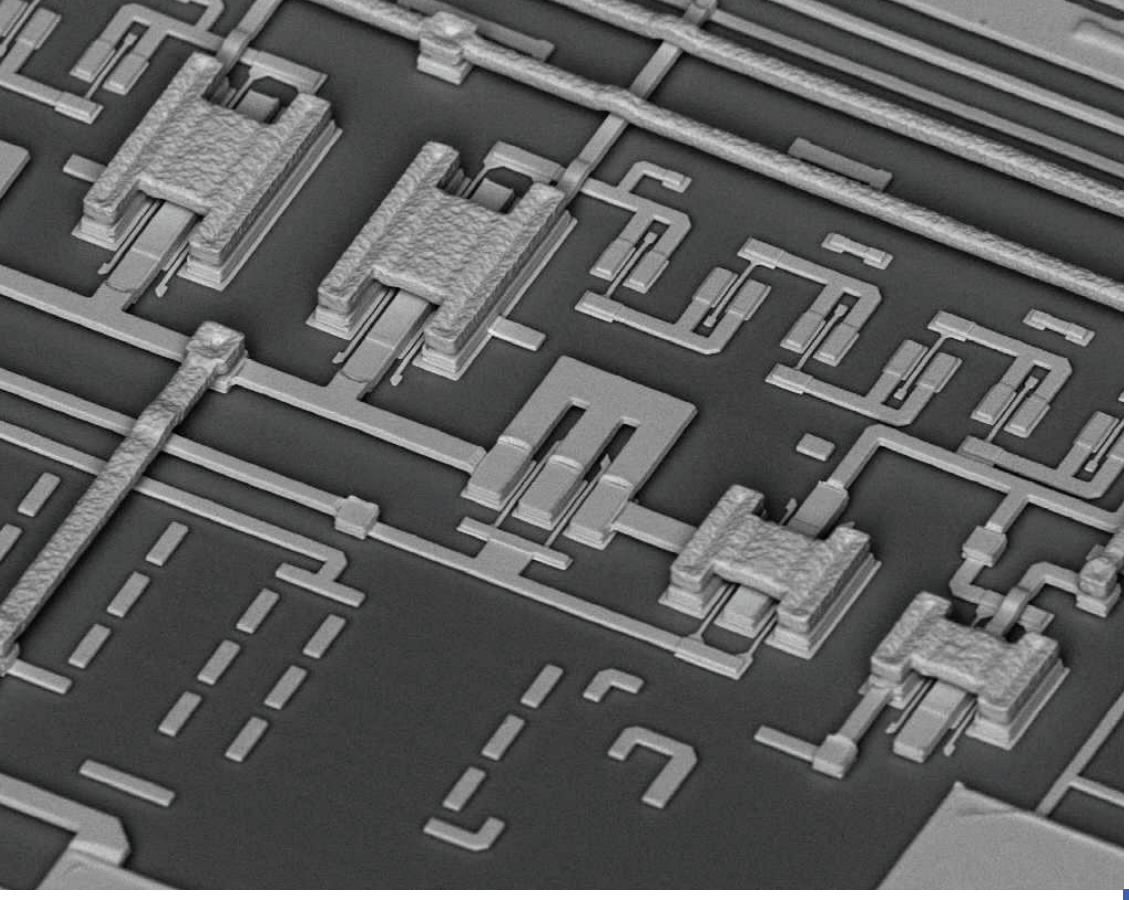

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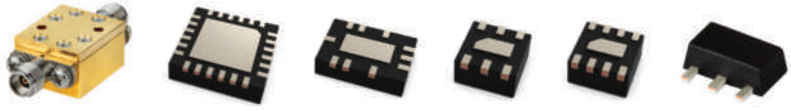

