Vol. 67 • No. 8

August 2024

Microwave Journal

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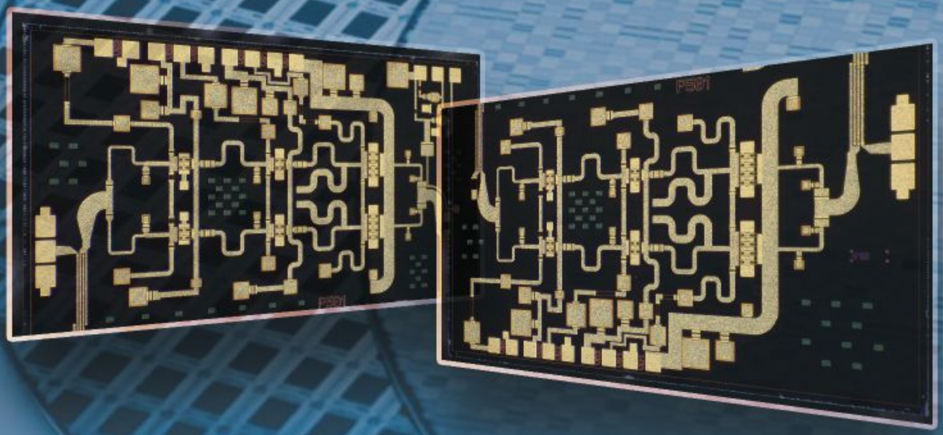
Miller MMIC is a global provider of RF semiconductor solutions with expertise in GaAs and GaN processes. We offer a diverse range of products tailored to various wireless applications. Our product lineup encompasses a wide array of offerings, including Low Noise Amplifiers, Distributed Amplifiers, Power Amplifiers, Driver Amplifiers, RF Switches, RF PIN Diode Switches, and numerous other voltage- and digitally-controllable RF components.



RF Distributed Low Noise Amplifiers

PN	Freq Low (GHz)	Freq High (GHz)	Gain (dB)	NF(dB)	P1dB (dBm)	Voltage (VDC)	Current (mA)	Package
MMW001T	DC	20.0	17~19	1~3.5	23 @ 10GHz	8.0	145	die
MMW4FP	DC	50.00	16.00	4.00	24.00	10	200	die
MMW507	0.20	22.0	14.0	4 - 6	28.0	10.0	350	die
MMW508	DC	30.0	14.0	2.5dB @ 15GHz	24.5	10.0	200	die
MMW509	30KHz	45.0	15.0		20.0	6.0	190	die
MMW510	DC	45.0	11.0	4.5	15.5	6.0	100	die
MMW510F	DC	30.00	20.00	2.50	22.00			die
MMW511	0.04	65.0	10.0	9.0	18.0	8.0	250	die
MMW512	DC	65.0	10.0	5.0	14.5	4.5	85	die
MMW5FN	DC	67.00	14.00	2.00	19.00	4.5	81	die
MMW5FP	DC	67.00	14.00	4.00	21.00	8	140	die
MMW011	DC	12.0	14.0		30.5	12.0	350	die

Low Noise Amplifiers

PN	Freq Low (GHz)	Freq High (GHz)	Gain (dB)	NF(dB)	P1dB (dBm)	Voltage (VDC)	Current (mA)	Package
MML040	6.0	18.0	24.0	1.5	14.0	5.0	35	die
MML058	1.0	18.0	15.0	1.7	17.0	5.0	35	die
MML063	18.0	40.0	11.0	2.9	15.0	5.0	52	die
MML080	0.8	18.0	16.5/15.5	1.9/1.7	18/17.5	5.0	65/40	die
MML081	2.0	18.0	25/23	1.0/1.0	16/9.5	5.0	37/24	die
MML083	0.1	20.0	23.0	1.6	11.0	5.0	58	die

RF Driver Amplifier

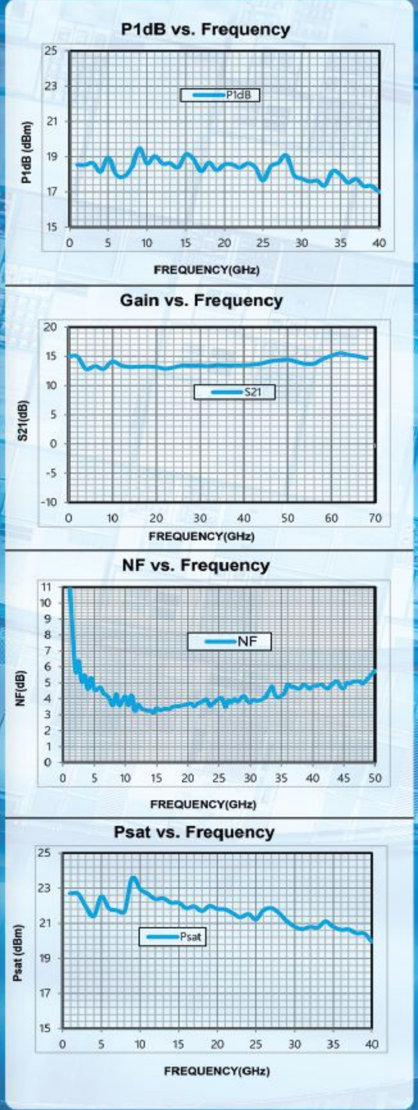
PN	Freq Low (GHz)	Freq High (GHz)	Gain (dB)	NF(dB)	P1dB (dBm)	Voltage (VDC)	Current (mA)	Package
MM3006	2.0	20.0	19.5	2.5	22.0	7.0	130	die
MM3014	6.0	20.0	15.0	-	19.5	5.0	107	die
MM3017T	17.0	43.0	25.0		22.0	5.0	140	die
MM3031T	20.0	43.0	20.0		24.0	5.0	480	die
MM3051	17.0	24.0	25.0	-	25.0	5.0	220	die
MM3058	18.0	40.0	20/19.5	2.5/2.3	16/14	5/4	69/52	die
MM3059	18.0	40.0	16/16	2.5/2.3	16/15	5/4	67/50	die

GaAs Medium Power Amplifier

PN	Freq Low (GHz)	Freq High (GHz)	Gain (dB)	P1dB (dBm)	Psat (dBm)	Voltage (VDC)	Current (mA)	Package
MMP107	17.0	21.0	19.0	30.0	30.0	6.0	400	die
MMP108	18.0	28.0	14.0	31.5	31.0	6.0	650	die
MMP111	26.0	34.0	25.5	33.5	33.5	6.0	1300	die
MMP112	2.0	6.0	20.0	31.5	32.0	8.0	365	die
MMP501	20.0	44.0	15.0	27 -- 32	29 - 34	5.0	1200	die
MMP502	18.0	47.0	14.0	28.0	30.0	5.0	1500	die

PN: MMW5FP

RF GaAs MMIC DC-67GHz



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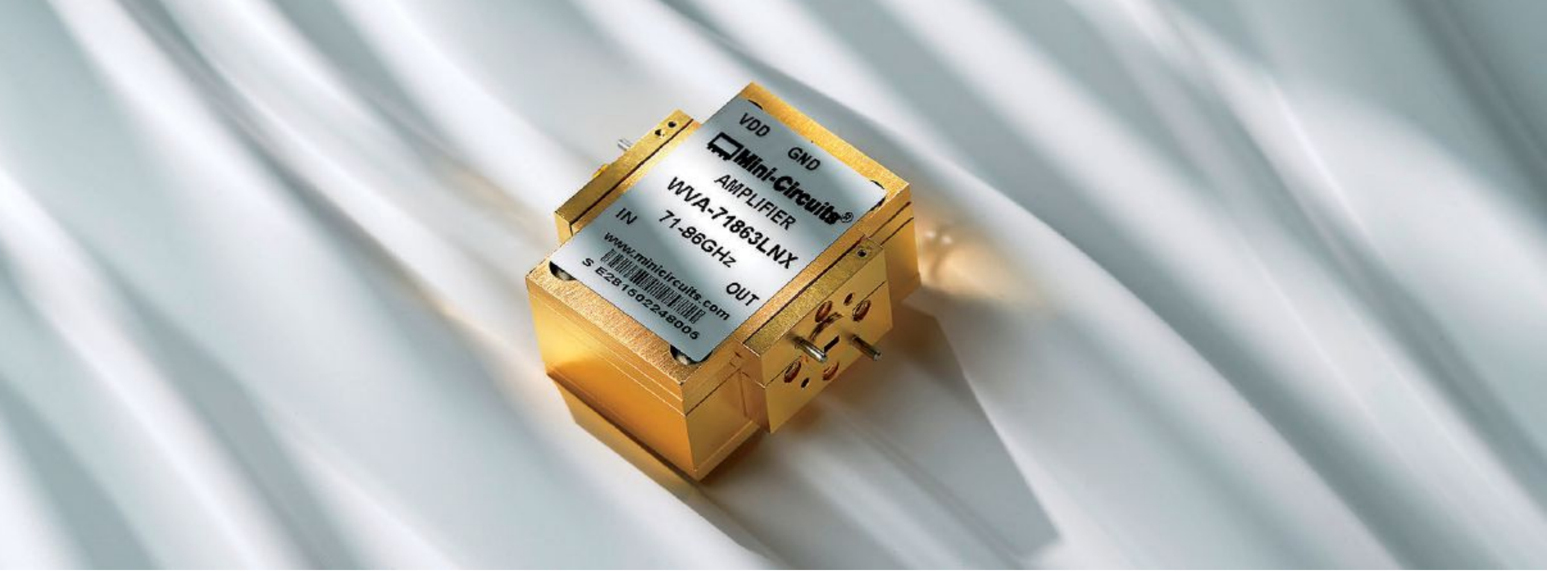

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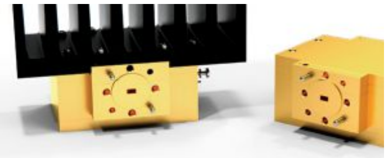

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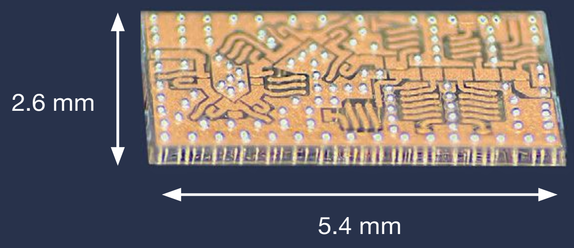

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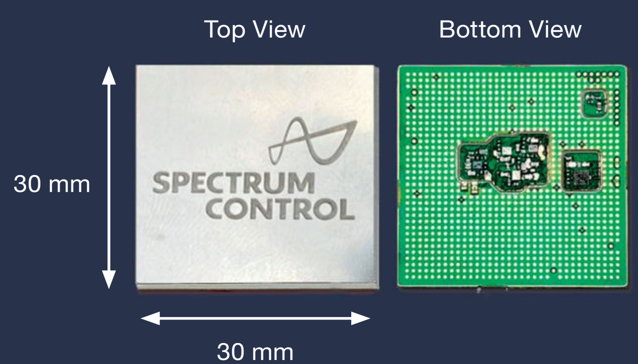

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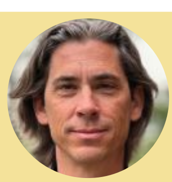

Jason Breitbarth, Founder of **Saetta Labs**, discusses his background, what led him to found Saetta Labs, how the company's products differentiate from competitive products and the future efforts of Saetta Labs.

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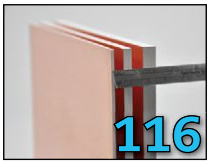

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Steve Sargeant, CEO of **Marvin Test Solutions**, discusses the company's heritage, product and market focus, fit with the Marvin Group and vision for the future.

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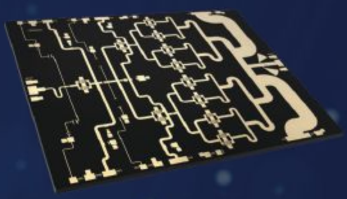

V

- NPA4000-DE | 47.0-52.0 GHz | 1.5 W
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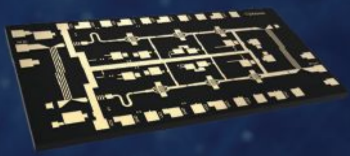

E

- NPA7000-DE | 65.0-76.0 GHz | 1 W
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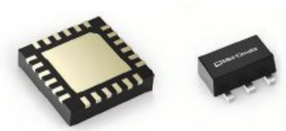

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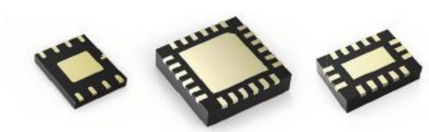

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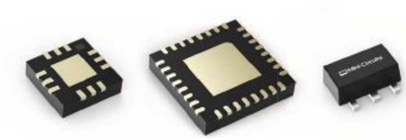

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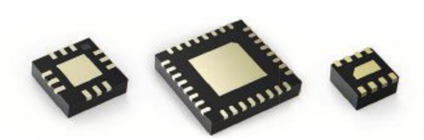

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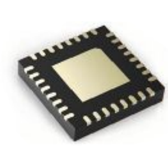

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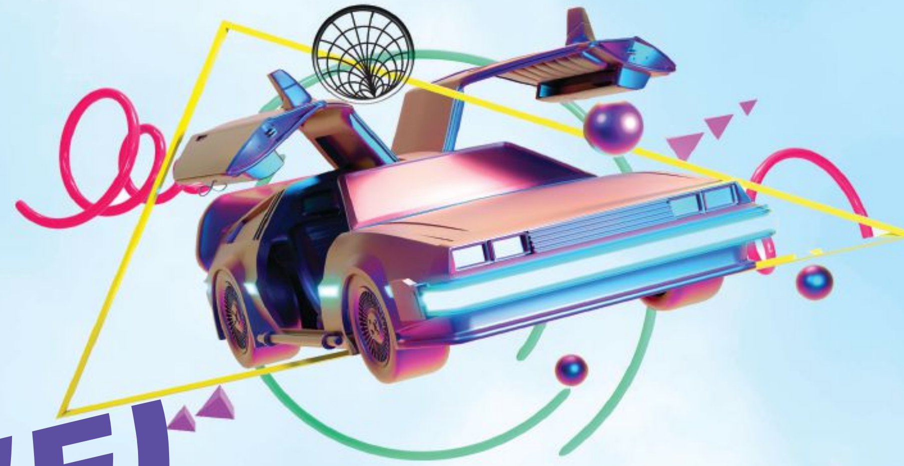
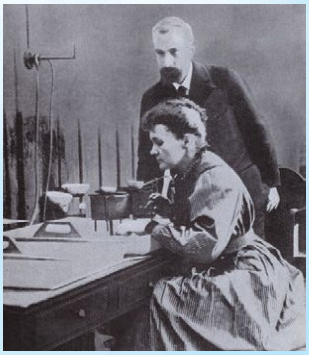


TIME TRAVEL

Eric Higham
Microwave Journal

Marie and Pierre Curie: Early Pioneers of Physics



Source: Wellcome Collection.

As European Microwave Week returns to Paris, it seems fitting to feature Marie and Pierre Curie. Pierre Curie was born in Paris in 1859. Building on a strong foundation in mathematics, Curie earned the equivalent of a master's in physical sciences from the University of Paris. To earn money for a doctorate program, Curie worked as a laboratory instructor. It was here that he was introduced to Maria Skłodowska. Skłodowska was born in Warsaw, Poland, in 1867 and followed her elder sister to Paris to study physics, chemistry and mathematics at the University of Paris. Their mutual passion for science and a small lab brought Curie and Skłodowska closer and they were married in 1895, with Skłodowska becoming Marie Curie.

Pierre Curie received his doctorate in 1895, based on his early studies of magnetism. Doing this research with his brother, Pierre is credited with discovering piezoelectricity. He also developed the Curie constant and Curie's Law, which quantifies the effect of temperature on paramagnetism. This earlier work also led to the discovery that ferromagnetic substances have a temperature, now known as the Curie temperature, above which they lose their ferromagnetic behavior.

Despite Pierre's accomplishments, the couple is best known for their work on radiation. In 1895, Wilhelm Röntgen discovered X-rays. In 1896, Henri Becquerel discovered that uranium salts emitted radiation that resembled X-rays and Marie began investigating uranium radiation for a possible thesis.

Using a device developed by Pierre and his brother during their magnetism investigations, Marie discovered that the air around a sample of uranium was electrically charged. Based on this, she hypothesized that the uranium radiation came from the atom and not from the interaction of molecules. This became an important step in proving that an atom was not indivisible. Marie became intrigued by material radiation and began investigating the radiation properties of other substances.

Together, the Curies made groundbreaking discoveries that revolutionized our understanding of the natural world. They discovered two previously unknown elements, polonium and radium, both of which were more radioactive than uranium. Their pioneering work led to the coining of the term "radioactivity." Recognizing the magnitude of their contributions, the Curies, along with Becquerel, were awarded the 1903 Nobel Prize in Physics, with Marie becoming the first woman to receive this honor.

Despite that success, the following years were turbulent. Pierre died crossing the street in Paris and Marie continued to fight sexism, xenophobia and scandal in France while continuing efforts to secure more lab funding. Despite developing an international standard for radioactive emissions, the curie, she failed to gain admission to the French Academy of Sciences.

But there were accomplishments. Marie accepted a chair, making her the first female professor at the University of Paris. As the importance of her work became better understood, Marie won a Nobel Prize in Chemistry in 1911. With that, she became the first person to win or share two Nobel Prizes and the first person and only woman to win in two different fields.

Marie's dedication to understanding radiation continued until her death in 1934. Many attributed her death to the passion of her life; the damaging effects of ionizing radiation, which were not understood at the time. With her passing, the couple who did so much to understand radiation were once again reunited in a cemetery outside Paris.

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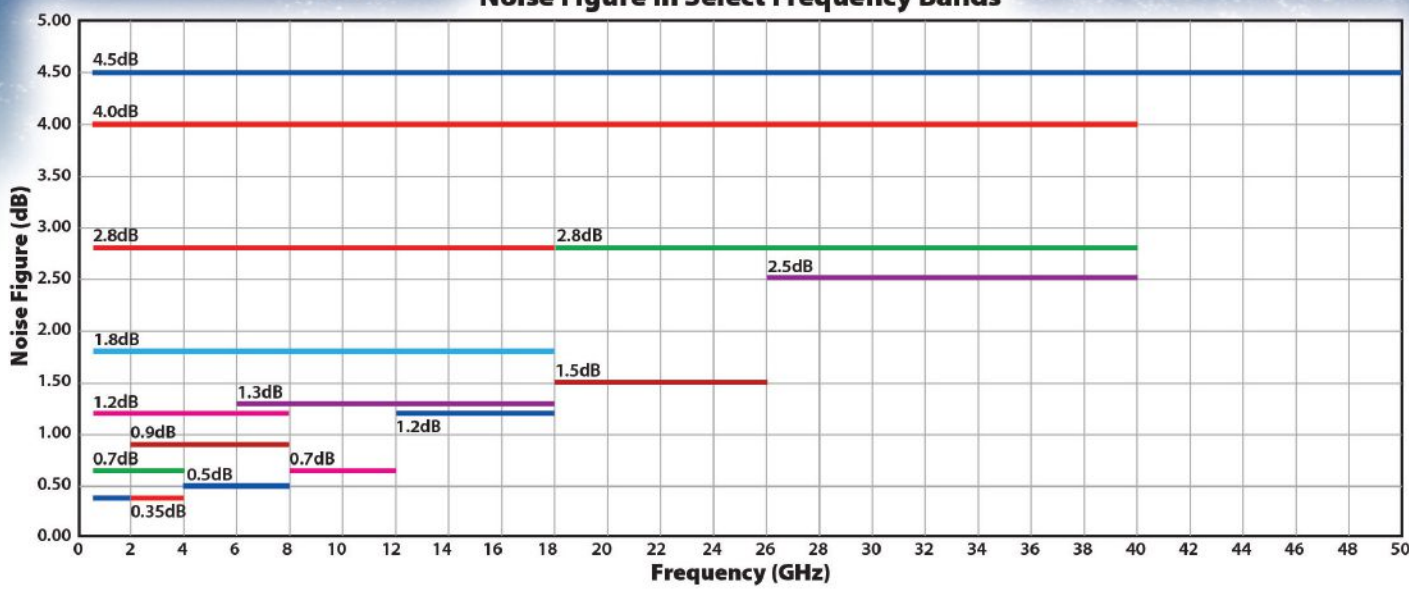


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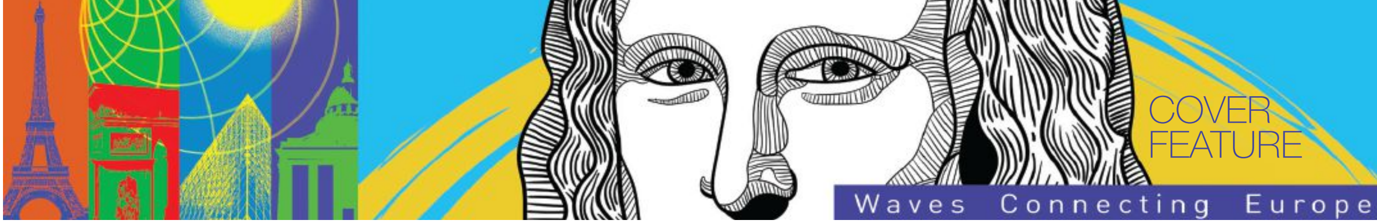

Chips and Pommes Frites: A French Semiconductor Success Story

A review of the microwave and wireless industry in France

Helen Duncan
MWE Media, U.K.