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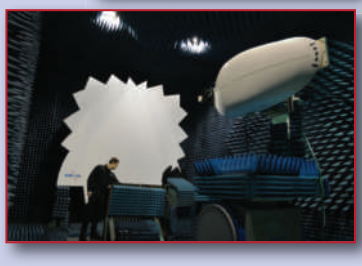
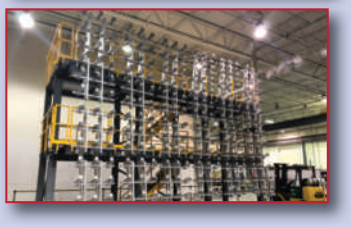
NSI-MI: Ensuring Confidence in Antenna Measurements, from θ to φ





What's in a name? A company's name may mirror its founder or reflect its products or market. It might not be an actual word, just a pleasant, multi-syllable sound. No matter the form, a company's name is a symbol of what the company represents, particularly the intangibles surrounding the product or service, intangibles that build customer trust and loyalty. The name NSI-MI Technologies has achieved that enviable brand status, representing the combination of two complementary companies with a long heritage in microwave antenna measurements.

Their story begins in 1956, with Scientific Atlanta and the first antenna pattern recorder for recording antenna gain measurements, using ink on glossy paper. Separately, Nearfield Systems Incorporated (NSI) formed in California in 1988 to develop near-field antenna measurement systems. Then, in 1997, Scientific Atlanta decided to focus on the cable market and spun out the antenna measurement division, known internally as Microwave Instrumentation Technologies—soon shortened to MI Technologies. MI Technologies specialized in far-field and compact antenna test range (CATR) measurements, a capability complementing NSI's focus. The two companies merged in 2016 to yield a comprehensive set of capabilities able to solve virtually any antenna challenge. At its two facilities outside Atlanta and Los Angeles, NSI-MI has six test ranges and a combined manufacturing footprint exceeding 126,000 square feet. The team comprises some 250 staff, and growing; more than 150 (60 percent) are mechanical, electrical, software and systems engineers.

In addition to performing antenna, radome and radar cross section measurements, NSI-MI offers a range of measurement systems, from standard products to target simulators for the defense market and specialized test systems for wireless and automotive applications. NSI-MI also designs and constructs complete antenna test ranges with full instrumentation and provides all types of support services to meet customer needs. The company doesn't stop at testing antennas; NSI-MI designs antenna systems and has a catalog of some 300 antenna products of various types that span frequency bands from 10 MHz to 170 GHz.

To improve antenna measurements, NSI-MI recently developed a Vector Field Analyzer (VFA) and a line of instrumentation products to support it. The VFA is the foundation of an enhanced antenna measurement system, combining accurate RF performance with fast measurements. The VFA's supporting products include motion control, mixers, backfit panels and remote controls.

NSI-MI's markets are strong and growing, driven by new technologies and applications: 5G, with massive MIMO and mmWave phased array base stations; automotive, where high-end cars and trucks are "antenna farms" of some 70 antennas; and satellite, launching a new generation of commercial rockets and satellites carrying antennas for broadband, IoT and telemetry.

From design to characterization, antenna technology is challenging, requiring ongoing diligence to ensure traceability to NIST standards. The NSI-MI team takes the challenge seriously, maintaining American Association for Laboratory Accreditation and providing leadership for technical groups such as the Antenna Measurement Techniques Association (AMTA). Many of NSI-MI's projects span years from concept to completion, and many customers have been customers for decades. That reflects NSI-MI's commitment to the success of a project, acting as an extension of the customer's team. Working collaboratively to ensure accurate antenna measurements is why NSI-MI's tag line is "Test with Confidence™."

www.nsi-mi.com

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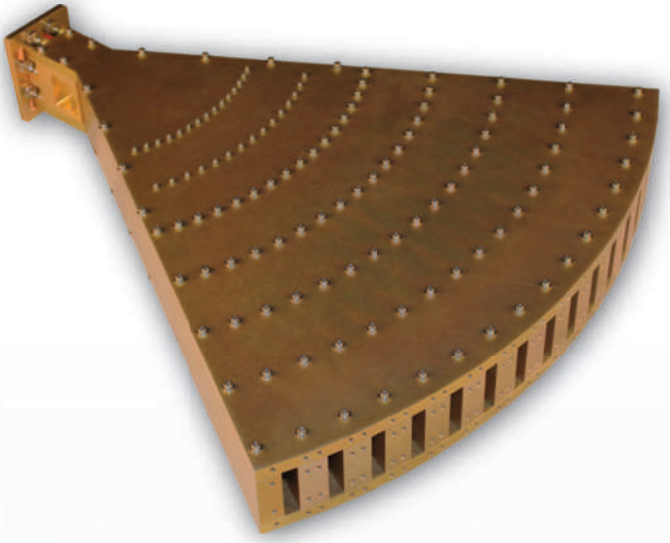

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C-Band	WR159	≈ 1.6 kW CW	**≈ 12.0 kW CW**
X-Band	WR90	≈ 0.55 kW CW	**≈ 2.4 kW CW**
Ku-Band	WR62	≈ 0.42 kW CW	**≈ 1.4 kW CW**
Ka-Band	WR28	≈ 0.02 kW CW	**≈ 0.4 kW CW**

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June 2021 - May 2022

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SMART HOME