During this summer and early autumn, France's capital city, Paris, will host two important global events. The first of these is, of course, the Olympic Games, which will run from July 26 to August 11. Then, just over a month after the end of the Games, European Microwave Week (EuMW) will take place at the Paris Expo Porte de Versailles conference venue.

Several changes have occurred in the French microwave industry since EuMW was last hosted in the capital in 2019.[1] One of the most notable trends is the strengthening of the semiconductor sector under the support of the Chips Joint Undertaking (Chips JU), a multi-billion euro program that mirrors the U.S. Chips Act and aims to build up the European Union's (EU) semiconductor capabilities while cultivating technological sovereignty.[2] France also remains particularly strong in microwave subsystems for its defense and aerospace sectors.

RF SEMICONDUCTORS

Much of France's semiconductor industry is focused in the Grenoble area. This area is located in the southeast part of the country, near the borders with Switzerland and Italy and it is home to the Crolles fabrication facilities of STMicroelectronics. Although headquartered in Geneva, Switzerland, STMicroelectronics has several sites in France, including an R&D facility in Rennes and other facilities in Paris and Le Mans, as well as in Grenoble itself. STMicroelectronics manufactures LDMOS RF power transistors for mobile base stations and GaN-on-Si devices for 5G and 6G through its partnership with MACOM.

FD-SOI: A FRENCH SUCCESS STORY

Two years ago, STMicroelectronics was one of four leading semiconductor players to jointly announce their intention to define a next-generation roadmap for fully depleted silicon-on-insulator (FD-SOI) technology. The other collaborators were Alternative Energies and Atomic Energy Commission (CEA), Soitec and GlobalFoundries.

FD-SOI is a planar CMOS process technology that delivers the benefits of reduced silicon geometries while simplifying the manufacturing process. Featuring a tight electrostatic control at the transistor level and the introduction of an innovative power management technique, the technology is ideally suited for low-power, RF and mmWave applications. The physical characteristics enable the technology to offer the


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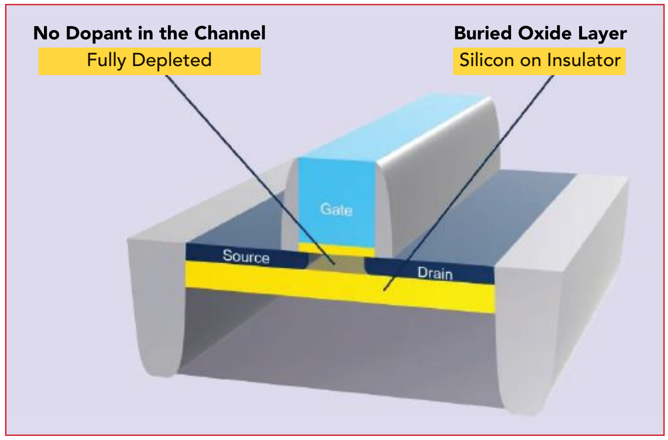

Fig. 1 **Physical properties of FD-SOI. *Source:* STMicroelectronics.**

best performance, power, area, cost and environmental (PPAC-E) impact for mixed circuits that combine digital, analog and RF blocks. A cross-section of an FD-SOI transistor is shown in ***Figure 1***.

CEA invented FD-SOI and was a keen advocate for its adoption within the Grenoble-Crolles ecosystem. There had already been a long-term R&D cooperation in place between CEA and the other three organizations. The benefits cited for FD-SOI technology include higher performance, lower power consumption and lower costs, as well as easier integration of additional features like RF connectivity, mmWave frequencies and security. The technology can address opportunities in automotive, IoT, 5G/6G and manufacturing 4.0 applications.

Following this agreement, STMicroelectronics and GlobalFoundries announced[3] their intention to create a new, jointly-operated 300 mm (12 in.) manufacturing facility adjacent to ST's existing fab in Crolles. This facility will support multiple technologies including FD-SOI, and is targeted to ramp up to full capacity by 2026. Dr. Thomas Caulfield, president and CEO of GlobalFoundries and Jean-Marc Chery, president and CEO of STMicroelectronics, acknowledged the support of the French Minister of the Economy and Finance and his team, along with that of the European Commission, in helping to reinforce the region's FD-SOI ecosystem. Chery further stated that the new manufacturing facility would support STMicroelectronics' ambition to grow its revenue to more than $20 billion.

The program benefited from significant financial support from the State of France, representing an overall projected cost of €7.5 billion for CAPEX, maintenance and ancillary costs. This is in line with the objectives set out in the European Chips Act for Europe to reach 20 percent of worldwide semiconductor production by 2030. The new manufacturing facility is expected to generate employment for around 1000 additional staff at the ST Crolles site and across its ecosystem of partners, suppliers and stakeholders.

Crolles-based Soitec is supplying the SOI substrates for its partners, building on its longstanding supplier relationship with GlobalFoundries.[4] Soitec sees FD-SOI as a key technology for the range of markets it addresses. These markets include connectivity, automotive, IoT and artificial intelligence.

PILOT LINES

Continuing the FD-SOI theme, in June 2024, the Grenoble-Crolles area hosted the launch of the FAMES Pilot Line,[5] an €830 million cross-EU project aligned with the Chips JU mission. CEA-Leti coordinates FAMES with participants across the EU.

The pilot line will develop five new sets of technologies, three of which are directly relevant to RF and microwave devices:

- Two new-generation nodes for FD-SOI, at 10 nm and 7 nm
- Several types of embedded non-volatile memories (OxRAM, FeRAM, MRAM and FeFETs)
- RF components (switches, filters and capacitors)
- Two 3D integration options (heterogeneous integration and se-

quential integration)

- Small inductors to develop DC-DC converters for power management integrated circuits.

FAMES is supported by 43 companies across the value chain, including materials providers and equipment manufacturers, EDAs, IDMs, system houses and end users, as well as the semiconductor companies themselves. ***Figure 2*** shows the geographical distribution of the consortium members across Europe.

"By integrating and combining a set of cutting-edge technologies, the FAMES Pilot Line will open the door to disruptive system-on-chip architectures and provide smarter, greener and more efficient solutions for future chips. The FAMES project will indeed pay special attention to semiconductor sustainability challenges," said Jean-René Lèquepeys, CTO of CEA-Leti.

Other French participants in FAMES are the SiNANO Institute in Grenoble, a non-profit network of researchers in the nanoelectronics field and Grenoble INP-UGA, the city's polytechnic institute of technology that combines engineering and management schools.

OTHER RF SILICON ACTIVITIES

Another multinational semiconductor vendor with a large footprint in France is NXP. It has facilities in Toulouse and Caen and an R&D site in Mougins on the Cote d'Azur in the south. NXP specializes in secure connectivity solutions.

NXP Toulouse is located at the epicenter of France's automotive, communications and industrial ecosystem in the area, which is also known for its aerospace industry. The Toulouse facility is a former Motorola/Freescale site with a 57-year history. It specializes in the design of RF semiconductors and sensors, with a particular emphasis on developing V2X communications for connected and autonomous vehicles (CAVs) and smart cities.

NXP Caen is located on the Effi-Science Campus in Normandy. At this location, it is part of a cluster of related companies and research organizations. NXP Caen, which was originally part of Philips, is involved in R&D and IC design.

COMPOUND SEMICONDUCTORS

In 2023, MACOM acquired OMMIC, one of France's two compound semiconductor fabs. OMMIC had a 40-year history of providing GaAs, InP and GaN MMICs for the space market and offering professional foundry services. More recently, they had been operating a 100 nm GaN-on-Si process for higher-volume opportunities in 5G and 6G infrastructure. MACOM has now established

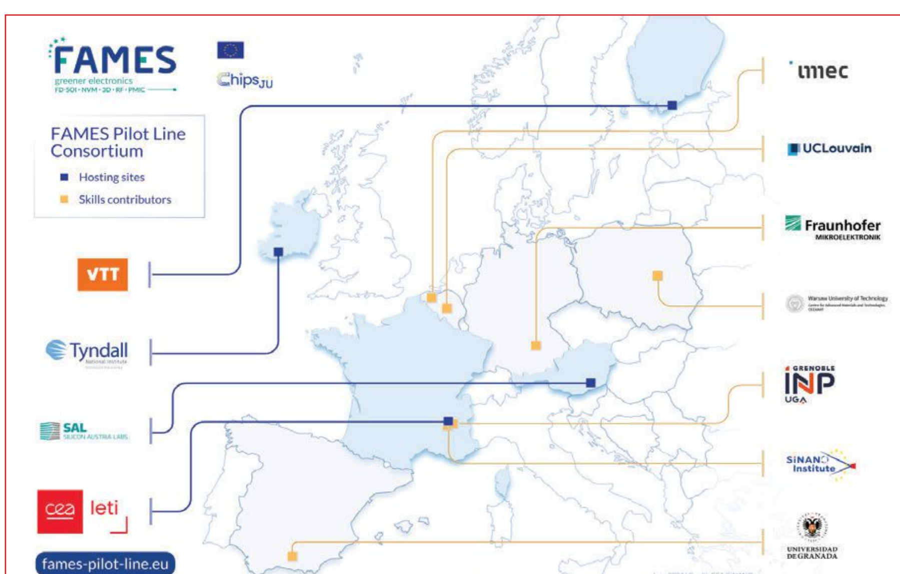

Fig. 2 Geographic locations of the FAMES Pilot Line Consortium members.

its European Semiconductor Center on the site in Limeil-Brévannes near Paris. It is dedicated to developing semiconductor technology and continuing to fabricate MMICs to support applications in space, telecoms, aerospace and defense. Products available from MACOM's European Semiconductor Center include MMICs covering DC to 110 GHz, offered as bare die, tabbed and packaged devices. The main product categories are PAs, LNAs, wideband amplifiers and core chips for both transmit and receive chains in phased array antennas.

France's growing position and reputation in the semiconductor industry are encouraging an increasing level of investment from outside the country, either by acquisition, as in the case of MACOM and OMMIC, or through the establishment of local design centers. Viper RF France is an example of the latter trend. Viper RF is a U.K. company that specializes in the design and supply of GaAs and GaN MMICs and microwave modules between 1 GHz and 150 GHz. In 2021, Viper RF established a wholly-owned French subsidiary in Cesson-Sévigné, near Rennes, to offer non-ITAR solutions aimed at the French and European markets.

France's other main compound semiconductor fab is United Monolithic Semiconductors (UMS). UMS, which is a joint venture between Thales Group and Airbus, has facilities in Germany as well as in Villebon, Paris. The latest product introduction from UMS is the CHA6354-QQA, a three-stage monolithic GaN HPA with up to 4 W of output power over a frequency range of 27.5 to 30 GHz. This device also includes a SPDT switch at the output. The HPA provides a linear gain of 27 dBm with a power consumption of 12 mA at a drain voltage of 25 V. The circuit is manufactured on a mature GaN-on-SiC HEMT technology and is particularly suited for satcom uplink and 5G applications. The input and output are internally matched to 50 Ω and contain integrated ESD RF protection. The CHA6354-QQA is available in a standard surface-mount 28-lead QFN 5×4 RoHS-compliant package.

TEST

France also boasts considerable expertise in RF and microwave test capabilities. Hytem is a company with a 30-year history, having first been established in 1994. Located south of Paris, it designs and manufactures RF and microwave test systems and components, including attenuators, switch matrix systems and phase shifters, along with coaxial cable assemblies up to 40 GHz. These components find use in cellular, military, transportation and medical applications.

Spherea spun out of Airbus 10 years ago and has since made several strategic acquisitions, including NoiseXT. In addition to NoiseXT's range of high spectral purity signal measurement and generation instruments, they have a broad range of RF products. These include test benches for mission equipment used in air and land military systems and for TCAS and radar, payloads for drones that characterize antenna radiation lobes and analyze signals, an RF software suite for broadband spectrum analysis and monitoring, electromagnetic intelligence and analysis of radar signals.

END USE MARKETS

Overall, France's RF and microwave market retains its traditional focus on the aerospace industry, much of which is concentrated around the Toulouse area.

Thales is the largest defense electronics company in Europe and is a leading supplier of ground, sea and air surveillance radars to armed forces, both within Europe and worldwide. Its subsidiary Thales Alenia Space, a joint venture between Thales (67 percent) and Leonardo (33 percent), was a prime contractor for the ASTRA 1P communications satellite that was successfully launched in June by a SpaceX Falcon 9 rocket from Cape Canaveral in Florida. Thales Alenia Space was responsible for the design, manufacture and assembly of the satellite and its integration and testing.

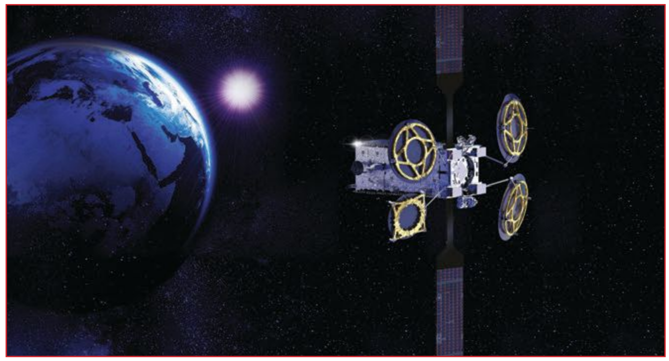

Fig. 3 The ASTRA 1P satellite. *Source:* © Thales Alenia Space/E. Briot.

The wide-beam geostationary satellite has a launch mass of five metric tons, a payload that includes 80 Ku-Band transponders and is capable of broadcasting more than 500 television channels simultaneously. ***Figure 3*** shows an artist's rendition of the ASTRA 1P satellite.

Safran Electronics & Defense is another French company in this sector. They specialize in avionics, helicopter controls and UAVs. Earlier this year, Syrlinks, a Safran Electronics & Defense company based in Rennes, announced that it would equip the latest generation of LeoStella LS-300 satellite buses with its high performance N-SPHERE GNSS receiver for low Earth orbit applications. LeoStella is one of the leading manufacturers of small satellite constellations in the U.S.

N-SPHERE is a new-generation GNSS receiver designed by Syrlinks. It implements state-of-the-art positioning and synchronization techniques to achieve real-time precise onboard orbit determination (P2OD). It can be synchronized with various GNSS systems and offers high precision positioning of the order of 10 cm, making it suitable for use by international defense customers.

Dassault Aviation is a French defense and aerospace company that manufactures military aircraft, including the Rafale fighter and business jets such as the Falcon, as well as military drones and space systems.

Airbus is a multinational company employing 134,000 people, with almost 48,000 of them in France. Its headquarters are in Toulouse, with other French sites for aerospace and defense located in Elancourt and Sophia Antipolis. Two years ago, Airbus launched a high altitude platform station (HAPS) connectivity services business based on its HAPS technology platform, Zephyr, enabling it to provide low latency connectivity services from the stratosphere for telecommunications and Earth observation.[6]

Automotive electronics is a growing area of interest for microwaves and RF companies, especially as the production of CAVs begins to grow. France not only has several domestic vehicle brands, Citroën, Renault, Peugeot and Bugatti being the best known, but it also has a very strong supply chain in the automotive sector. ■

References

1. H. Duncan, "Du Pain, Du Vin, Du Fromage, Des Microondes: EuMW En Route to the French Capital," *Microwave Journal*, August 2019, Web: www.microwavejournal.com/articles/32656-du-pain-du-vin-du-fromage-des-microondes-eumw-en-route-to-the-french-capital.
2. The Chips Joint Undertaking (Chips JU), Web: www.chips-ju.europa.eu/.
3. "STMicroelectronics and GlobalFoundries to Advance FD-SOI Ecosystem," *Microwave Journal*, July 2022, Web: www.microwavejournal.com/articles/38521-stmicroelectronics-and-globalfoundries-to-advance-fd-soi-ecosystem.
4. "GLOBALFOUNDRIES and Soitec Announce RF-SOI Wafer Supply Agreement," *Microwave Journal*, November 2020, Web: www.microwavejournal.com/articles/34911-globalfoundries-and-soitec-announce-rf-soi-wafer-supply-agreement.
5. FAMES Pilot Line, Web: www.fames-pilot-line.eu/.
6. "Airbus to Deliver Connectivity Services Using its Leading Zephyr HAPS," *Microwave Journal*, July 2022, Web: www.microwavejournal.com/articles/38575-airbus-to-deliver-connectivity-services-using-its-leading-zephyr-haps.

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Safran Launches Skyjacker Counter-Drone System

At Eurosatory 2024, Safran Electronics & Defense announced the launch of its Skyjacker counter-drone solution. Skyjacker is an effective response to the growing threat posed by drones in the battlespace and at sensitive installations. Skyjacker's strength lies in its unique spoofing capability: it alters the trajectory of a drone to neutralize the threat it represents by simulating the GNSS signals, ensuring guidance toward its target. Coupled with radar detection and optronic identification, Skyjacker can efficiently defeat isolated drones and drone swarms in land and naval environments.

Skyjacker replaces the hostile drone's satellite guidance signals with modified signals designed to deceive the drone about its position to disrupt or interrupt its mission. Skyjacker is particularly well suited to countering saturation attacks, such as swarming drones. The system can also defeat isolated drones piloted remotely by an operator and deliver effects at ranges from 1 to 10 km (over 6 miles).

Skyjacker's modular design incorporates a command and control unit to manage the entire system, as well as one or more spoofing transmitters. It can be coupled with a wide array of sensors, such as optronic sights, radars and RF detectors, lasers, communication jammers and other effectors. Skyjacker can be deployed as a mobile version or interconnected with existing surveillance and fire control systems on land vehicles or naval vessels.

To deliver an initial mobile version of Skyjacker, Safran Electronics & Defense teamed with Hologarde, which designed the Bassalt anti-drone system for the French Air and Space Force to protect major events (Paris Olympics Games, G7 summit, Bastille Day parade). Safran Electronics & Defense and Hologarde demonstrated Skyjacker's effectiveness at the Coubertin LAD II exercise organized by the Air and Space Force's Air Defense and Air Operations Command at Air Base 107 in Vélizy-Villacoublay, near Paris, in March 2024.

Skyjacker (Source: Safran S. A.)

Future Soldier System Developed by Indra and GMV

Indra and GMV have taken a decisive step forward in the development of the Future Soldier System (SISCAP, in Spanish), after carrying out an operational demonstration at the Toledo Infantry Academy with this solution, which boosts the soldier's communication, information and fire efficiency capabilities.

As a result of an R&D program funded by the Ministry of Defence through the Subdirectorate General for Planning, Technology and Innovation (SG PLATIN), the progress of this new development is being supervised by the Directorate General for Armaments and Material.

Indra and GMV's aim is to equip combatants with advanced technologies for use in digitalized theaters of operations, where they will have to operate in a network with systems adapted to the new combat cloud concept.

FSS (Source: Indra)

Each soldier will have a viewfinder attached to their helmet that, through augmented reality, will allow them to visualize the route to follow and the position of their companions and to receive different tactical indications about threats and identified targets. They will also have both day and night viewfinders, personal cameras (visible and thermal) to gather images and an advanced radio that will position them by satellite and allow them to transmit voice and data, as well as setting up different groups for improved coordination.

The regulation weapon will incorporate its own viewfinders and cameras that extend the range and accuracy of fire and allow the possibility of indirect fire, so that the image captured by the weapon's viewfinder can also be seen in the helmet's viewfinder, thus avoiding exposure when turning a corner or entering an enclosed area. It will also incorporate controls to manage communications without having to release the rifle and to prevent friendly fire.

The platoon leader will have a tablet connected to the battlefield management system used in the U.S. Army's armored vehicles, thus integrating the unit into the chain of command.

In exercises held recently at the Toledo Infantry Academy, a platoon of legionnaires evaluated the system by simulating a reconnaissance mission and other day and night surveillance missions. They also conducted various day and night shooting tests. The next and final test that SISCAP will undergo in the coming months will add to this equation the presence of the 8x8 Dragon armored vehicle, which will act as a communications node between the unit and the tactical command and control center.

For More Information

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Indra and GMV's goal is to close this first development phase this year, delivering the first seven functional prototypes in platoon-leader configuration. In subsequent phases, the possibility of manufacturing an initial pre-series of 40 or 50 systems will be studied for evaluation in real operations, and then, from 2030 onwards, for larger-scale production.

Thales Unveils OpenDRobotics

With OpenDRobotics, Thales is taking collaborative combat to the next level through the development of a revolutionary integrated system that ties together robotics technologies and different types of drones to provide an automated mission system capability.