Qorvo enables the smarts of the connected home – IoT interoperability.
No matter the protocol.

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MOBILE

Qorvo ships at least one RF component into every 5G handset produced.
Enough to support 1.4 billion mobile devices.

AUGUST 2021

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BIOTECHNOLOGIES

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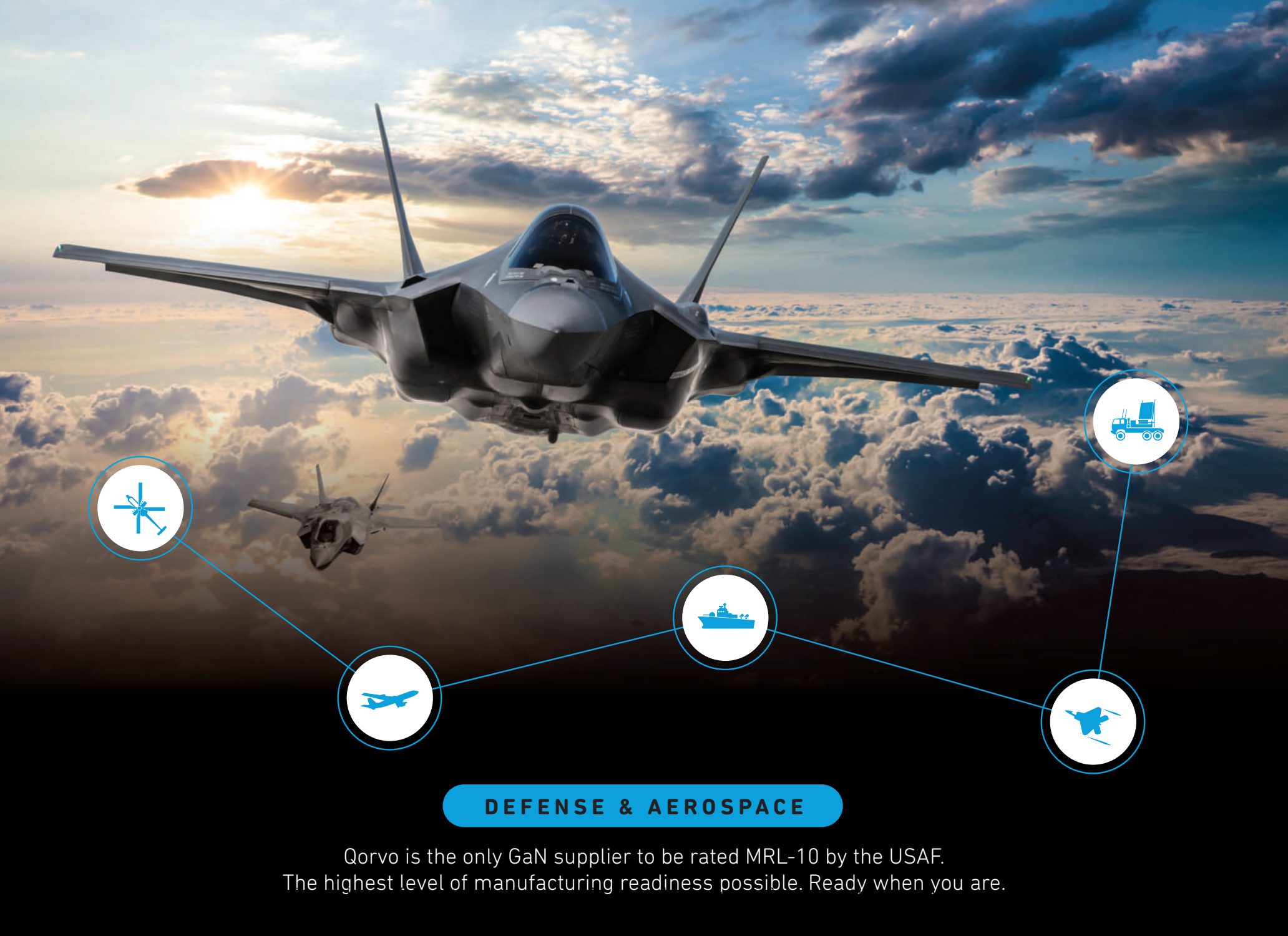

DEFENSE & AEROSPACE

Qorvo is the only GaN supplier to be rated MRL-10 by the USAF.
The highest level of manufacturing readiness possible. Ready when you are.

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WIRELESS INFRASTRUCTURE

Qorvo has shipped over 100 million RF devics for 5G applications. Go anywhere with Qorvo.

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WI-FI CONNECTIVITY

Qorvo solutions simplify Wi-Fi designs, deliver performance and maximize family time.

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MOTOR CONTROL

Qorvo BLDC motors cut the power and complexity of next-generation appliances.

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Qorvo UWB delivers new user experiences. Mobile and consumer.
Advanced auto and payment security. Digital transformation of factories.

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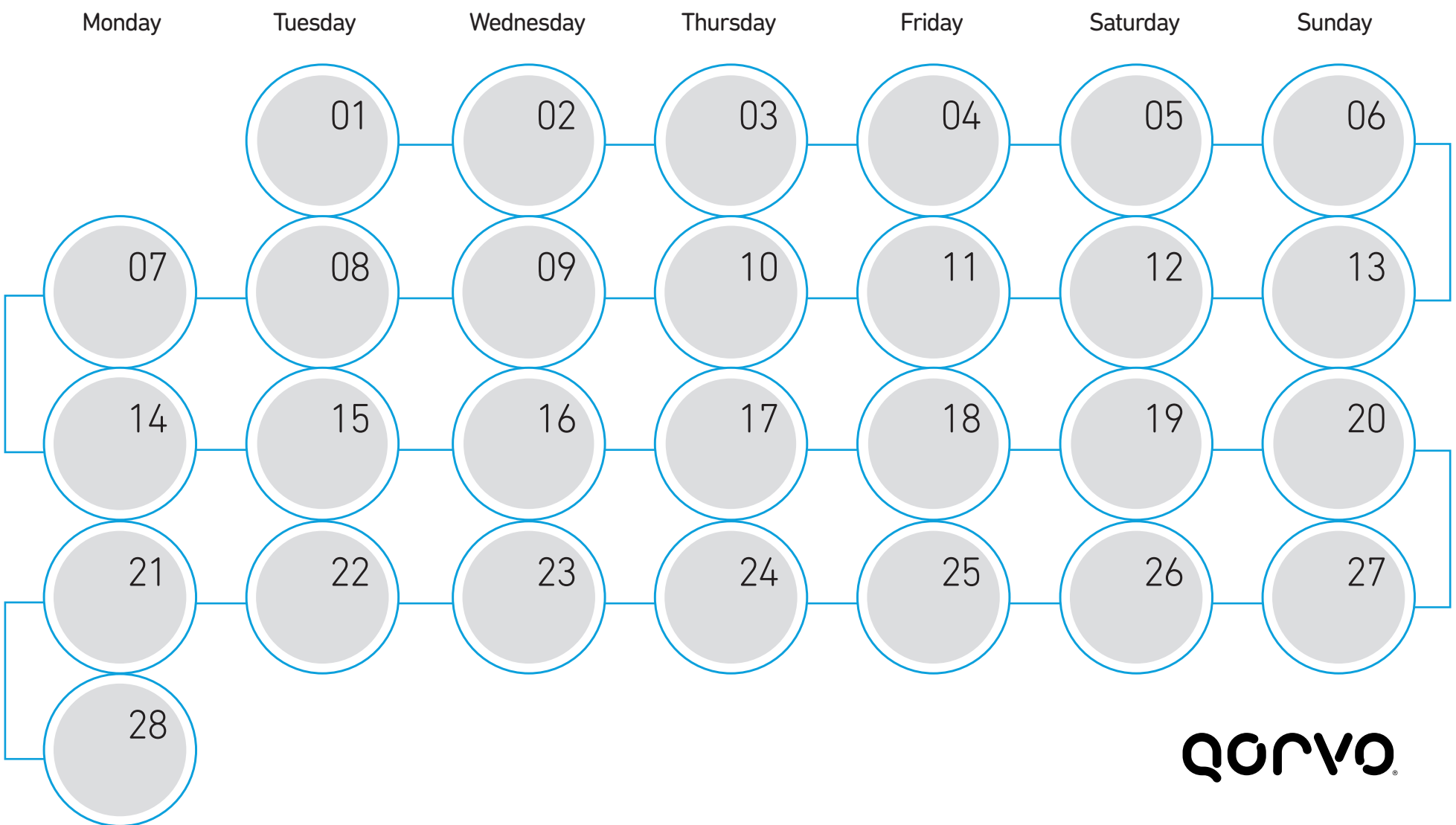

qorvo

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Qorvo makes smart factories of the future possible with 5G, wireless connectivity and ultra-wideband solutions. That means more productivity, efficiency and profitability.

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WEARABLES

Qorvo's RF supports modules used in smart watches, VR headsets, fitness trackers, smart glasses and more. Take Qorvo tech with you wherever you go.