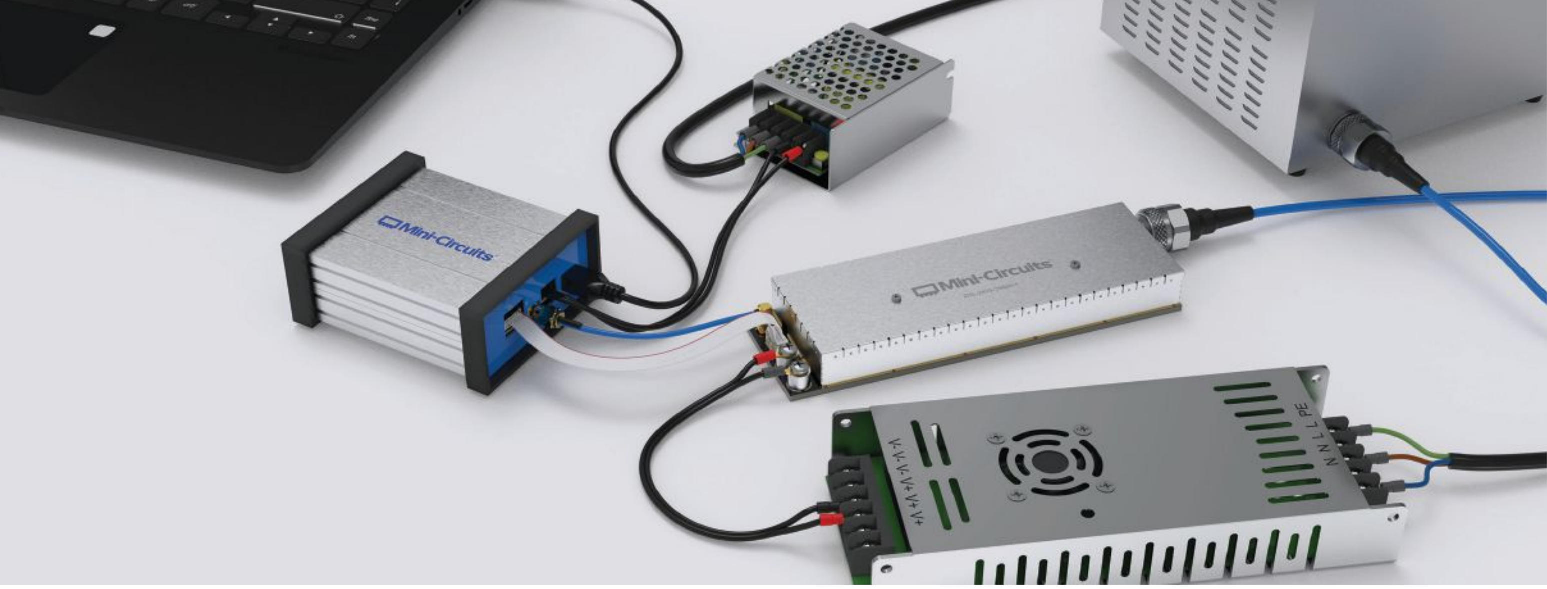
Recent conflicts have demonstrated the operational value of drones and robotic systems in terms of battlefield transparency and speed of action to enhance mission effectiveness while keeping human operators out of harm's way. These systems can also saturate enemy defenses without requiring larger numbers of human operators or increasing the cognitive burden on the forces already deployed.

Thales is a pivotal player in the field of collaborative combat, providing AI modules, connectivity solutions, mission systems that enable engaged units to operate as a network and a unique ability to integrate with conventional assets already in service with land forces.

OpenDRobotics (Source: Thales)

Building on the success of CohoMa II Robotics Challenge, the OpenDRobotics initiative creates operational value by coordinating the capabilities of a wide range of drones and robotic systems, providing command-and-control and extending collaborative combat functions by capitalizing on the group's long-standing experience with tactical mission systems, particularly the Scorpion program.

OpenDRobotics has a central role to play in a broad spectrum of armed forces missions, such as reconnaissance, intelligence, CBRN, Special Forces operations, cavalry and artillery. It builds on the open-source Robot Operating System and STANAG 4586 standards, which are widely used by NATO and were developed as collaborative initiatives to promote easier integration of drones and robotic systems developed by partners and third parties.



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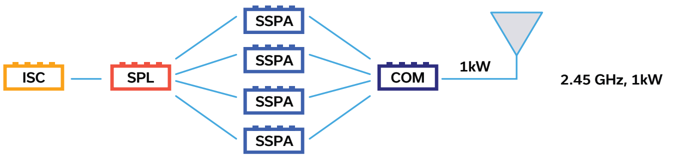

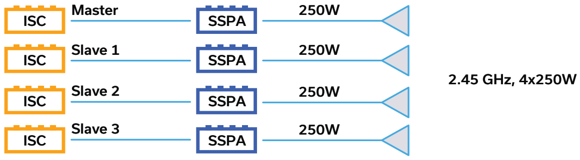

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RF GaN: Telecom Infrastructure Takes the Lead

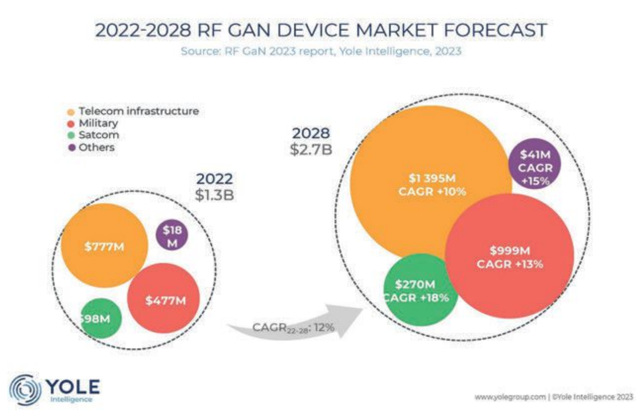
In telecom infrastructure, GaN has penetrated various base stations with its high power and high frequency performance benefits. With the transition from remote radio heads to advanced antenna systems in macro/microcells, massive MIMO requires more power amplifier units per base station. The higher PAE and broadband capability at frequencies above 3 GHz compared to LDMOS is an opportunity for GaN to grow. The GaN-based telecom infrastructure device market will represent almost 45 percent of the total market by 2028.

As a traditional GaN market, the defense segment is one of the main drivers for GaN RF. GaN-on-SiC is still the primary platform supplying demanding applications in defense radar, electronic warfare and defense communication applications.

In this dynamic context, Yole Intelligence has released its annual RF GaN report. This study provides an overview of the market and the players in the various segments, along with their product ranges and technologies. The company, part of Yole Group, outlines each segment's market dynamics and main technologies. Analysts also explain the requirements of the various RF markets and their corresponding impact on the need for different technologies, along with geographical specificities.

In 2022, SEDI, Qorvo and Wolfspeed were the leading players in the RF GaN device business, while NXP has gained significant growth by entering the telecom market's supply chain. The S.I. SiC wafer market remains shared by the three major suppliers, Wolfspeed, Coherent and SICC. In the defense segment, Raytheon, Northrop Grumman and Chinese CETC are leading GaN adoption. Department of Defense-trusted Wolfspeed and Qorvo are also GaN foundries. Focusing on the suppliers to the telecom market, Ericsson and Nokia continue developing the supply of RF GaN devices to source from multiple suppliers while Samsung cooperates closely with Korean device players. Since the U.S. sanction, Huawei and ZTE have turned to the Chinese supply chain to develop domestic capability.

With technology node evolution, device players developing platforms for the Ku/K/Ka-Bands are even targeting nodes under 0.1 μm for sub-THz frequencies and a potential 6G market in the future. The target of the emerging GaN-on-Si platform for RF applications is a sub-6 GHz small cell by leveraging the efficiency and wide bandwidth at a lower power level. However, considering the complexity of changing the design of handset systems, it is a longer-term target market for GaN-on-Si.

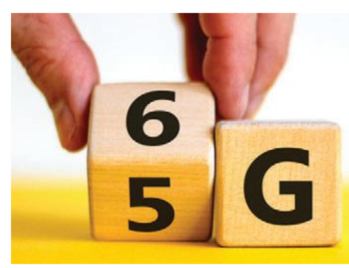


RF GaN Market Forecast (Source: Yole Intelligence)

New Technical Recommendations Will Support Network Evolution Toward 5.5G and 6G for Wi-Fi7 and 400GE

The World Broadband Association (WBBA) has published technical recommendations for networking evolution in the 5.5G era to address the increasing demands for ubiquitous 10 Gbps access for businesses, campuses and homes.

Network 5.5G (Net5.5G) defines the next-generation data communication network infrastructure for network evolution in the era of 5.5G and artificial intelligence (AI) computing. Building a future-proof digital IP transport foundation to deliver secure operations, reduced construction costs and improved efficiency for networks, constitutes a Net5.5G framework.



5.5G (Source: Shutterstock)

Net5.5G marks the evolution of existing 5G mobile network technologies, offering downlink speeds of 10 Gbps and uplink speeds of 1 Gbps. End users will be able to use it to set up their own IoT networks within their residential properties, with smartphones and other connected devices able to be used as gateways.

For Telcos, Net5.5G holds the key to enhanced monitoring and analytic capabilities, while service providers are empowered to offer managed services for the smart home. Net5.5G also offers benefits to data center operators, as the additional bandwidth can help support larger AI training models for business uses.

Supporting further industry digitalization and key AI applications, Net5.5G will also provide an excellent customer experience for services requiring high speed, high-quality communication, underpinning new trends such as Wi-Fi 7 and computing-aware networks.

The 'Network Evolution for the 5.5G and 6G Era'

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Technical Recommendations, published for the first time during BDC Shanghai 2024, can be found on the WBBA's website.

Global 5G Connections Reach Nearly Two Billion

The wireless telecommunications industry experienced another quarter of strong expansion and technological advancement, driven by the relentless advance of 5G technology. In the first quarter of 2024, the global adoption of 5G connections continued its steady climb, reaching nearly two billion with the addition of 185 million new connections, according to data from 5G Americas and Omdia.

North America leads the charge in 5G adoption, with 5G connections comprising 32 percent of all wireless cellular connections. Notably, the region experienced healthy growth in the first quarter, adding 22 million new connections to operator networks. In the first quarter of 2024, North American 5G connections totaled 220 million.

Last quarter, Latin America also witnessed solid growth in 4G LTE and 5G connections, adding eight million new LTE connections for a total of 591 million across the region. Additionally, the region continues to embrace the 5G revolution, with nine million new 5G connections added to reach a total of 48 million. 4G LTE subscriptions continue to remain strong throughout the region, even as the availability of 5G handsets and spectrum continue to grow.

Looking ahead, Omdia forecasts paint a picture of the telecommunications landscape we can expect to see throughout this decade. Global 5G connections are projected to reach 7.7 billion by 2028, with North America forecast to boast an impressive 700 million 5G connections by the same year.

The IoT ecosystem will continue to remain a fundamental component of the digital revolution. Currently, global IoT subscriptions stand at 3.3 billion, complemented by 6.7 billion smartphone subscriptions. Forecasts suggest that IoT subscriptions will reach 5 billion, while smartphone subscriptions will surge to 8 billion by 2028, highlighting the evolving nature of connectivity and the interconnectedness of our digital world.

Globally, the number of deployed 5G networks has exceeded the pace of 4G LTE network deployments at the equivalent time in the technology cycle. There are nearly as many 5G North American deployments as there are 4G LTE networks. Currently, there are 316 commercial 5G networks worldwide, a number that is expected to grow alongside continued significant investments in 5G infrastructure worldwide.

Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Honeywell announced that it has agreed to acquire **CAES Systems Holdings LLC (CAES)** from private equity firm Advent International for approximately $1.9 billion in an all-cash transaction. This represents approximately 14x estimated 2024 EBITDA on a tax-adjusted basis. This acquisition will enhance Honeywell's defense technology solutions across land, sea, air and space, including new electromagnetic defense solutions for end-to-end RF signal management. With CAES' scalable offerings and Honeywell's current defense and space portfolio, the combined company will grow Honeywell's established production and upgrade positions on critical platforms that include F-35, EA-18G, AMRAAM and GMLRS, while also introducing offerings on new platforms like Navy Radar (SPY-6) and UAS and C-UAS technologies.

Gilat Satellite Networks Ltd. announced that it has signed a definitive agreement to acquire **Stellar Blu Solutions LLC**, which will become a core component of Gilat's IFC growth strategy. Stellar Blu Solutions is a U.S.-based leading avionics solution provider of next-generation satcom terminal solutions. The acquisition is a significant step in Gilat's initiative to increase its presence in the growing IFC market. Gilat expects its annual revenues from the acquired business to range between $100 million to $150 million beginning in 2025, based on Stellar Blu's existing backlog. The acquisition is expected to be accretive on a non GAAP basis starting in the second half of 2025.

COLLABORATIONS

Anritsu and **ETS-Lindgren** announced test support for devices using narrowband non-terrestrial network (NB-NTN) protocol. The collaboration combines the strengths of ETS-Lindgren and Anritsu to offer a comprehensive solution for the testing and validation of NB-NTN devices. The partnership leverages Anritsu's MT8821C Radio Communication Analyzer, a solution for RF verification and functional tests of mobile devices, with ETS-Lindgren's EMQuest™ Antenna Measurement Software and Wireless Test Solutions. Anritsu's MT8821C supports cellular technologies, including LTE-Advanced and IoT, in accordance with 3GPP RF test specifications. Recognized for its wide dynamic range, the MT8821C maintains a stable wireless connection even in challenging, high loss environments.

KATIM, an **EDGE Group** entity and leader in the development of ultra-secure communication solutions, and **Thales** have started discussing the co-development of software-defined radio technologies in the United Arab Emirates (UAE). A declaration of intent was signed at the international defence and security show, Eurosatory, by Didier Pagnoux, CEO of KATIM; Abdelhafid Mordi, CEO Thales in the UAE; and Christophe Groshenry, vice president, radio at Thales and in the presence of Hamad Al Marar, managing director and CEO of EDGE Group, Waleid Al Mesmari, president, space and cyber technologies of EDGE Group, Pascale Sourisse, president and CEO Thales International, and Christophe Dumas, CEO Thales Secure Communications and Information Systems in France.

Ericsson, in collaboration with **3 Denmark**, **TV 2** and **Sony**, has successfully trialed a live television broadcast of a high-profile football match over a 5G standalone (SA) network, leveraging cutting-edge mmWave technology. The landmark trial at Parken Stadium in Copenhagen marks a transformative leap in the production and consumption of live sports entertainment in Denmark. The live broadcast was transmitted over 3 Denmark's 5G SA infrastructure, which is supplied exclusively by Ericsson and includes the dual-mode 5G Core solution, transport and RAN. The trial was the first of its kind in Denmark utilizing 5G mmWave on a 5G SA network.

BAE Systems and **GlobalFoundries (GF)** announced a new collaboration to strengthen the supply of critical semiconductors for national security programs. Under the strategic agreement, the companies will align technology roadmaps and collaborate on long-term strategies for increasing U.S. semiconductor innovation and manufacturing, with the joint goal of advancing the ecosystem for domestic fabrication and packaging of secure chips and solutions for use in aerospace and defense systems. Together, the companies will engage in long-term planning for emerging technologies and collaborate on research and development in a range of areas, including advanced semiconductor packaging and integration, GaN on silicon chips, silicon photonics and advanced technology process development.

Exolaunch, a global leader in launch mission management, integration and satellite deployment services, announced a new launch and deployment services agreement with **Sateliot**, the first company to operate a low earth orbit (LEO) 5G NB-IoT satellite constellation based in Barcelona, Spain, and San Diego, Calif., marking the first collaboration between the two companies.

Eclipse Global Connectivity, **ThinKom**, **Kontron** and **Display Interactive** have embarked on an innovative collaboration to retrofit a fleet of more than 50 narrow-body aircraft with the ultimate high speed connectivity. This groundbreaking solution is set to revolutionize in-flight connectivity for airlines worldwide.

NEW STARTS

Valvo Bauelemente GmbH of Hamburg, Germany, a leading European manufacturer of high-power microwave and RF components, announced it is rebranding and unveiling a new name, **Microwave Techniques GmbH**. This announcement comes as part of a stra-

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tegic alignment with its parent company, Microwave Techniques LLC, a global leader in high-power microwave and RF solutions. In 2023, Microwave Techniques acquired Valvo (now Microwave Techniques GmbH), to take advantage of synergies across teams, facilities, products and resources in the U.S. and Germany. Since then, the combined company has continued exploration of advanced research and development of its design, engineering and manufacturing of circulators, isolators, loads and windows, as well as further innovations for various high-power microwave and RF component product lines.

ACHIEVEMENTS

Quantic Croven (Croven Crystals) celebrates 70 years of innovation and exceptional service to the RF and microwave industry. Since its founding, the company has continually pushed boundaries in quartz crystal resonator technology, supporting a wide array of mission-critical defense and space applications. The company was originally founded in 1954 as W. Gary-Wright Electronics to assemble quartz crystal resonator products for various Canadian defense applications. It later changed its name to "Croven Ltd." to reflect its focus on crystal oven products. In 1959, the company established the Ovenaire subsidiary, specializing in precision ovens and oscillators.

Rohde & Schwarz joined **AI-RAN Alliance** and leverages its test and measurement expertise to unlock the potential of AI for wireless communications. By joining the AI-RAN Alliance, Rohde & Schwarz further aligns itself with key industry players such as NVIDIA, Ericsson, Nokia and Samsung and strengthens its role in the development of AI-native air interface test methodologies. Rohde & Schwarz will contribute its cutting-edge test and measurement solutions and many years of expertise to the alliance for the optimization of next-generation wireless networks. Prior to joining the alliance, Rohde & Schwarz collaborated with NVIDIA's research team on 6G research, pioneering a test bed for exploring neural receiver implementations that promise to revolutionize the air interface by improving performance and network efficiency.

Mavenir, **Qualcomm** and **EchoStar** successfully demonstrated the Reduced Capability (RedCap) 5G capabilities of its Open virtualized Radio Access Network (Open vRAN) solution on the Boost Mobile Network in the U.S. This milestone demonstration, delivered using Qualcomm's Snapdragon® X35 5G Modem-RF System, marks the first validation of 3GPP RedCap 5G capabilities on an Open RAN network, indicating significant promise for existing and future 5G IoT and connected device use cases.

Arctic Semiconductor announced that its low-power, high performance 4×4 transceiver, IceWings, is powering a new small cell platform that has passed 3GPP specification and will soon be available in mass pro-

RF & Microwave Amplifiers

10KHz-75GHz

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MILITARY APPLICATIONS

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Model Number	Frequency Range	Rated Power Watts	Gain dB
10KHz-250MHz, Low Frequency Amplifiers			
AMP2080B	10kHz-250MHz	100	50
AMP2080C-1	10kHz-250MHz	150	52
AMP2080C	10kHz-250MHz	300	55
AMP2080D	10kHz-250MHz	600	58
80-1000MHz, VHF, UHF Range Amplifiers			
AMP2032	80-1000MHz	300	55
AMP2071-2	80-1000MHz	500	57
AMP2071A-LC	80-1000MHz	750	60
AMP2115-LC	80-1000MHz	1300	61
AMP2121-LC	80-1000MHz	2000	63
700MHz-6.0GHz, Broadband Amplifiers			
AMP2070C	0.7-6.0GHz	100	50
AMP2070A	1.0-6.0GHz	150	52
AMP2030-LC	1.0-6.0GHz	300	55
AMP2030-600-LC	1.0-6.0GHz	600	58
AMP2030D-LC	1.0-6.0GHz	750	59
AMP2030LC-1KW	1.0-6.0GHz	1000	60
2.0-8.0GHz, SC Band Amplifiers			
AMP2085-1	2.0-8.0GHz	120	51
AMP2085C	2.0-8.0GHz	200	53
AMP2085E-1LC	2.0-8.0GHz	250	54
AMP2085E	2.0-8.0GHz	400	56
6.0-18.0GHz, High Frequency Amplifiers			
AMP2118	6.0-18.0GHz	40	46
AMP2111	6.0-18.0GHz	50	47
AMP2033-LC	6.0-18.0GHz	100	50
AMP2065A-LC	6.0-18.0GHz	200	53
AMP2065B-LC	6.0-18.0GHz	300	55
AMP2065E-LC	6.0-18.0GHz	500	57
18-26.5GHz, K-Band, Millimeter Amplifiers			
AMP4032	18.0-26.5GHz	10	40
AMP4065LC-1	18.0-26.5GHz	20	43
AMP4065-LC	18.0-26.5GHz	40	46
AMP4065A-LC	18.0-26.5GHz	100	50
AMP4065B-LC	18.0-26.5GHz	200	53
26.5-40.0GHz, Ka-Band, Millimeter Amplifiers			
AMP4072	26.5-40.0GHz	10	40
AMP4066LC-1	26.5-40.0GHz	20	43
AMP4066-LC	26.5-40.0GHz	40	46
AMP4066A-LC	26.5-40.0GHz	100	50
AMP4066B-LC	26.5-40.0GHz	200	53
18.0-40.0GHz, Millimeter Amplifiers			
AMP2145A-LC	18.0-40.0GHz	10	40
AMP2145B-LC	18.0-40.0GHz	25	44
AMP2145C-LC	18.0-40.0GHz	50	47
40.0-50.0GHz, Q-Band, Millimeter Amplifiers			
AMP4076-1	40.0-50.0GHz	5	37
AMP4076A	40.0-50.0GHz	20	43
AMP4076B	40.0-50.0GHz	40	46
AMP4076C	40.0-50.0GHz	80	49

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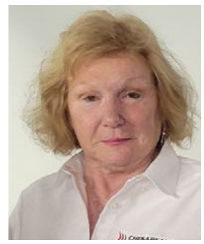
duction. In addition to Arctic's IceWings the platform includes Skyworks Solutions, Inc.'s family of power amplifiers and timing products, as well as Synergy Design's carrier-grade 5G vRAN solutions. This cost-optimized platform enables service providers and private network developers to deploy custom 5G networks at scale, a pivotal milestone in 5G infrastructure development.

CONTRACTS

Raytheon, an RTX business, was awarded a $677 million contract to continue to produce AN/SPY-6(V) radars for the **U.S. Navy**. This is the third option exercised from the March 2022 hardware, production and sustainment contract that is valued up to $3 billion over five years. Under this contract, the U.S. Navy will receive seven additional radars, increasing the total amount of radars under contract for procurement to 38. The U.S. Navy is integrating SPY-6 into its surface fleet beginning with the USS Jack H. Lucas (DDG 125) that was commissioned in October 2023. The USS Richard M. McCool Jr. (LPD 29) is the second ship and the first to deploy the (V)2 variant.

Stellant Systems Inc. recently announced that its **Power Systems Technology (Stellant PST)** business was awarded $8 million for multiple contracts for the procurement of its high-power solid-state power amplifiers. The awards were received from several major domestic prime contractors. These highly integrated amplifiers, which utilize the latest in solid-state GaN transistor and semiconductor technology, are essential transmit and receive elements in complex data communication systems for both legacy and new applications. They are a result of Stellant's investments in surface-mount and chip/wire technologies and the people that design and produce these state-of-the-art products.

PEOPLE

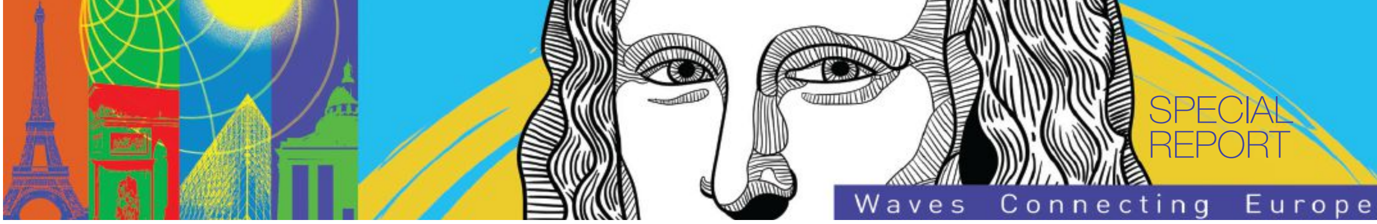


▲ *Bernadette Rawlins*

Chesapeake Advanced Technologies, a technical sales organization for Maryland, Washington D.C., Delaware, Virginia, Pennsylvania (Pa.) and New Jersey (N.J.), announced the addition of **Bernadette Rawlins** as regional account manager for the Pa. and N.J. territory. Rawlins spent the last 15 years in sales and business development positions with Cobham/CDES antenna and RF module group in Lansdale, Pa.

REP APPOINTMENTS

ERZIA announced a new distribution partnership with **Impulse Technologies**, a manufacturer and distributor of RF components based in New York. As ERZIA continues to grow and expand its reach in the U.S., it was natural to partner with an industry pioneer and trusted RF distributor.



Welcome to the 27th European Microwave Week

Guillaume Ducournau, General Chair
University of Lille, IEMN-CNRS, France

Dear colleagues and friends of the microwaves community, it is our great pleasure to welcome you, just after 2024 Paris Olympics, to the 27th European Microwave Week (EuMW). This year, the EuMW stops at Vi-Paris, Porte de Versailles, Paris, 22-27 September 2024.

"Waves Connecting Europe" is our motto to keep in mind how important microwave technologies are fundamental to connect people in this planet. The COVID period and series of lockdowns showed us how important it is to stay connected to each other.

The European Microwave Week was initiated by the European Microwave Association (EuMA) in 1998. EuMW 2024 continues the series of successful microwave events held in Amsterdam, London, Munich, Milan, Manchester, Nuremberg, Paris, Madrid, Utrecht (Virtual) and Berlin, with:

- The 54th European Microwave Conference (EuMC), from 23 to 24, September 2024
- The 19th European Microwave Integrated Circuits Conference (EuMIC): from 24 to 26, September 2024
- The 21st European Radar Conference (EuRAD): from 25 to 27, September 2024.

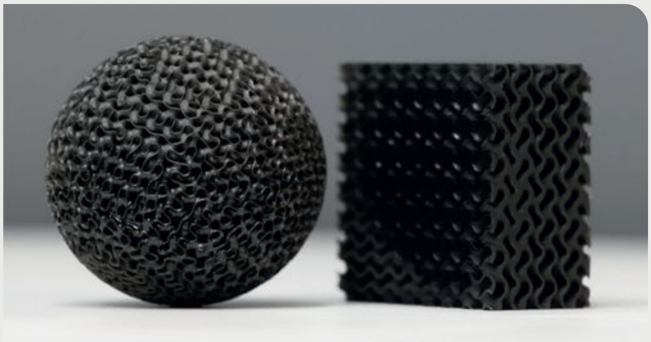
The EuMW 2024 received 800 papers and thanks to the excellent work of the 437 reviewers, the 121 members of the TPC were able to prepare 101 technical regular sessions representing 506 papers. The programme contains 25 Workshops and four Short Courses, as well as Special Sessions, covering the most relevant topics ranging from microwave and mmWave circuits, antenna and transceiver systems for 5G and beyond, THz, microwave photonics, high data rate communications and Special Sessions, as joint APMC sessions link with activities in the Asia Pacific Region.

This year's programme will boost and intensify the interaction between industry and academia thanks to a number of keynotes who will open select sessions. New topics related to sustainability in microwaves have been introduced in the EuMW technical program, with dedicated sessions. Two MTT-S intersociety panels will also cover the sustainability topic and the microelectronics and chip initiatives: Attractivity, Youth and Environment.

Internationally renowned speakers will discuss the latest trends and developments in their keynotes at the conference's Plenary Sessions. Among these, at the Opening Session of the EuMW, we are very happy to welcome Jean-Pierre Raskin of Louvain School of Engineering, who will present "Information Communication Technology for the Best and the Worst." The EuMIC opens with Andrei Cathelin of STMicroelectronics, with a talk on "FD-SOI: game-changer in the IoT arena." The EuRAD opening will welcome Peter Burke from University of California, Irvine, to discuss "Microwaves, from nano to macro," with focus on nano-radars and drones.

The 2024 DSS will discuss future defense strategies and technological advances, starting with the General Bordelles, Ministry of Defence, France.

The automotive forum will continue to provide an open platform for industrial experts to discuss



technical aspects and market issues in the area of microwaves in automotive industry, with oral and poster presentations.

The 6G Forum is a one-day journey to dive into the main important research and development trends of 6G. This forum, with invited speakers from industry, operators, vendors and academia will give a complete vision of the 6G panorama: European initiatives, key enabling technologies and cross-views with operators, OEMs and applications. A "6G-corner" in the exhibit will showcase state-of-the-art industrial and academic live demos of first 6G systems.

The Women in Microwave Engineering (WiM) event, co-sponsored by the IEEE MTT-S, will focus on the topic "Woman in Academia: an European Tour of Boosters and Breaks." Attendees will have the chance to visit the "Musée d'Art Moderne," with "La féé électricité de Raouf Dufy."

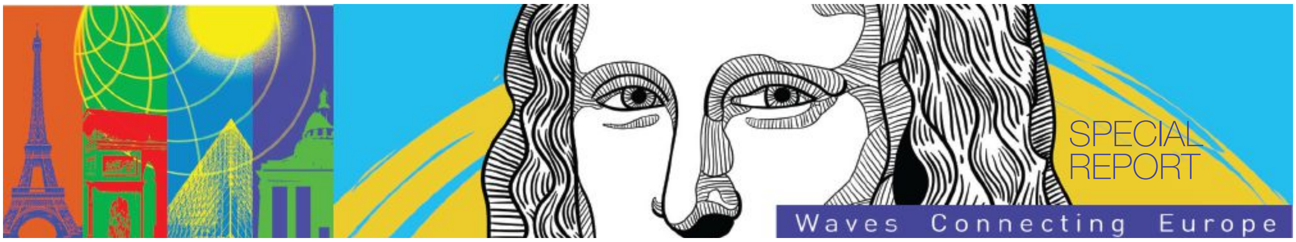
Students schools will also be running during the week, this year on design and radar topics, with lectures and hands-on/labs.

Young professionals and students are also welcome to participate in the meet-up (Sunday) for networking and find their future job at the Career Event on Wednesday afternoon (job dating with 16 companies' talent teams present on-site) and the student career party Wednesday evening.

Another key event of the EuMW is the European Microwave Exhibition. This year is expected to be the largest RF trade show in Europe since the first EuMW, with 5,000+ expected visitors, 1,700 to 2,000 conference delegates and 300+ international exhibitors.

We will also be able to meet together in the traditional EuMIC Get-Together, Welcome Reception sponsored by Keysight Technologies and the EuRAD lunch on Friday.

At the top of these, this year, each delegate will be able to enjoy a seated lunch during the conference days. We are really looking forward to hosting and seeing you in Paris for an exciting in-person EuMW! ■



Attending EuMW 2024: Bonjour

Pat Hindle, *Microwave Journal*

The 27th edition of the European Microwave Week (EuMW 2024) will take place in Paris, France, and continues the annual series of highly successful microwave events that started back in 1998. EuMW 2024 will take place 22 – 27 September and comprises three co-located conferences: European Microwave Conference (EuMC), European Microwave Integrated Circuits Conference (EuMIC) and European Radar Conference (EuRAD). In addition, EuMW 2024 includes the Defense, Security and Space Forum, Automotive Forum, 5G to 6G Forum, plus an extensive exhibition. EuMW 2024 provides the opportunity to participate in conferences, workshops, short courses and special events such as Women in Microwave Engineering. "Waves Connecting Europe" is the slogan for 2024 to represent new possibilities for individuals and objects to communicate, sense and move together. The venue for EuMW 2024 is the Paris Convention Centre in Paris and is easy to reach from two international airports – Paris-Charles de Gaulle Airport (CDG) and Orly Airport (ORY) – with a wide range of public transport options available to travel to and from the airports: shuttle buses, metro (metro station: Porte de Versailles – Parc des Expositions) and railway connections (RER).

The EuMC is Europe's largest conference dedicated to microwave, mmWave and terahertz devices, systems and technologies and will give you opportunities to share and discuss your recent findings with peers and experts across this region of the spectrum. The conference is being held 24 – 26 September and it represents the main event in the EuMW. A broad range of high frequency related topics, from materials and technologies to integrated circuits, systems and applications will be addressed in all their aspects: theory, simulation, design and measurement. Examples include the latest developments of filters and passive components, modeling and design of RF MEMS and microsystems, high frequency and high data rate microwave photonics, highly stable and ultra-low noise microwave and mmWave sources, new linearization techniques, 6G, IoT and the impact of new packaging technologies on development applications. The topic "Sustainability and environmental impact" has been added this year, as the conference is aiming in addressing both the use of RF devices to enhance the sustainability of our societies, as well as investigating the environmental impact of RF technologies and identifying long-term mitigation measures.

The 19th EuMIC will be held as part of the European Microwave Week 2024. Initiated by the GAAS® Association in 1990 and renamed in 2006, the conference is being held 23 – 24 September. The EuMIC conference is jointly organized by the GAAS® Association and Eu*M*A and is the premier European technical conference for all topics ranging from RF, microwave and terahertz electronics over to ultra-fast mixed signal circuits and systems to optoelectronics. Established as the key contributor to the success of the overall EuMW, the EuMIC conference is the largest scientific event in Europe related to microwave ICs.

The 21st EuRAD will be held 25 – 27 September, also part of EuMW 2024. This radar conference is the

major European event for the present status and the future trends in the field of radar research, technology, system design and applications. The EuRAD conference will bring together a global network of researchers, practitioners and institutes working on topics related to the following four areas of focus: Radar Sub-systems and Phenomenology, Radar Signal and Data Processing, Radar Architecture and Systems and Radar Applications.

The Defense, Security and Space Forum will cover "How Future Defense Strategies are Driving Technological Advancements from Devices to Systems" and takes place Wednesday, 25 September from 11:20 – 17:40. The 5G to 6G Forum covers "Innovations, Challenges, and Roadmap – An Electronics Perspective" and takes place Thursday, 21 September from 08:45 – 18:20. The Automotive Forum covers imaging radars and antenna technology taking place on Monday, 23 September from 08:30 – 17:50.

The annual European Microwave Exhibition, which is by far the largest RF and microwave trade show in Europe, is held in conjunction with the conferences. The exhibition also includes a series of technical seminars and exhibitor workshops describing commercial products and processes. The European Microwave Exhibition takes place 24 – 26 September with more than 300 exhibiting organizations occupying more than 4,000 square meters of space. The exhibition offers its exhibitors an unrivaled opportunity to see new products and services offered by leading companies in the RF and microwave industry. It also offers a forum for discussing trends and exchanging scientific and technical information with industry experts.

Come join us at the heart of the 'ville lumière,' Paris and enjoy the European Microwave Week. Join us in Paris to discover innovations and new paradigms for the microwave community as we look toward Horizon 2030. ■

INVITED PAPER

State of Wireless RAN 2024

Earl Lum
EJL Wireless Research, Salem, N.H.

2024 marks a critical fork in the road for the wireless radio access market and industry. The majority of 5G New Radio (NR) non-standalone (NSA) deployments have been completed at most, if not all, Tier 1 mobile operators worldwide. Network modernization projects continue at a slower cadence than the initial rollout of 5G NR networks in the previous five years as the industry is in the midst of a global capital expenditure (CAPEX) slowdown for wireless RAN equipment. The future for the industry looks dim, unless you are in the local Chinese market.

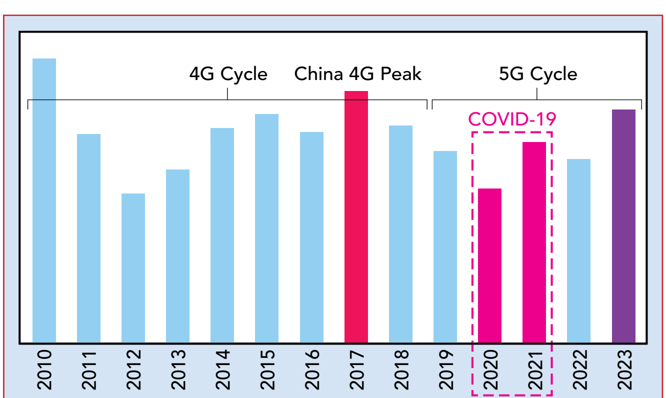


Fig. 1 **Historical RU/AAU Shipments, 2010-2023. *Source:* EJL Wireless Research LLC ©2024.**

LOOKING BACK AT HISTORY

Shipments for radio units/active antenna units (RUs/AAUs) in 2023 reached the third-highest level since 2010. They have recovered significantly from the most recent industry bottom in 2020, at the height of the COVID-19 pandemic. It is worth noting that RUs deployed during the 5G cycle are primarily multi-band 4T4R configurations as opposed to the single-band 2T2R/4T4R configurations during the 4G cycle. Additionally, there has been a higher mix of 5G NR AAUs shipped during the 5G cycle as compared to the 4G TDD-LTE AAUs shipped during the 4G cycle. The lower shipment volumes in the 5G cycle reflect the cannibalization of single-band 4G RUs and the artificial negative impact from 2020 to 2021 from COVID-19. The latest RU/AAU historical summary from EJL Wireless is shown in ***Figure 1***.

FORWARD-LOOKING TRENDS FOR RU/AAU MACRO SITE DEPLOYMENT

Given CAPEX guidance from major mobile operators globally, the current outlook for 2024 RAN equipment is very negative. The need to "monetize 5G" for mobile operators is shifting the financial focus to a lower CAPEX run rate in the future. Additionally, the majority of mobile operators have

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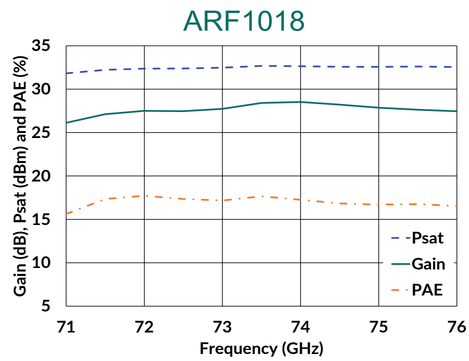

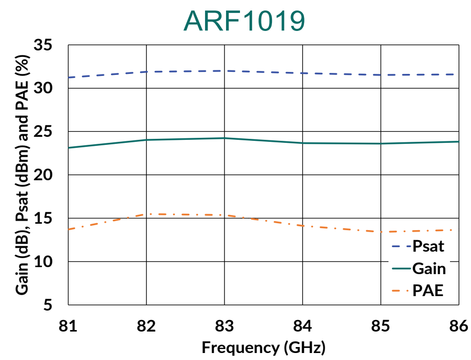

NEW!

1.8 W Psat E-Band Power Amplifier GaAs MMICs

Altum RF's new E-band PA GaAs MMICs support today's demanding mmWave telecom and SATCOM applications by offering high output power and gain for longer-range links. The ARF1018 covers 71–76 GHz with 1.8 W Psat (including bonding transitions from die) and 27 dB small-signal gain. The ARF1019 covers 81–86 GHz with 1.6 W Psat (including bonding transitions from die) and 24 dB small-signal gain. Both bare die MMICs measure a compact 3.5 x 4.1 x 0.05 mm^3 and include an on-chip integrated power detector.

Part Number	Frequency Range (GHz)	Gain (dB)	Psat (dBm)	PAE (%)	OIP3 (dBm)	Vdd/Idq (V/A)
ARF1018	71–76	27	32.5	18	39	4.0/2.0
ARF1019	81–86	24	32.0	15	38	4.0/2.0

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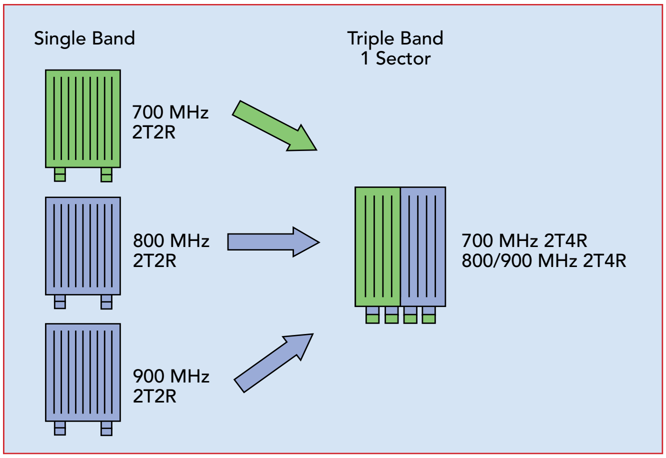


Fig. 2 **Single-sector, low-band integration. *Source:* EJL Wireless Research LLC ©2024.**

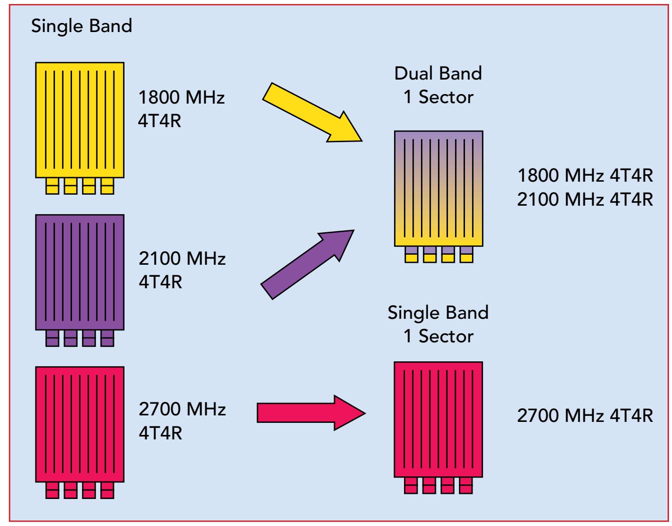


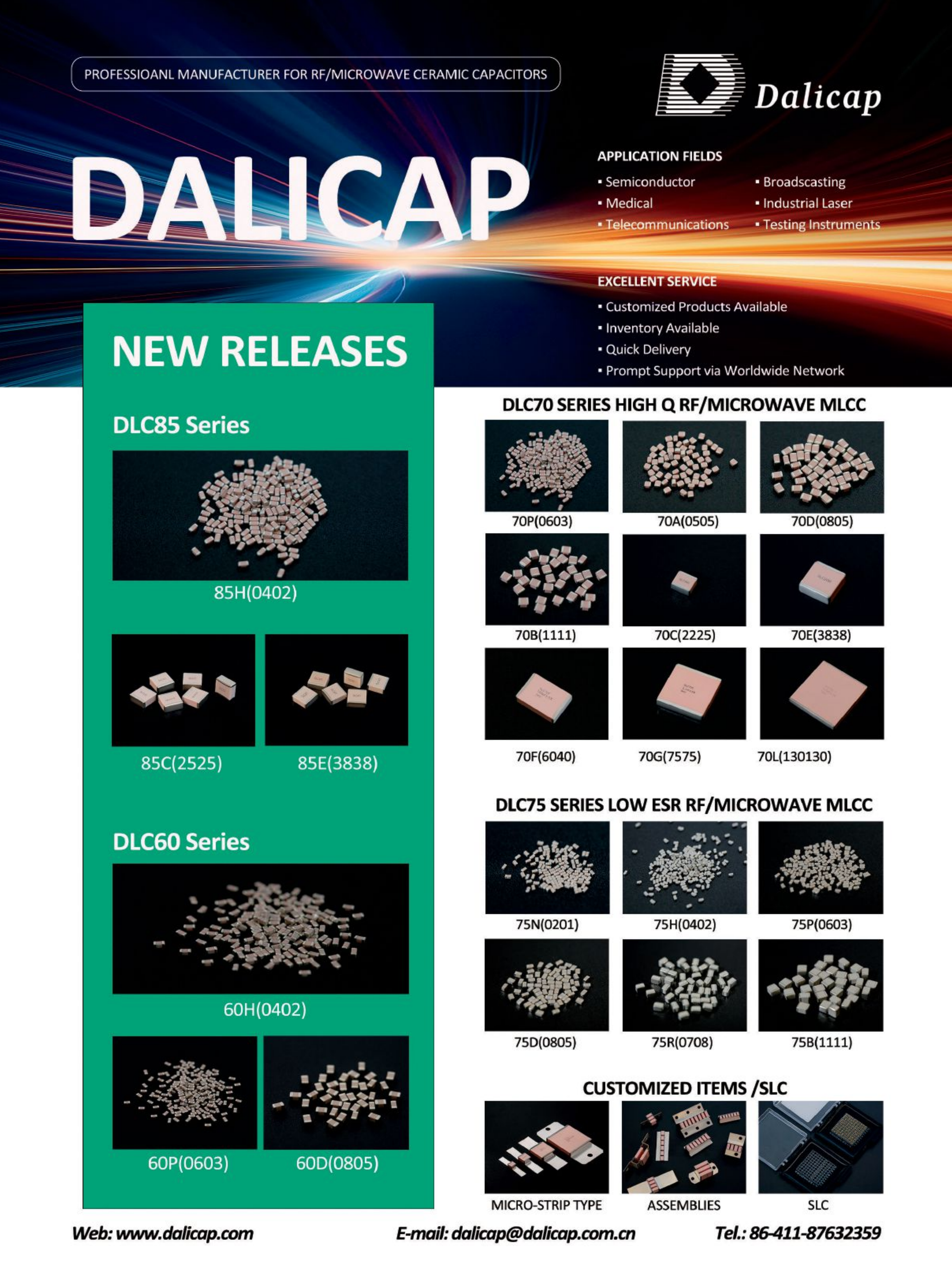
Fig. 3 **Single-sector, multi-band and single-band integration. *Source:* EJL Wireless Research LLC ©2024.**

deployed Phase 1 network coverage requirements for their 5G networks and are waiting for Phase 2 network capacity enhancements.