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Qorvo products traveled to Mars twice. 500 million miles
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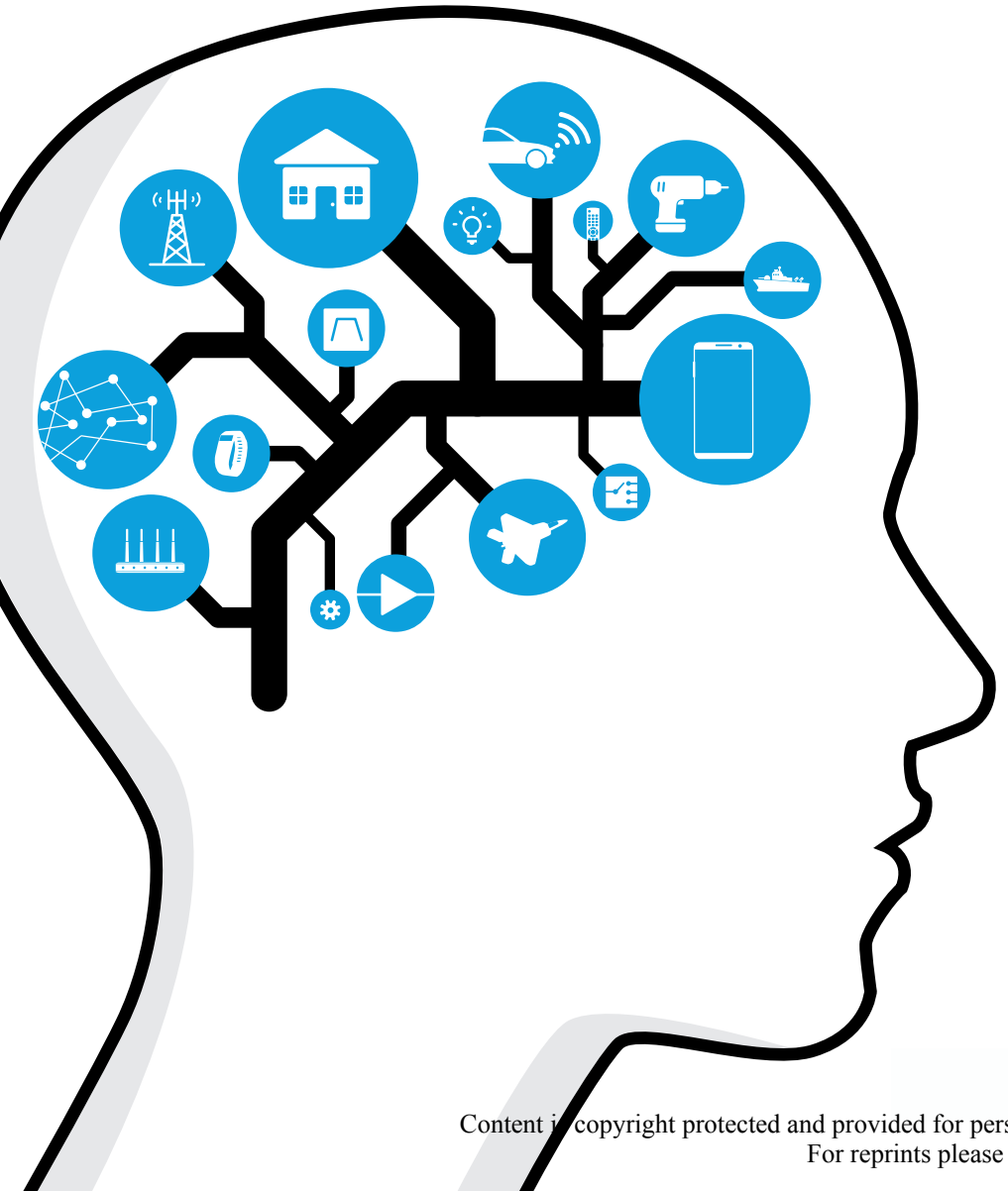
MAY 2022

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
						01
02	03	04	05	06	07	08
09	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

FEED YOUR GENIUS



CHECK OUT OUR DESIGN HUB

Qorvo connects the world. From the IoT and smartphones to defense and everything in between. Explore our resources to find out how.

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DOWNLOADABLE SOFTWARE

Qorvo MatchCalc™

GaN MODELS

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RF Impedance Matching Calculator

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GLOBAL

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All Product Lines,
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Get assistance from our global network of authorized channel partners, who keep inventory on hand and provide design engineers with deep technical expertise and localized design support for the latest Qorvo products.

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Cultivating the Next Generation of Wireless Solutions

QORVO'S RF ACCELERATOR PROGRAM

qorvo RF Accelerator

CROWD SUPPLY | MOUSER ELECTRONICS

Crowd Supply
A crowdfunding and e-commerce platform used by a global community of top-notch engineers and product designers to bring new hardware to life.

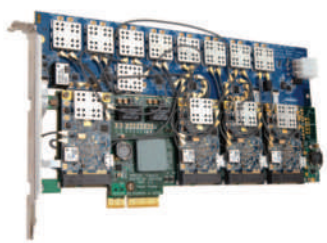
Qorvo RF Accelerator
A global electronics accelerator program managed by Crowd Supply focused on funding, manufacturing and shipping real manufactured products using Qorvo components to customers.

FEATURED PARTICIPATING PROJECTS

Lime microsystems

LimeRFE by Lime Microsystems
A software-definable RF front-end module for LimeSDR platforms.

https://www.crowdsupply.com/lime-micro/limerfe



fairwaves

XYNC by Fairwaves
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https://www.crowdsupply.com/fairwaves/xync

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