MACRO SITE TOWER/ROOFTOP TRENDS

The landscape is challenging for mobile operators planning to deploy mobile networks and RU/AAUs in 2024 and beyond. The following concerns are likely to shape their decisions:

- Nearly all mobile towers are no longer owned and operated by the mobile operator, which increases the focus on reducing operating expenses (OPEX) for leasing tower sites
- Reducing forward OPEX costs involves a network modernization strategy to upgrade older legacy equipment with the most integrated RUs and passive antennas
- The typical five-band macro site uses frequency bands of 800/900/1800/2100/2600 MHz or 600/700/800/1900/2100 MHz. These sites use one single-band radio per frequency band per sector, resulting in 15 macro RUs, which put pressure on OPEX
- The single-band, low-band macro 2T2R RUs typically use 600/700/800/900 MHz frequency bands and they need to be upgraded to dual-band or triple-band macro RUs to reduce total radio count per sector
- The single-band, mid-band macro 4T4R RUs that use 1800/1900/2100/2600 MHz frequencies need to be upgraded to dual-band at 1800/2100 MHz or 1900/2100 MHz or triple-band at 1800/2100/2600 MHz macro RUs to reduce total radio count per sector
- The mobile operator must choose between a radio integration-per-sector or a radio integration-per-site modernization strategy. A radio-per-sector strategy focuses on integrating frequency bands and radios for a single sector of a macro site, usually grouping frequency bands (low or mid). A radio-per-site strategy would be like the old Nokia Flexi radio architecture,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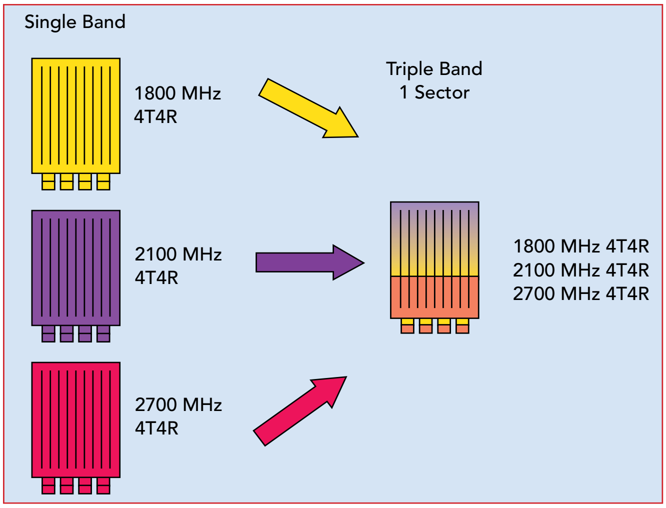

Fig. 4 **Single-sector, mid-band RRU integration. *Source:* EJL Wireless Research LLC ©2024.**

where all three sectors for multiple frequency bands (low-band, mid-band or both) are combined into a single-site radio unit. ZTE Corporation is leading the charge for multi-band integration.

Part of the challenge for operators is that many combinations of frequency bands and radio architectures are used in base stations to meet subscriber needs. The following diagrams provide examples of some integration strategies the operators and equipment manufacturers are pursuing. ***Figure 2*** shows an integration concept for a single sector, multi-band, macro RU.

Figure 3 shows an example of integrating multi-band, mid-band radios into a dual-band radio in a single sector, along with a single-band, mid-band radio.

Figure 4 shows the same single-sector, multi-band integration shown in Figure 2, but at mid-band frequencies.

Figure 5 conceptually shows what ZTE is doing to lead the way in single-sector, multi-band, low-/mid-band macro RU integration. Finally, ***Figure 6*** shows a representative diagram of what the company is doing to integrate multiple sectors, bands and radios into a single RU for the base station.

NETWORK CAPACITY TRENDS

There are three ways to address a mobile operator's needs for increasing network capacity:

- Spectrum
- MIMO layers
- Sectorization.

Spectrum

3GPP n96/n102/n104

Spectrum remains the most important resource for mobile operators developing capacity evolution strategies. However, asking what spectrum assets are still usable and wideband in the 3GPP frequency range 1 (FR1) from 410 to 7125 MHz is a valid question. The global mobile operators are focusing on the upper portion of the n96 frequency band (6 to 7 GHz) for 5G NR Advanced (5.5G) and possibly 6G services. The full bandwidth of the n96 spectrum has been allocated for unlicensed Wi-Fi 6E/7 services, primarily in the Americas. ***Figure 7*** shows the bandwidth and the band designations for the 3GPP 6 to 7 GHz spectrum bands.

The countries that have adopted using the entire 5925 to 7125 MHz spectrum for unlicensed services are:

- ITU Region 1: The U.S., Argentina, Brazil, Canada, Columbia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Saudi Arabia and South Korea
- ITU Region 2: Saudi Arabia
- ITU Region 3: South Korea.

Nearly all other countries have adopted only the lower 500 MHz 3GPP n102 sub-band for unlicensed services and are considering the upper 700 MHz for licensed applications. The 3GPP n104 band is where the battle to the death between the Wi-Fi Alliance and 3GPP/GSMA will be fought for future spectrum allocations for both terrestrial and non-terrestrial mobile networks within the ITU and individual regulatory agencies worldwide. The allocation of n96 in the Americas, South Korea and Saudi Arabia puts these countries at a severe disadvantage in finding spectrum for 5G NR Advanced and 6G services, unless these countries go back and reallocate only the n102 portion of the band for unlicensed usage.

China has allocated the 3GPP n104 6425 to 7125 MHz with 700 MHz bandwidth spectrum for 5G NR Advanced services. China's Ministry of Industry and Information Technology is expected to issue licenses to its four mobile operators in 2025, China Broadnet, China Mo-

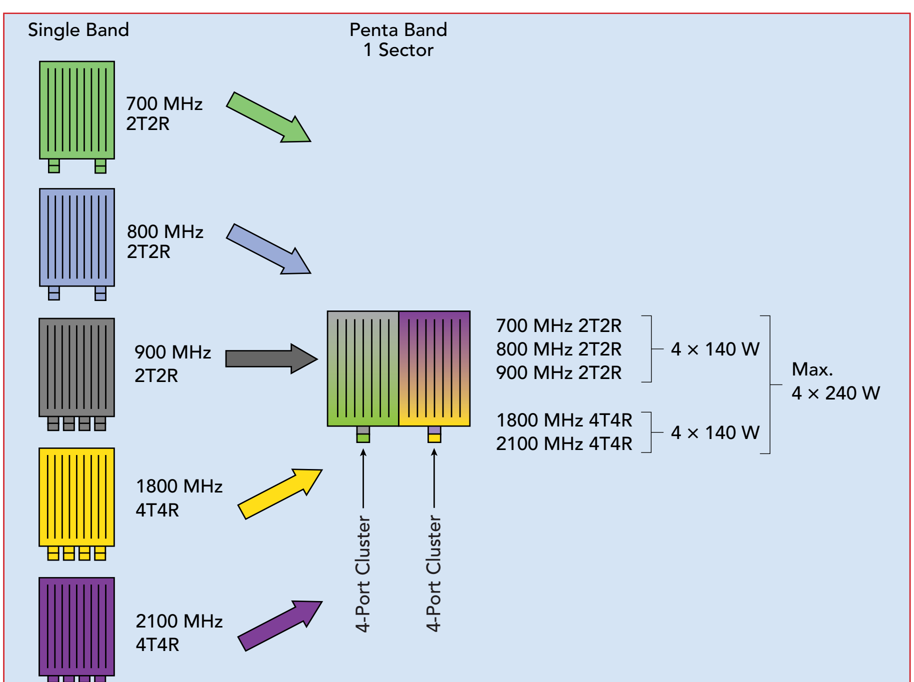

Fig. 5 **ZTE macro RU integration. *Source:* ZTE Corporation, EJL Wireless Research LLC ©2024.**

bile, China Telecom and China Unicom. Other countries and regions, such as those in Europe, the Middle East and Asia Pacific, could adopt the n104 spectrum for mobile and non-terrestrial 5G NR Advanced and 6G services and leave the n102 spectrum for unlicensed Wi-Fi services.

India has not yet adopted any spectrum within n96 for any services and could follow the same n102/n104 split as the rest of the countries in ITU Regions 1 and 3.

3GPP FR3/FR4/FR5

The other main chunks of the spectrum that 3GPP is focused on are:

- FR3 7.125 to 24.25 GHz
- FR4 71 to 114.25 GHz
- FR5 114.25 to 275 GHz.

The FR5 band includes parts of the D-Band (110 to 170 GHz) and J-Band (220 to 330 GHz) and all of the G-Band (140 to 220 GHz) and H-Band (170 to 260 GHz).

The realistic and most likely choice is the FR3 spectrum for 5G NR Advanced and 6G. This spectrum sits between the FR1 and FR2 bands, and the ecosystem for RF components and systems can be ramped into commercial use. The belief is that this can happen more quickly than systems can be developed in the FR4 and FR5 bands.

Auctions

Now that potential spectrum has been identified across various regions and countries, is there any money available for spectrum auctions given the price per MHz/pop spent on the 5G spectrum? This is doubtful, given the current capital markets structure for debt and the cash-poor situation for many mobile operators. This could be a very significant roadblock on the path to 5G NR Advanced and 6G. Again, the reader must remember that there has been little monetary gain and return on investment in 5G technology/spectrum for most mobile operators except for the Chinese.

Evolution of MIMO

Within the frequency-division duplex (FDD) segment, there are two important issues to explore. The first is determining the ben-

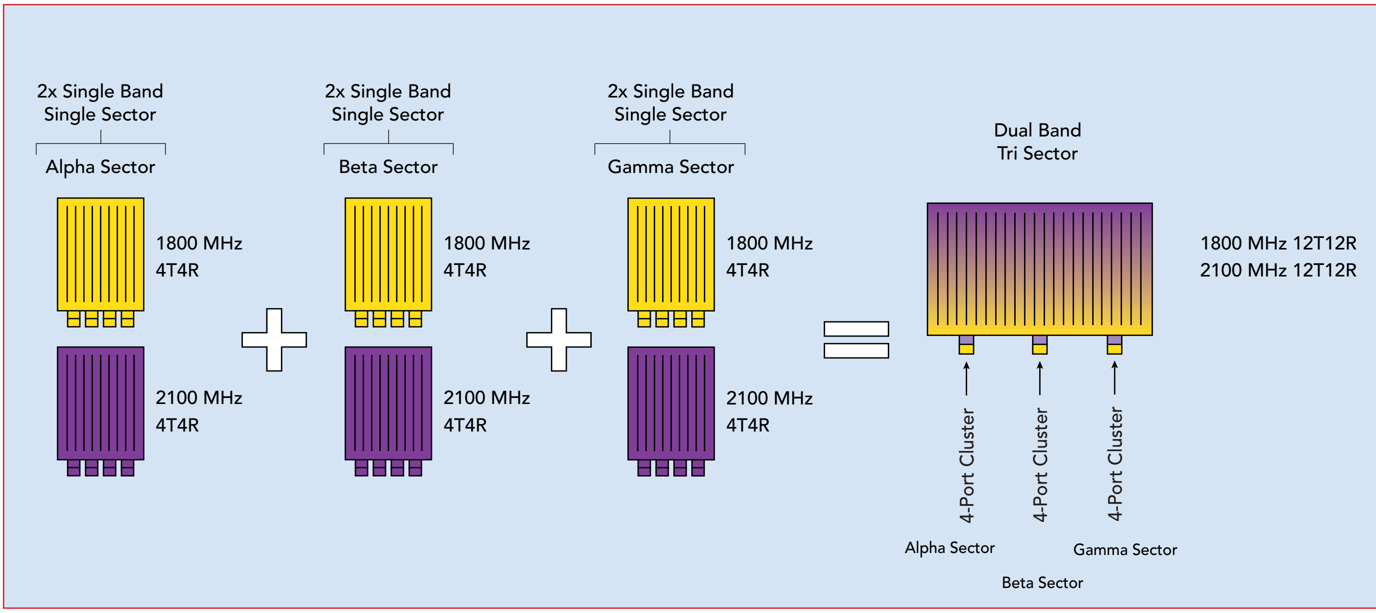

Fig. 6 **Tri-sector, multi-band, mid-band Macro RU integration.** ***Source:*** **ZTE Corporation, EJL Wireless Research LLC ©2024.**

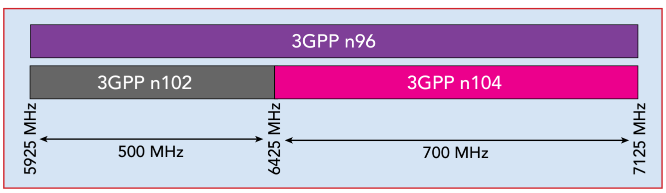

Fig. 7 **3GPP 6 to 7 GHz spectrum bands.** ***Source:*** **EJL Wireless Research LLC ©2024.**

efits of modernizing the mobile network from existing 4T4R macro RUs to 16T16R/32T32R FDD AAUs at mid-band spectrum. The second is evaluating whether these benefits outweigh an evolution to FDD 8T8R. There is a much higher likelihood that 32T32R FDD will result in a capacity gain of approximately 50 percent from 4T4R FDD units. However, this comes with a power consumption penalty for single- or dual-band, mid-band 32T32R FDD systems. The argument against 8T8R FDD is that the incremental capacity gain of approximately 10 percent is not worth the replacement effort. Proponents of this argument believe that this small capacity gain will be quickly absorbed and the mobile operator will still need to upgrade to the 32T32R solution. The question then becomes, why not just use it in the first place? China has embraced the 8T8R strategy for mid-band 1.8/2.1 GHz spectrum while the U.S. is adopting the 32T32R solution instead. Europe and other regions will most likely be operator-dependent.

For the TDD segment, Chinese OEMs Huawei Technologies and ZTE Corporation have focused on the extra-large antenna array architecture to use in the 6 to 7 GHz band to extend the downlink and uplink cell radius using 128T128R and 256T256R architectures. In the current FR2 mmWave and future FR3 spectrum, very large antenna element arrays of up to 1024 or even higher are expected to extend the cell radius.

Evolution of Multi-Beam Antennas

Increasing the MIMO order and the number of layers is not the only way to increase network capacity. Sector splitting and dual-beam, 33-degree half-power beamwidth (HPBW) antennas can increase macro site capacity compared with legacy single-beam, 65-degree HPBW antenna configurations. However, these antenna solutions are typically side-by-side and there is significant sidelobe interference between the two beams, which ultimately reduces capacity. Multi-beam antennas have been used extensively in high-capacity venues that can support more than eight beams. However, these antennas are very wide and have significant wind load issues on a macro site tower or rooftop installation. There are no wind issues for an indoor arena or domed stadium. However, solutions available today in the market can create 9 to 24-sector macro sites using just 4T4R technology that outperforms current state-of-the-art massive MIMO (mMIMO) three-sector solutions. The challenge is that this goes against the industry RAN equipment giants, as they would need to license the technology and kill off the mMIMO marketing campaigns for the mobile industry.

CONCLUSION

Ultimately, the mobile operator has many technical and financial decisions to address over the next few years. These decisions will determine where their expenditures go and can push the mobile industry in different directions, depending on the international market outside of China. The mobile industry is permanently fractured between China and the rest of the world and 5G NR Advanced will only increase the size of the rift in the future until 6G network features become clearer and these systems begin deploying. The EJL Wireless view is that opportunities outside of China will be available but at a fraction of the size and without the leverage and scale of Chinese deployments to reduce global pricing. As a result, 5G NR Advanced and 6G system and network pricing will increase for the rest of the world. ■

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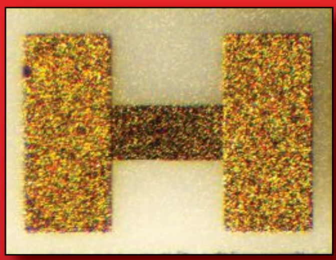

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INVITED PAPER

Quantum Microwave Engineering: Key Skills for Every Quantum Hardware Engineer

Alan Salari
Quaxys LLC, Vienna, Va.

The expansive realm of quantum information science and technology (QIST) encompasses quantum computing, communication, sensing and simulation. These groundbreaking technologies are poised to rapidly reshape our world. Aspects like secure quantum communication, quantum internet and advanced quantum sensors are on the horizon, set to become integral parts of our daily lives. Quantum computing, however, poses significantly greater challenges and requires more time to realize its anticipated potential. ***Figure 1*** illustrates a superconducting quantum computer.

The QIST field is still emerging. As the discipline continues to develop, it will present numerous technical challenges alongside the demand for a highly skilled workforce. A significant part of this challenge lies in cultivating a multidisciplinary workforce that combines excellent analytical skills with specialized expertise in engineering and science.

Hughes et al. highlight the quantum industry's urgent demand for skilled professionals in *Assessing the Needs of the Quantum Industry*.[1]

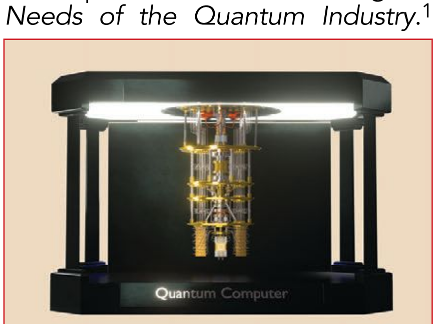

Fig. 1 **A superconducting quantum computer.**

Conventional quantum engineering training tends to be a prolonged process, posing a challenge. However, by prioritizing essential real-world technical skills crucial for quantum research and development, the training process can be accelerated. Furthermore, there is a significant opportunity to upskill current professionals, including hardware and software engineers, to meet the increasing demands of the QIST field. To expedite this transition, having resources that facilitate rapid training is crucial. Recognizing this need, companies like Quaxys are specializing in practice-oriented courses for specialized microwave and quantum hardware training. These efforts have also spawned books, such as *Microwave Techniques in Superconducting Quantum Computers*[2], that aim to impart essential skills for quantum hardware engineers involved in the development of semiconductor quantum platforms, covering topics like superconducting, spin and topological qubits.

Quantum computing platforms fall into two categories: natural systems like atom and ion qubits and artificial systems like superconducting, spin and topological qubits. Each category demands specific skills, some unique to the platform and others shared. The following sections investigate the four primary skill sets: microwave engineering, cryogenic engineering, nanofabrication and data acquisition and measurement that are crucial for quantum hardware engineers and companies working on semiconductor qubits to enable success in this field.

MICROWAVE ENGINEERING

The realm of quantum technologies, particularly semiconductor qubits, has opened numerous possibilities for hardware engineers specializing in microwave and embedded hardware engineering. As a starting point, it is instructive to explore some of the fundamentals. These include the definition of a qubit and the rationale behind utilizing microwave frequencies for superconducting qubits.

A qubit is a fundamental unit of information in quantum computing, representing a two-level quantum system. The encoding of information occurs through the ground state, represented as "0" and the excited state, represented as "1."

In the following, we conceptually describe how a superconducting qubit can be implemented as a nonlinear LC circuit to mimic the behavior of an atom. ***Figure 2a*** illustrates an atom relaxing from a higher-energy level to a lower one. The characteristic of this transition is the emission of a photon with a certain frequency corresponding to the difference in energy levels, as shown in the diagram. In an atom with more than two levels, such as the hydrogen atom, a series of spectral emission lines result from an electron transitioning from a higher-energy orbit to a lower-energy orbit. These are called Balmer series transitions of a hydrogen atom and are shown in ***Figure 2b***. The n values are integers corresponding to the principal quantum numbers involved in the transition. Each transition has a unique frequency, as shown. It's pos-

sible to mimic this atomic behavior using a superconducting circuit.

A superconducting LC circuit can be shown to be a quantum harmonic oscillator with equidistant energy levels, as illustrated in ***Figure 2c***. Consequently, there is no unique transition frequency between energy levels, making it impossible to isolate and address only two energy levels to build a qubit.

By adding non-linearity to the LC circuit using a Josephson junction, we can build an anharmonic quantum oscillator with non-equidistant energy levels, as shown in ***Figure 2d***. This results in unique transition energies between energy levels, similar to a real atom. This type of nonlinear superconducting circuit provides a two-level system with a unique transition frequency, enabling the construction of a qubit.

Consider the scenario where the energy difference between the ground and excited states is low, allowing thermal energy in the qubit's environment to cause the qubit to transition from the ground state to the first excited state. This uncontrolled thermal transition is undesirable since we seek precise external

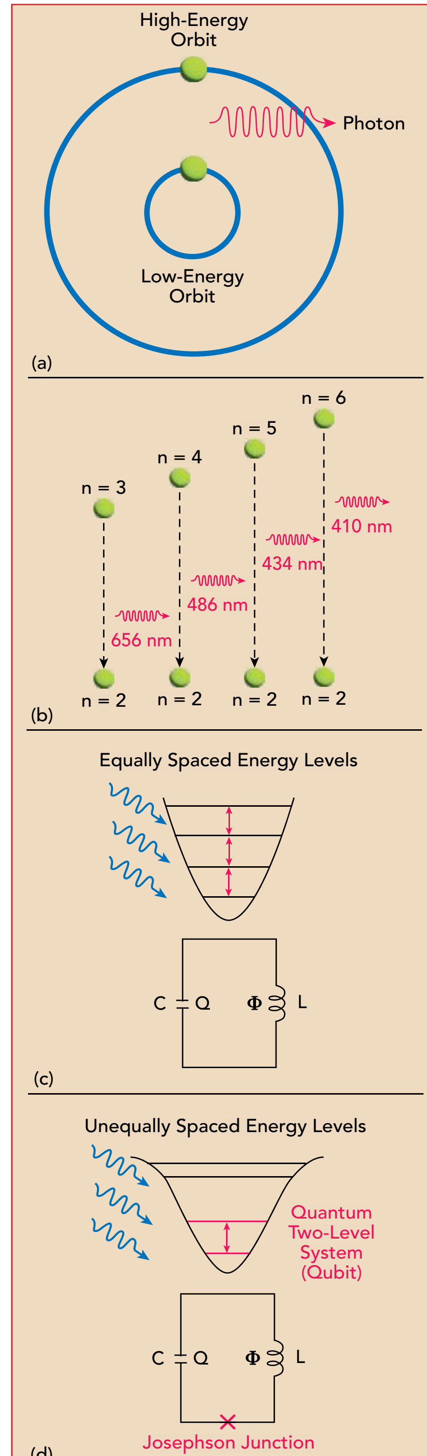

Fig. 2 (a) Photon emission as an electron relaxes to a lower-energy orbit. (b) Hydrogen atom Balmer series transitions. (c) Quantum harmonic oscillator with equidistant energy levels. (d) Anharmonic quantum oscillator.

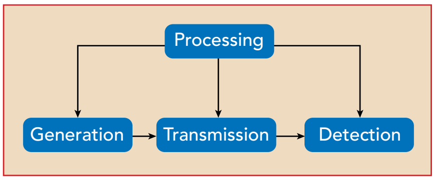

Fig. 3 **Technical areas related to microwave engineering.**

control over the qubit's state.

Semiconductor qubits are housed within a dilution refrigerator for various reasons. Foremost among these reasons is the need to mitigate uncontrolled excitation caused by thermal energy. The thermal energy can be calculated in ***Equation 1***:

$$E_{th} = k_B T \quad (1)$$

Where:
k_B = Boltzmann's constant
T = temperature

A rough calculation provides insight into the possible effects of unwanted thermal energy. The thermal energy calculated in Equation 1 will have an associated frequency. The Planck-Einstein relationship of $E = hf$ can be used to determine the frequency (f_{th}) associated with thermal energy in a dilution refrigerator. This is shown in ***Equation 2***:

$$f_{th} = k_B T/h \quad (2)$$

Where:
h = Planck's constant

A typical dilution refrigerator can achieve a temperature of 20 mK, corresponding to a frequency of f_{th} = 0.4 GHz. To minimize the occurrence of thermal excitations from the ground to the excited state of the qubit, it is essential for the qubit's transition energy (E_{01}) to be much higher than the thermal energy, i.e., $E_{01} >> E_{th}$. The term "much higher" implies at least 10x greater, which leads to a transition frequency $f_{01} = 10f_{th}$ = 4 GHz.

Most superconducting charge qubits, such as the transmon, operate in the microwave frequency range of 2 to 10 GHz. Microwave frequencies are particularly appealing since they are sufficiently high to leverage standard cryogenic and well-established microwave techniques and components commonly used in the telecommunications industry. While higher frequencies may offer certain advantages, they pose challenges regarding component cost, design complexity and fabrication capabilities. Therefore, to effectively design and operate superconducting qubit hardware, it is necessary to have a solid understanding of microwave systems and components.

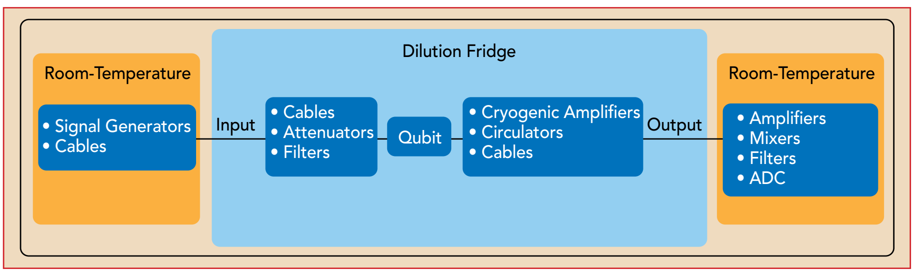

Fig. 4 **Microwave link for a superconducting quantum computer.**

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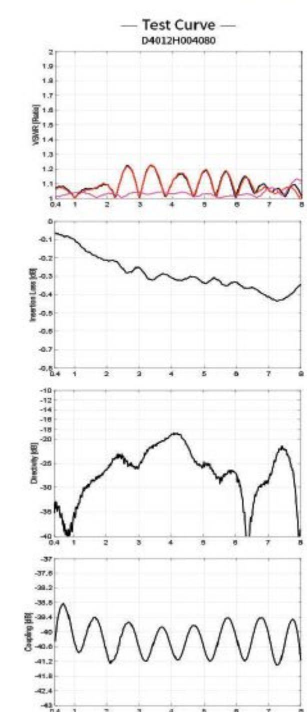
D4002H004080	120	40	1.3	1.3	0.8	40±1.0	±0.8	18
D3005H004080	250	30	1.4	1.4	0.7	30±0.9	±1.3	14
D4005H004080	250	40	1.4	1.4	0.7	40±1.0	±1.4	14
D3008H004080	400	30	1.4	1.4	0.7	30±0.9	±1.3	14
D4008H004080	400	40	1.4	1.4	0.7	40±1.0	±1.4	14
D3012H004080	600	30	1.4	1.4	0.7	30±0.9	±1.3	14
D4012H004080	600	40	1.4	1.4	0.7	40±1.0	±1.4	14
0.4-8GHz Dual-Directional Coupler								
D3002HB004080	120	30	1.3	1.3	0.8	30±1.0	±1.0	18
D4002HB004080	120	40	1.3	1.3	0.8	40±1.0	±1.0	18
D3005HB004080	250	30	1.4	1.4	0.7	30±0.9	±1.5	14
D4005HB004080	250	40	1.4	1.4	0.7	40±1.0	±1.6	14
D3008HB004080	400	30	1.4	1.4	0.7	30±0.9	±1.5	14
D4008HB004080	400	40	1.4	1.4	0.7	40±1.0	±1.6	14
D3012HB004080	600	30	1.4	1.4	0.7	30±0.9	±1.5	14
D4012HB004080	600	40	1.4	1.4	0.7	40±1.0	±1.6	14

*Theoretical I.L. Included



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Microwave engineering involves the generation, transmission, processing and detection of microwave signals as shown, generically, in ***Figure 3***. Depending on the application, one or more of the four functional areas described in Figure 3 may be involved. In certain applications, such as microwave heating, detection may not be necessary. On the other hand, detection is essential in fields like radio astronomy. However, in applications like a communication link or a superconducting quantum computer, all four areas play a crucial role. To enhance the understanding of these concepts, they will be expressed in the context of a microwave link in the next section.

MICROWAVE LINK

A microwave link contains four main functions: signal generation, transmission, processing and detection. A microwave link can be a communication link between two cell phones or it can be used to transfer information within a superconducting quantum computer. The goal is to engineer the microwave link in a way that guarantees successful signal detection, be it a message transmitted from a cell phone or the state of a qubit. This section will examine a microwave link in a superconducting quantum computer, as illustrated in ***Figure 4***, where each functional box shows the components involved in the microwave link.

Microwave signals are used to control and read out the state of superconducting qubits. As shown in Figure 4, the microwave signals are generated at room temperature and transmitted into a dilution refrigerator using microwave coaxial cables. Along the way, filters and attenuators process the signal to reduce noise. After interacting with the qubit, the signal is processed using cryogenic amplifiers and sent back to room temperature using special microwave cables. The signal is amplified, filtered and down-converted as the final room temperature processing step to prepare it for detection. Finally, a digitizer converts the analog signal into a digital signal that a computer can process.

As a signal travels down a microwave link, it is affected by cables, amplifiers, filters and various other passive and active components that amplify or attenuate it. To guarantee the successful detection of the signal at the receiving end, a comprehensive link budget analysis is conducted. This analysis calculates all gains and losses within the microwave link, ensuring the presence of adequate power and a sufficient signal-to-noise-ratio for accurate detection of quantum states.

MICROWAVE SYSTEMS

This section explores how a microwave signal is influenced by noise, interference, distortion and nonlinear effects as it travels through a link. To ensure successful signal detection, it is crucial to comprehend and analyze these effects on microwave signals. To effectively analyze and design a microwave system, it is important to have a system-level understanding of the critical performance factors along with the effects that will degrade this performance. The analytical tools used for microwave system analysis are powerful, enabling a microwave system and its components to be treated

as a black box. This allows designers to examine the inputs and outputs of the system without requiring a deep knowledge of electromagnetics or microwave engineering.

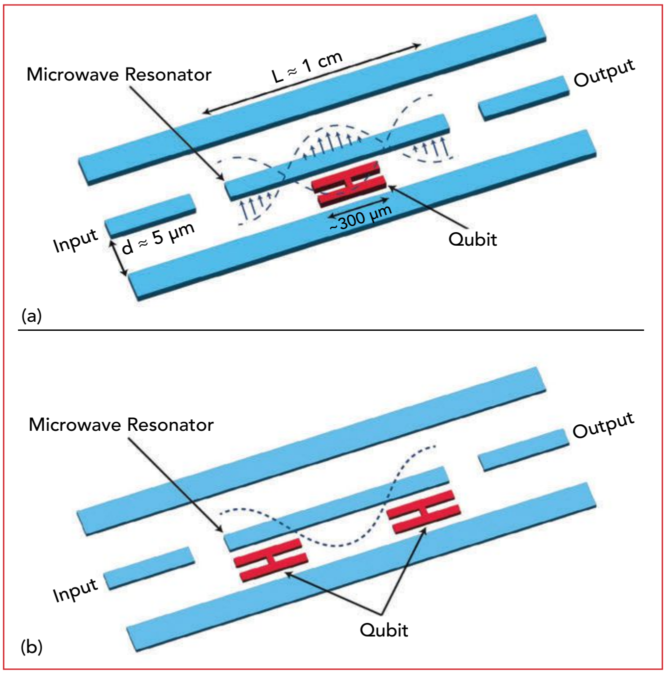


Fig. 5 **(a) A single qubit coupled to a coplanar waveguide resonator. (b) Two qubits coupled to a coplanar waveguide resonator.**

As mentioned in the previous section, the essential first step in designing and evaluating a microwave link begins with performing link budget calculations. Subsequently, the effects of distortion, interference and noise on microwave systems need to be examined because these are crucial factors that affect system performance. Furthermore, nonlinear effects need to be explored in microwave systems. Some of these effects include 1 dB compression point, harmonic levels and intermodulation distortion, which are essential for designing and optimizing system performance and efficiency.

MICROWAVE COMPONENTS

The next step is to understand cryogenic and room temperature microwave components. These components include, but are not limited to, amplifiers, mixers, filters, power combiners, attenuators, up-converters and down-converters. This knowledge can be divided into three main areas:

- **Noise engineering** needs a detailed understanding of all the coupling paths to the qubit and how to block them using components such as filters, attenuators, special microwave cables and circulators.
- **Microwave signal processing techniques** involve filtering, amplification, down-conversion and up-conversion. These techniques play a vital role in qubit operation. They involve transmitting modulated pulses to the qubits and subsequently down-converting readout signals for digital post-processing.
- **Microwave measurement techniques** use instru-

ments like network and spectrum analyzers, signal generators and high frequency oscilloscopes. These instruments are used to perform component-level, system-level and qubit measurements.

Single-qubit and two-qubit operations are the backbone of quantum algorithm implementation. ***Figure 5a*** depicts a single qubit superconducting system where the qubit is coupled to a coplanar waveguide resonator. ***Figure 5b*** shows a two-cubit system coupled to a coplanar waveguide resonator. Microwave components and techniques are necessary for the control and readout of the qubits.

CRYOGENIC ENGINEERING

As mentioned earlier, semiconductor qubit experiments are commonly conducted near absolute zero in a dilution refrigerator, at temperatures ranging from 10 mK to 50 mK. These low temperatures play a crucial role in mitigating disruptive factors, such as noise, which could lead to the collapse of the qubit's delicate quantum states. A typical quantum processing unit is shown in ***Figure 6***.

A pivotal role of a dilution refrigerator lies in protecting qubits from coupling to the environment. A quantum engineer must understand that there are conducted and radiated pathways that allow noise to affect the qubit. This is shown, generically, in ***Figure 7***. This understanding enables the application of techniques, such as filtering and shielding, to block these pathways and protect the qubit from decoherence. For this purpose, a combination of filters, circulators, attenuators, shielding and various cable types, like lossy microwave cables, are used to minimize the noise level coupled to the qubit. For a quantum engineer, a comprehensive understanding of a dilution refrigerator and its components, along with noise pathways, is essential before undertaking qubit experiments.

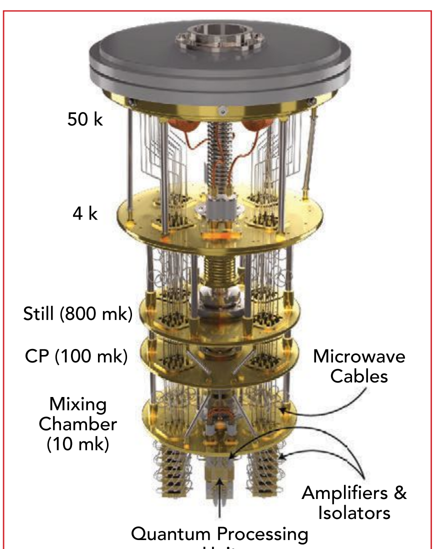


Fig. 6 **Dilution refrigerator.**

NANOFABRICATION

Nanofabrication techniques are crucial for the development of nanocircuits used in semiconductor qubits, with electron beam lithography machines being a common tool in this process. Proficiency in diverse fabrication methods is advantageous for quantum engineers. These engineers can benefit from familiarizing themselves with key processes and tools like electron beam lithography, as well as metal deposition techniques such as sputtering and thermal evaporation. In academic settings, a single individual may handle all aspects of qubit fabrication and operation, but in the industrial landscape, dedicated teams specialize in this field. Quantum hardware engineers in the industry may not need extensive knowledge of nanofabrication techniques since requirements will be based on specific roles within the company. To illustrate typical nanofabrication techniques used on a superconducting quantum computer, ***Figure 8a*** shows a Josephson junction that is comprised of two superconducting electrodes separated by an extremely thin insulating layer. Cooper pairs can coherently tunnel across the insulating barrier. The Josephson junction equivalent circuit is also shown in the diagram.

Figure 8b shows the implementation of a Josephson junction using aluminum electrodes and an Al/AlOx/Al oxide layer.

Figure 8c shows two parallel Josephson junctions forming a superconducting quantum interference device (SQUID). The Josephson energy or the total inductance can be controlled using an external flux.

Finally, ***Figure 8d*** shows the implementation of a SQUID with a

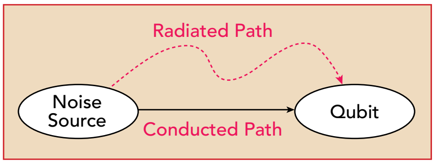


Fig. 7 **Noise coupling paths to a qubit.**

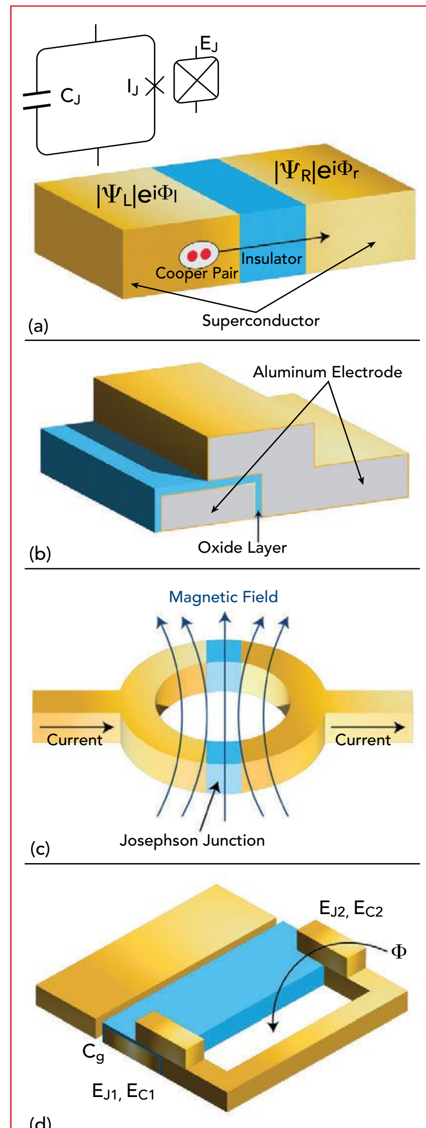


Fig. 8 **(a) Josephson junction. (b) Implementation of Josephson junction. (c) Parallel Josephson junctions form a SQUID. (d) SQUID implementation.**

Josephson junction with a charging energy of E_{Ji} and E_{Ci}. C_g is the gate capacitance to control the charge. Josephson junctions and SQUIDs are essential components for a superconducting quantum computer, so it becomes very important to master these nanofabrication techniques.

DATA ACQUISITION AND QUANTUM MEASUREMENTS

After fabricating the qubits and housing them in a dilution refrigerator, along with addressing all microwave engineering aspects, the quantum system is ready for operation. Operating a quantum processor involves the precise control and readout of qubits to successfully implement single-qubit and two-qubit gates, which are fundamental for implementing quantum algorithms. This phase of the process demands a thorough understanding of quantum mechanics and quantum measurements, along with expertise in instrument automation and data acquisition.

These processes are coordinated with control software that interfaces with various instruments and microwave subsystems to generate the necessary microwave pulses for qubit control and readout. Quantum engineers need to be adept at utilizing diverse communication protocols such as serial communication, GPIB, LAN and USB. Software that is commonly employed to ensure efficient data acquisition includes Matlab, Python and Labber. Quantum hardware engineers should be proficient in at least one of these software tools to ensure that data acquisition tasks are completed seamlessly. Additionally, coding skills are invaluable, particularly for those wishing to develop customized measurement codes within these software environments.

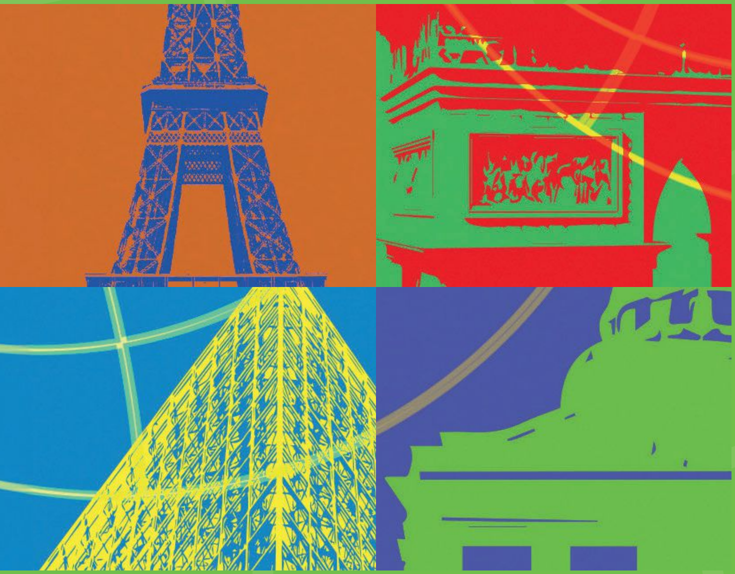
CONCLUSION

This article has discussed four of the most important skill sets for semiconductor quantum hardware development. It is important to realize that the next generation of quantum engineers does not need to be experts in all four areas. Individuals will specialize and focus on specific areas to gain expertise and companies may choose to specialize in different niches within the larger quantum market.

The upcoming generation of quantum engineers will play a crucial role in advancing revolutionary technologies and their success hinges on effective skill-based training. Quantum hardware engineers need proficiency in diverse areas like microwave engineering, cryogenic techniques, nanofabrication, data acquisition and quantum measurements to successfully contribute to the development of quantum processors. Closing the talent gap requires a strategic emphasis on well-designed courses and hands-on training with real-world applications. Utilizing resources like books and online courses can significantly accelerate the learning process for aspiring quantum engineers. ■

References

1. C. Hughes, D. Finke, D. -A. German, C. Merzbacher, P. M. Vora and H. J. Lewandowski, "Assessing the Needs of the Quantum Industry," *IEEE Transactions on Education*, doi: 10.1109/TE.2022.3153841.
2. A. Salari, "Microwave Techniques in Superconducting Quantum Computers," *Artech House*, 2024.



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WS-08		Full Day	Photonic Technologies for Radio Frequency Applications
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WS-14		Half Day	Characterization, Calibration, and Production Test of Phased Array Antennas (PAA) for Non-Terrestrial-Network (NTN)

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WM-03		Half Day	Last advances in scanning microwave microscopy including metrology and emerging applications
WM-04		Half Day	Packaging and RFICs for Wireless Communication and Radar Sensing above 100 GHz

Thursday 26 September 2024			
WTh-01		Half Day	Integrated Microwave Photonics for communication and sensing
WTh-02		Half Day	Radar Networks
WTh-03		Half Day	Integrated antenna systems for next-generation D-band communication and radar systems
WTh-04		Full Day	Microwave Photonics for Wireless Sensing
SC-03		Full Day	Basics of Systems Engineering for the Microwave Engineering Community

Friday 27 September 2024			
WF-01		Full Day	Last advances in free-space radar sensing for electromagnetic materials modelling and characterization
WF-02		Full Day	Chipless RFID Systems: Future and Challenges
SC-02		Half Day	Introduction to implantable antennas: implant antenna design methodology, numerical analysis and modelling, prototyping and testing, and phantoms
SC-04		Half Day	Radar Waveform Optimization Mastery
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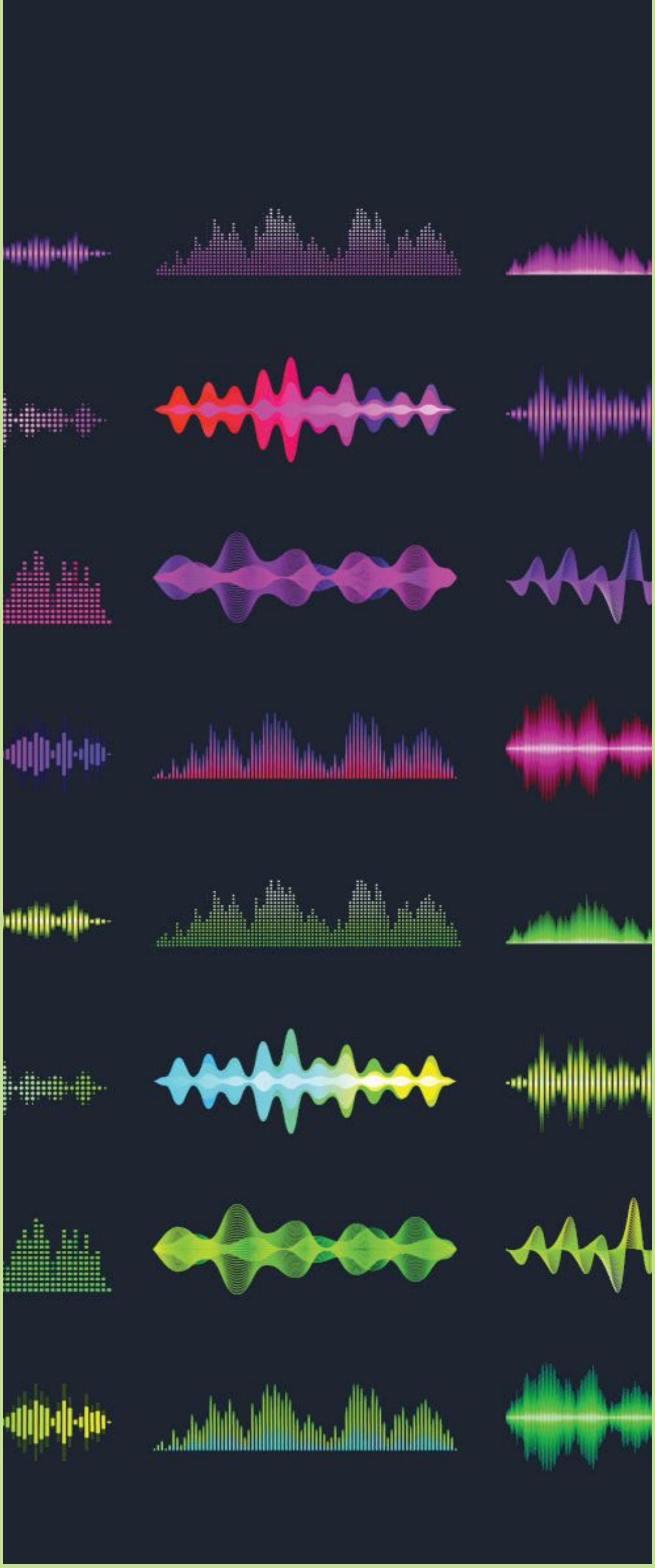

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TABLE OF CONTENTS

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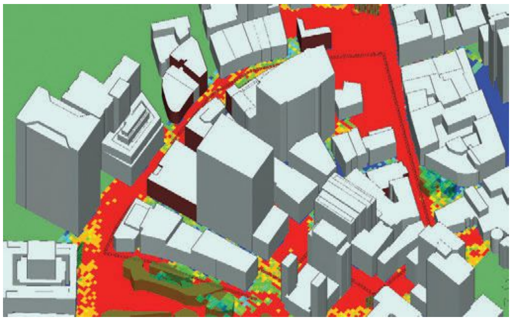
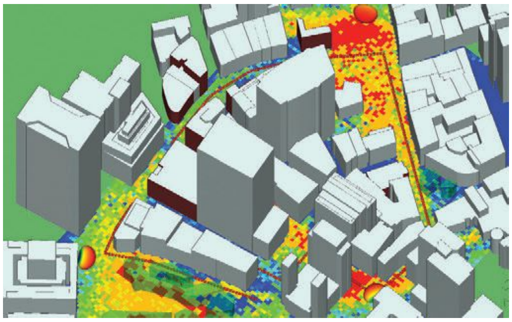




Beamforming with massive MIMO (top) shows significant improvement to throughput over links between single antennas (bottom)

Enabling Extreme Mobile Broadband and Wireless Fiber

Thomas Chen, Donuwan Navaratne, Tom Huang, Habib Rastegar, Patrick Houghton and Andrew Chen
SwiftLink Technologies, Richmond, Canada

Over the past several years, companies have been developing technology to enhance data transmission capacity through the advancement of what the 5G vision called "Extreme Mobile Broadband" (EMB). At SwiftLink, this effort has spanned eight years and the result has been advances in chip technology and the development of phased array antenna beamformers. This article describes the efforts that have gone into the EMB beamformer solutions.

These EMB beamformers are designed to support a wide range of frequencies, encompassing all the bands used in low Earth orbit (LEO) satellite communications and the upcoming 5.5G/6G cellular networks. They are compatible with a diverse array of devices and demonstrate the capability to deliver high speed data transmission. With this wideband solution, the concept of the "Internet of Everything" (IoE) is closer to realization. As illustrated in the diagram in ***Figure 1***, there is a benefit to connecting everything through a combination of non-terrestrial and terrestrial network resources. The EMB chip signifies a pivotal step towards the realization of this vision of the IoE and more ubiquitous global connectivity. By facilitating seamless wireless connectivity and integrating fiber-like speeds into wireless infrastructure, users are on the brink of an era where every device connects with unprecedented efficiency and reliability. The dream of a fully wireless world, where every interaction and transaction can occur instantaneously and without physical constraints, is on the horizon.

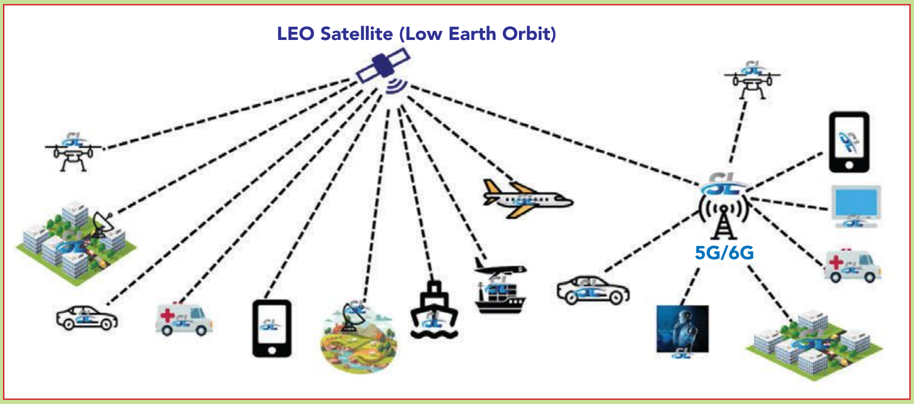


Fig. 1 **Universal network connecting LEO satellites and 5.5G/6G devices.**

These EMB chips operate at mmWave frequencies to provide full compatibility with non-terrestrial LEO communications networks and the emerging 5.5G terrestrial network infrastructure. This combined frequency range of 24 to 44 GHz has 20 GHz of bandwidth at mmWave frequencies. The EMB chiplet solution envisions extending coverage and network interconnectivity to 6G and satellite communications at even more mmWave communication frequency bands.

MMWAVE SOLUTIONS

Every step in the evolution of mobile technology is driven by solving consumer problems. The problem comes first and technologists target these problems by creating innovative solutions. It is the role of the industry to drive down the cost of technology solutions so they are accessible to more consumers. The massive transmission capacity and capabilities bring unprecedented experiences to the consumers and it is these experiences that service providers are looking to monetize. This massive transmission capacity will lead to a great upheaval of communication technologies, providing opportunities such as Tbps peak data rates, Gbps user experience data rates, millisecond latency, centimeter positioning accuracy and millions of connections per square kilometer.

mmWave technology harnesses high frequencies to revolutionize communication. Communications at these higher frequency bands deliver data transmission speeds that are exponentially higher than those of 4G networks. However, to enable interconnectivity for terrestrial networks typically operating below 6 GHz with LEO networks that may operate into Ka-Band, operating with a bandwidth of more than 20 GHz is necessary.

The adoption of mmWave technology represents a significant leap forward in the telecommunications industry, offering a robust solution that meets the burgeoning demand for high speed, high-capacity communication networks. As users transition into the 5.5G era, innovations in the industry must ensure that users and networks are well-equipped to handle the ever-increasing data requirements of a hyper-connected world. It is also worth noting that the upcoming 6G wireless communication networks are looking to incorporate the benefits of mmWave frequencies while also considering the balance with deployment, coverage and capacity issues. THz technology and frequencies, the future of information transmission, are expected to provide even higher data transmission rates than mmWaves, laying the technical foundation for 6G networks. Furthermore, the mmWave/THz bands are envisioned to provide fiber-like bandwidth over a wireless link. The SwiftLink EMB single-chip solution can receive mmWave signals from a phased array antenna feed and then down-convert those signals to IF frequencies that will drive the IF modem. Since these ICs can down-convert mmWave frequencies across the 20 GHz bandwidth from 24 to 44 GHz, using a single device, system providers only need one chip and one antenna array to meet universal deployment requirements in 5.5G/6G and satellite communication networks.

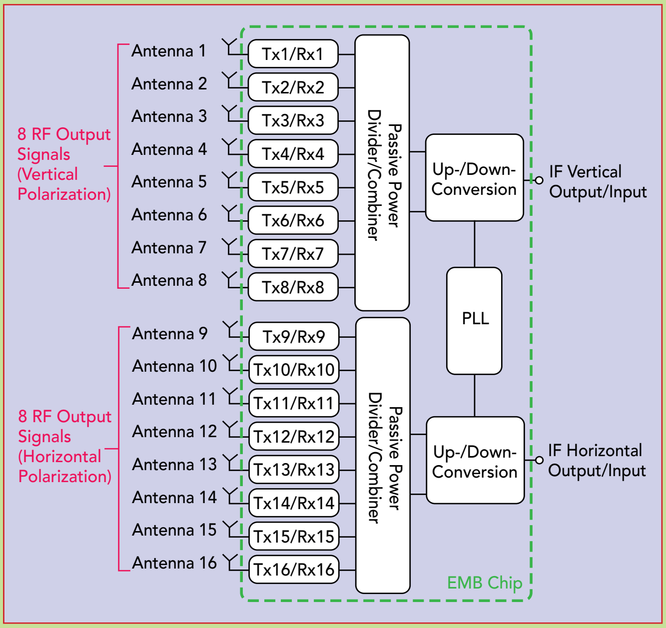


Fig. 2 **Block diagram of EMB beamformer.**

Figure 2 shows a block diagram of the EMB beamformer configured with a 16-element antenna array. Each antenna element connects to a transmit/receive (Tx/Rx) channel. These channels couple to one of two passive power dividers/combiners and they are followed by an up-/down-conversion (UDC) block. In transmit mode, the IF input signal enters the UDC, where the signal is up-converted to RF frequency for transmission in the Tx/Rx channels. The Tx/Rx channels amplify and shift the phase of the RF signals that will be transmitted from the antennas. In receive mode, the antennas collect the RF signals and the Tx/Rx stages amplify and phase shift the signal for IF down-conversion in the UDC.

The EMB chips that realize these functions are fabricated using the GlobalFoundries GF 45RFSOI process, a 45 nm RFSOI CMOS node. This process improves the transistor performance capabilities at mmWave frequencies and it is a mature process with high production wafer yields. This is important because the Tx/Rx channel performance largely dictates the beamformer capability and cost is always a concern. ***Figure 3*** shows a block diagram of the Tx/Rx channel.

As Figure 3 shows, the phased array antenna element feeds the input Tx/Rx switch. In receive mode, the LNA amplifies the mmWave signal received by the antenna. The LNA

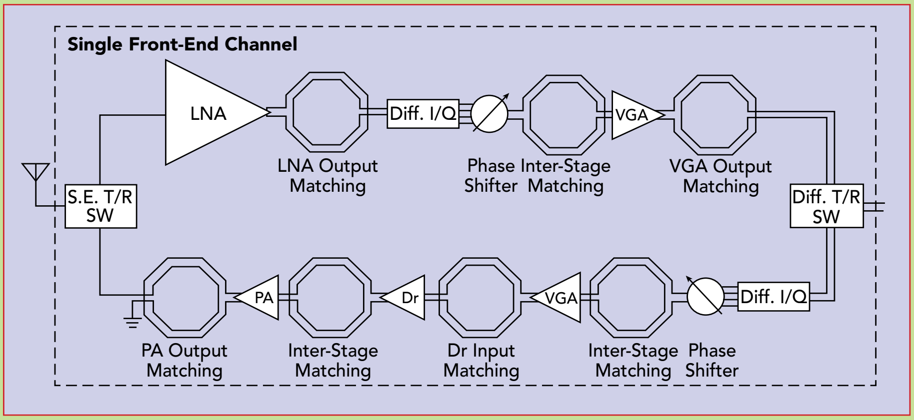


Fig. 3 **EMB beamformer chip Tx/Rx channel block diagram.**

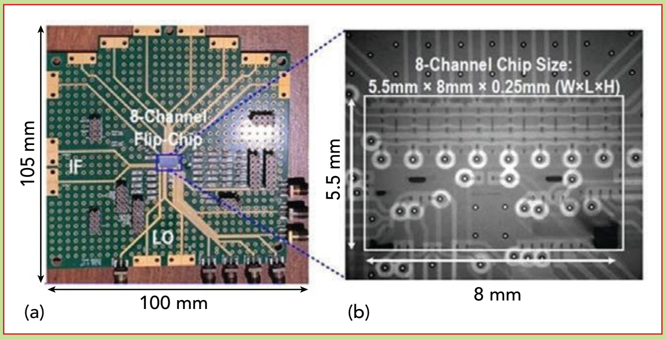


Fig. 4 (a) 8-channel EMB chip on test board and (b) chip X-ray.

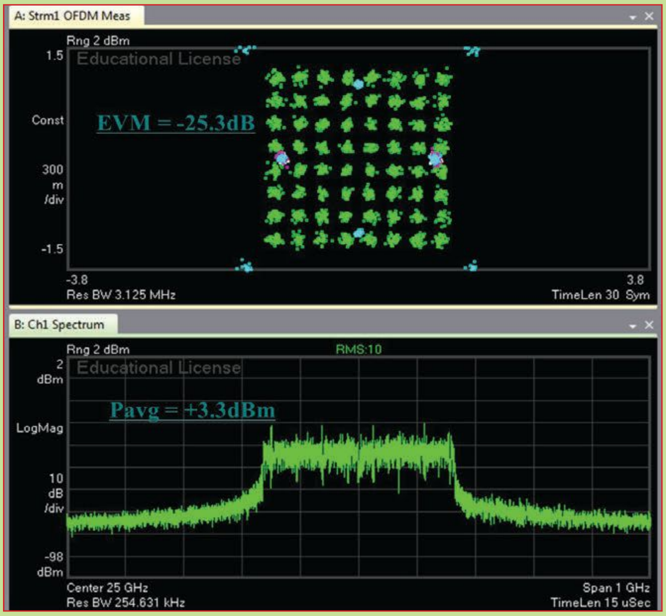


Fig. 5 EVM results for the EMB Tx/Rx channel at 25 GHz.

drives a differential I/Q section that feeds a phase shifter. After the signal is phase-shifted, it is amplified by a variable gain amplifier (VGA). Matching for the LNA and VGA is accomplished with on-chip circuit elements. The output matching network of the VGA connects to an output Tx/Rx switch that directs the received signal to the processing circuitry.

In transmit mode, the Tx/Rx switch routes the modulated signal from the processing circuitry to a phase shifter. Since the transmit power is substantially higher than the receive power, the output of the phase shifter will go through several stages of amplification. In the EMB beamformer chip design, this lineup includes a VGA that feeds a driver amplifier (DR) and, finally, a power amplifier (PA). Again, all the amplifiers are matched using on-chip circuit elements. The PA is the final amplification stage to ensure that the transmit signal to the antenna element is at the required levels. For both the receive and transmit signals, the phase shifters are essential to array beam steering, making this a vital function in the beamformer operation. ***Figure 4*** shows the eight-channel EMB chip mounted in a flip-chip configuration on a connectorized 105 × 100 × 5 mm evaluation board in Figure 4a and an X-ray photograph of the 5.5 × 8 × 0.25 mm eight-channel chip in Figure 4b.

TABLE 1
TX/RX PERFORMANCE SUMMARY

	Measurement Frequency (GHz)			
Parameter	25	28	37	40
Tx $OP1_{dB}$ (dBm)	+16.9	+16.5	+16.7	+16.0
Tx PA + SW efficiency at $OP1_{dB}$ (%)	23.1	23.7	24.2	22.0
Tx total DC power draw (mW)	345	304	333	300
Rx conversion gain (dB)	31.8	34.8	33.5	33.6
Rx noise figure (dB)	7.3	5.3	5.9	7.0
Rx $IP1_{dB}$ (highest gain) (dBm)	-24.3	-25.3	-26.7	-26.6
Image rejection ratio (IRR) (dB)	> 30	> 30	> 30	> 30

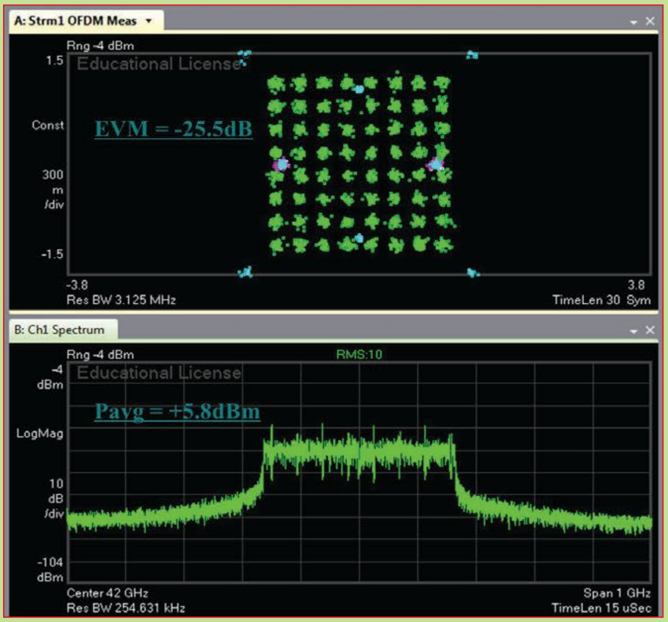


Fig. 6 EVM results for the EMB Tx/Rx channel at 42 GHz.

While the architecture is relatively common, what differentiates this development from competitive solutions is the 20 GHz bandwidth over the 24 to 44 GHz frequency range. This result is possible because great care has been taken to ensure that each functional block of the Tx/Rx channel shown in Figure 3 achieves the necessary 20 GHz operation bandwidth at the frequencies of interest. ***Table 1*** shows typical RF measurement results for the Tx/Rx channel.

As Table 1 shows, the transmitter output P_{1dB} is greater than +16 dBm across a broad frequency range. In addition to an output power level, emerging wireless modulation schemes require that the transmit channel deliver a high-fidelity, wideband-modulated output signal while maintaining sufficient average output RF power. ***Figure 5*** shows measurement results for error vector magnitude (EVM) and transmitter output power when transmitting a 400 MHz bandwidth signal with a 64-QAM OFDM modulation scheme at an RF carrier frequency centered around 25 GHz. ***Figure 6*** shows the results from the same set of test conditions for the

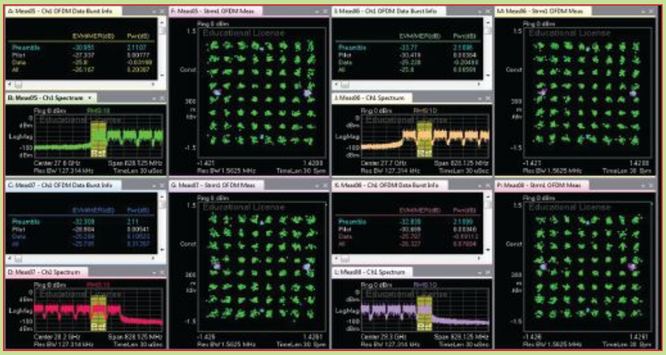


Fig. 7 Measured 8-CCA results for the EMB chip at 28 GHz.

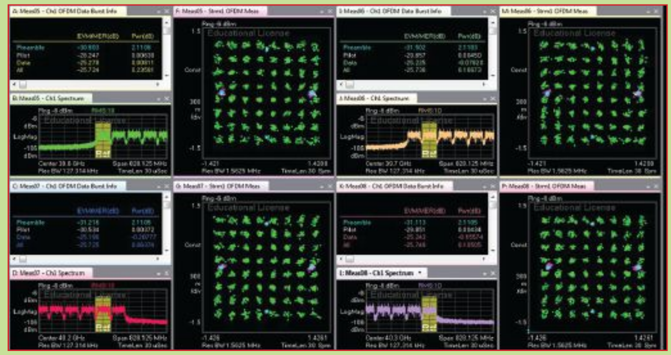


Fig. 8 Measured 8-CCA results for the EMB chip at 40 GHz.

64-QAM signal centered at 42 GHz.

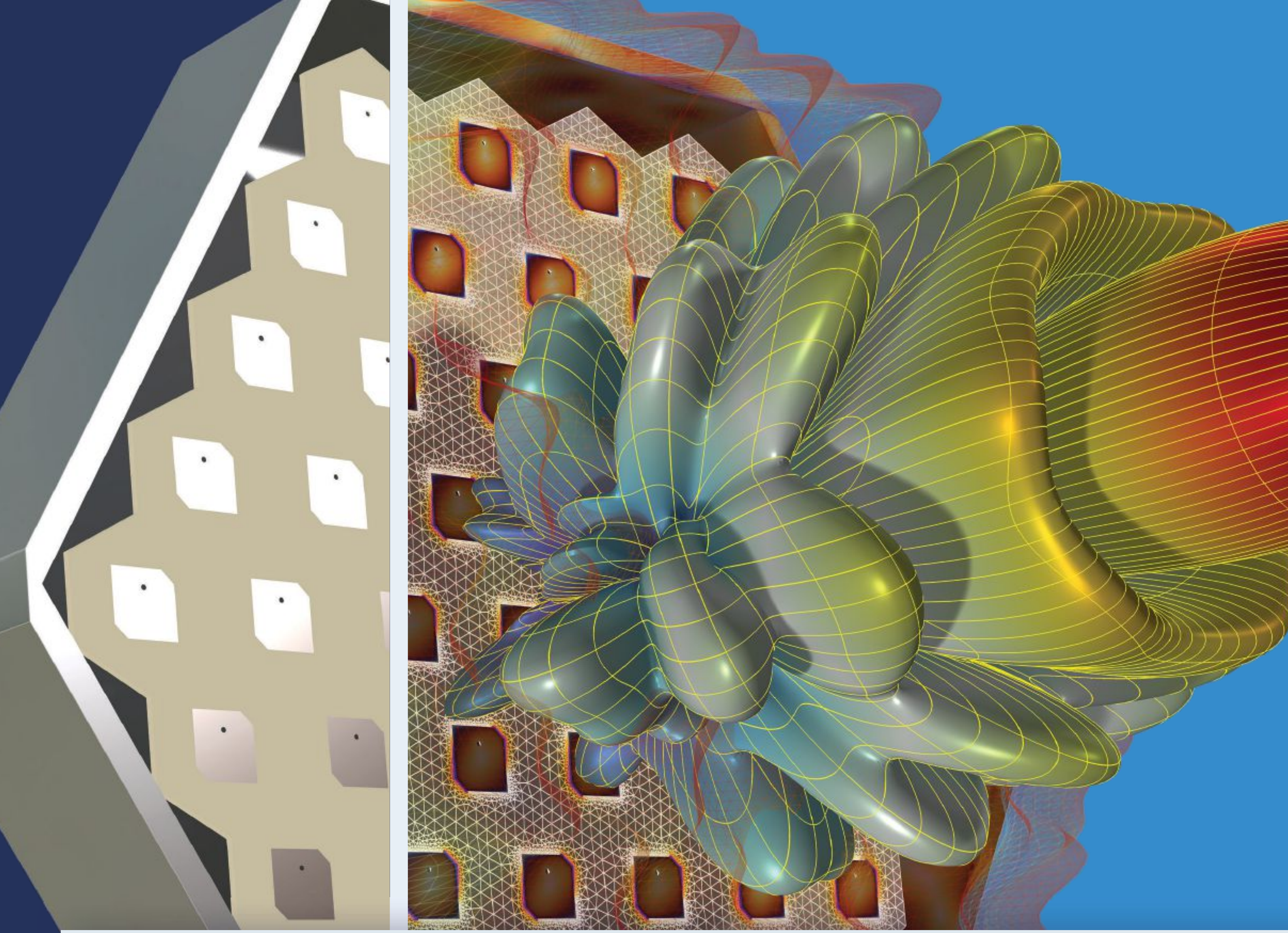
Part of the reason that operators are going into the mmWave and THz bands is to increase bandwidth, which translates to higher data rates and capacity. A common technique to get more bandwidth is to aggregate several smaller channels. ***Figure 7*** shows that the EMB chip will support this architecture. The results in Figure 7 show EVM and transmitter output power results when transmitting a 100 MHz bandwidth signal using a 64-QAM OFDM modulation scheme with an eight-component carrier aggregation (8-CCA) at an RF carrier frequency centered at 28 GHz. ***Figure 8*** shows the same measured data set for an RF carrier centered at 40 GHz. In terms of receiver performance, ***Figure 9*** shows measured constellation and spectral results with the concurrent wideband-modulated 64-QAM image signals at various power levels.

The EMB receiver is tested with concurrent wideband-modulated 64-/256-QAM image signals over a range of power levels and frequency spacings. The result is a reduction in EVM on the demodulated desired signal. This is attributable to a diminished SNR and an expanded spectral overlap.[1-2] Despite these conditions, the desired signal exhibits a clear constellation and is successfully demodulated for 6/12 Gbps, 64-QAM signals with EVM results of -32.56 dB and -27.6 dB, respectively. For an 8 Gbps, 256-QAM signal, the EVM is -33.47 dB. These measurements show a decrease from the -35.14 dB, -30.48 dB and -35.1 dB EVM values for 6/12 Gbps, 64-QAM and 8 Gbps 256-QAM signals when only the desired signal is taken into account.[1-2] As shown in Figure 9, when only the desired signal is applied to the receiver input, the result is an 18 Gbps, 64-QAM signal with an EVM value of -26.65 dB.

Systems that support high data transmission rates will enable many exciting applications that will benefit from mmWave and THz frequency bands. For example, metauniverses and the tactile internet can usher in a more immersive and intense user experience, including holographic communication. Users will be able to touch and see friends remotely in real-time as they appear in three dimensions in front of them. The advent of THz bands and mmWave capabilities makes such disruptive experiences possible.

INTEGRATING SATCOM AND THE TERRESTRIAL NETWORK

Satellite communications have been used for decades in maritime and in-flight connectivity applications. Emerging LEO constellations are revolutionizing connectivity opportunities with lower latency and lower transmit power capabilities



and requirements. These satcom systems are becoming pivotal for global communication since their large geographic footprints provide options to counter terrestrial network constraints. Satellite networks can function as space-based relay stations for various data types across multiple frequency bands, including Ka- and V-Band. Satcom system architecture includes the space segment (satellites with transponders), the ground segment (Earth stations) and the user segment (end-users with satellite terminals). Technological advancements such as high-throughput satellites and LEO constellations are being developed to meet the demands for increased data rates and enhanced reliability. Like terrestrial communications, satcom systems are venturing into higher frequency mmWave bands and advanced transceiver and antenna technology, along with more sophisticated signal processing techniques to address channel capacity and speed challenges. Currently, these services require a separate user terminal. While the industry is starting to see the emergence of direct-to-satellite mobile connectivity, data rates for these connections are low. Receivers operating at mmWave frequencies with integral beamformers, like those being developed by SwiftLink and others, could enable future mobile phones to link to satellites.

The integration of 5.5G and artificial intelligence (AI)-driven management brightens the future of satcom. These emerging techniques are poised to enhance spectrum utilization and system performance. This will cement the role of satcom as a foundational element of connectivity, supporting applications from emergency response to universal internet access and affirming its leadership in communication technology.

COMPUTING POWER AND INFORMATION CAPACITY WILL REVOLUTIONIZE THE FUTURE

Consumer wants drive data traffic needs and, ultimately, wireless technology. First voice, then data, then the internet and now video. The next application that will drive data traffic and bandwidth demand is AI. AI promises many new applications and capabilities, from real-time language translation to real-time image analysis. Most of AI's capabilities require high performance computing power in specialized AI data centers using AI chips from companies like NVIDIA and specialized AI software. The processing and computing capabilities required for AI are currently beyond the capabilities of mobile phone processors. To provide users with seamless, real-time AI functionality, networks must handle the data and compute needs of AI. This requires the data speeds of optical communication links or enhanced wireless networks enabled by mmWave and THz technologies.

In the digital era, computing power and information transmission capacity are the fundamental forces propelling technological advancement. By heading into mmWave frequency bands, with 20 GHz of bandwidth and doing this on a workhorse RF CMOS process, version 1 of the EMB chip extends the capabilities of traditional 5G bands and enables new ones. These activities adhere

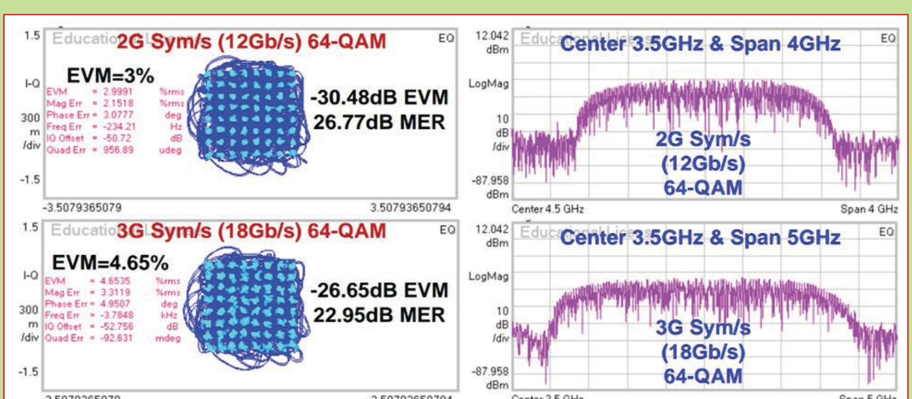


Fig. 9 Measured constellation and spectral data for the EMB chip.

to ITU standards while also pushing boundaries by dramatically increasing the expected transmission speeds up to 18 Gbps. This increase in performance not only enhances wireless data transmission infrastructure capabilities it also has implications for emerging AI applications.

AI processing relies on enormous amounts of data and can benefit from these advancements in transmission capacity. Increasing data transmission capabilities benefit AI processor operations by facilitating a more robust and seamless flow of data. This is essential for training complex neural networks and deploying AI solutions at scale. Improving the wireless pathway to help carry the high data traffic of AI systems will enable real-time analytics and decision-making processes that are crucial for the next generation of AI applications. These technologies and capabilities are set to be the foundation of the architecture of tomorrow's digital landscape. The fusion of wireless high speed data transmission with advanced computing power is set to unlock new horizons in AI development, driving the world to a future where the potential of AI can be fully realized.

The leap in computing power is the outcome of several important innovations: CMOS transistor scaling, the collaborative evolution of the CPU and GPU, the multicore revolution and heterogeneous computing in CPUs and the evolution of GPU for general-purpose computing. Advancements in multicore technology and heterogeneous computing are making CPUs more efficient in processing complex tasks. Initially designed for graphics rendering, GPUs have become vital in general-purpose computing due to their powerful parallel-processing capabilities, playing crucial roles in deep learning and scientific computing.

CMOS transistor scaling has also been significant in the information transmission capacity space, enabling breakthroughs in mmWave and THz technology. Scaling means smaller transistors that can operate at mmWave frequencies, which allows high-power transmission from a phased array antenna. The EMB chip architecture relies on Tx/Rx channels that operate in parallel. Since each Tx/Rx channel drives an individual antenna element, a large phased array beamformer has many parallel paths, which resembles the parallel processing of a modern GPU processor.

CONCLUSION

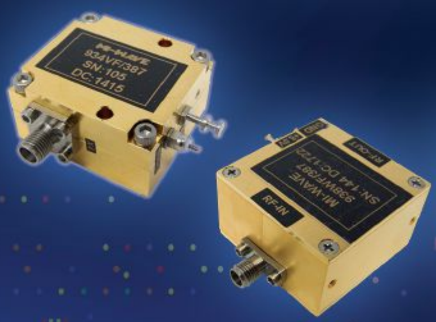
The industry stands as the vanguard of information capacity innovation. To enable this innovation, mmWave wideband technology is spearheading the continuous advancement of transmission capabilities. These emerging wideband technologies will lay the robust technical foundation for next-generation communication standards, including 5.5G, 6G and satellite communications. They will also pave the way for the seamless integration of terrestrial and non-terrestrial networks to form the backbone of a hyper-connected future. Concurrent revolutions in computing power and information transmission capacity are the twin engines driving the rapid pace of technological evolution.

As we stand on the edge of this new digital era, the advancements spearheaded by these industries are set to redefine our daily experiences. The integration of faster data rate capabilities and AI is poised to catalyze a paradigm shift in how the world interacts with technology. This synergy will unlock a level of digitization that delivers unparalleled convenience and efficiency, revolutionizing personal lives and professional environments. The promise of this technological renaissance is a world where the seamless and intelligent application of digital solutions enhances every aspect of our existence. ■

References

1. M. -Y. Huang, T. Chi, S. Li, T. -Y. Huang and H. Wang, "A 24.5–43.5-GHz Ultra-Compact CMOS Receiver Front End With Calibration-Free Instantaneous Full-Band Image Rejection for Multiband 5G Massive MIMO," *IEEE Journal of Solid-State Circuits*, Vol. 55, No. 5, May 2020, pp. 1177–1186.
2. M. -Y. Huang, T. Chi, F. Wang, S. Li, T. -Y. Huang and H. Wang, "A 24.5-43.5GHz Compact RX with Calibration-Free 32-56dB Full-Frequency Instantaneously Wideband Image Rejection Supporting Multi-Gb/s 64-QAM/256-QAM for Multi-Band 5G Massive MIMO," 2019 IEEE Radio Frequency Integrated Circuits Symposium (RFIC), Boston, MA, USA, 2019, pp. 275-278.

ACTIVE COMPONENTS



MULTIPLIERS

Frequency -Multiplication-Pin -Pout

85-109 GHz, x9, 15 dBm
90-170 GHz, x6 or x8, 15 dBm,10 dBm
110-150 GHz, x6, 17 dBm, 13 dBm
195-225 GHz , x12, 12 dBm, 12 dBm

AMPLIFIERS

Frequency-Gain-Psat

75-110 GHz, 30 dB, 28 dBm
88-115 GHz, 25 dB, 24 dBm
100-170 GHz, 25 dB, 24 dBm
110-145 GHz, 20 dB, 15 dBm
195-220 GHz , 20 dB, 12 dBm
210-230 GHz , 20 dB, 16 dBm

MIXERS

Frequency - IF - LO Power - Conversion Loss

120-160 GHz, DC-12 GHz, 13 dBm, 13 dB
170-210 GHz, DC-12 GHz, 12 dBm, 9 dB
210-230 GHz, DC-5 GHz, 13 dBm, 13 dB
200-220 GHz, DC-15 GHz, 0 dBm, 12dB

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Single-Layer Alumina Waveguide-to-Coplanar Transition in D-Band

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TIMA, Université Grenoble Alpes, Grenoble, France

While mobile communications claim the traditional sub-6 GHz bands and hungrily expand in the low mmWave region as they strive for higher data rates, lower latency and ubiquitous communications, other applications are shifting higher in frequency, beyond the conventional 40 GHz bands, as a consequence. The E-Band region (70 to 90 GHz) is being commercially populated primarily by terrestrial and satellite communications leveraging multi-GHz channels in that band.[1] To further expand the available bandwidth, W-Band (90 to 110 GHz) and D-Band (110 to 175 GHz) are the natural evolution and commercial interest in these bands comes mainly from terrestrial communications.[2] Wireless fronthaul and backhaul links are seeing timely and cost-effective deployments for mobile networks. The need for N × 10 Gbit/s data rates constantly pushes the envelope of regulatory limits and technological bounds.

The nature of 100 GHz signals implies substantial integration of the radio front-end. This is a key aspect determining the final performance. MMICs, used to implement the active RF functions,[3] must be interconnected to low-loss distribution networks and antennas, often in waveguide technology.[4]

This article proposes a transition between a coplanar waveguide (CPW) that might be used to integrate a MMIC and a rectangular waveguide, as shown in ***Figure 1***. In industrial applications, such transitions entail specific requirements and desired features that must align with standard fabrication and assembly procedures. A key requirement is reducing design complexity while maintaining versatility. The proposed transition configuration meets both criteria, utilizing a single-layer printed circuit board (PCB) that can accommodate four different feeding arrangements to simplify the design and enhance adaptability.

TRANSITION DESIGN

Requirements and State-of-the-Art

The design concept is based on three requirements:

- The transition must be low cost and have the broadest operating band that does not require an external back-short
- The transition design must be hermetic and compatible with standard PCB assembly, which implies a final washing
- The interconnection should match a waveguide section and 50 Ω coplanar transmission line by exploiting a single dielectric layer compatible with thin-film technology.

Existing solutions proposed in the literature address only some of these requirements. Some citations[5-7] require a multi-part custom waveguide structure, while others[8-10] involve an undesirable back-short component or suffer from radiation loss. To meet all the requirements, the proposed design is based on a single layer of AD996 Superstrate alumina from Coorstek Inc. with a nominal thickness of 0.005 in. The thin-film carrier substrate has outstanding electrical performance, especially in the mmWave range[11] and is physically stable.[12]

The integration concept is represented in Figure 1. The MMIC is placed on the top layer of the alumina circuit and wire bonded to a 50 Ω grounded coplanar waveguide (GCPW). Then, the signal is routed into a hollow metallic waveguide to exploit its intrinsic high quality factor. For D-Band, the standard is the WR-06, which nominally operates from 110 to 170 GHz and features a 1.651 mm × 0.8255 mm rectangular section.

The transition must work from 130 to 175 GHz in this case, implying a 29.5 percent bandwidth. Return loss must be better than 15 dB, while the insertion loss must be a maximum of 1 dB. In addition, eliminating the need for an external back-short and fully sealing the

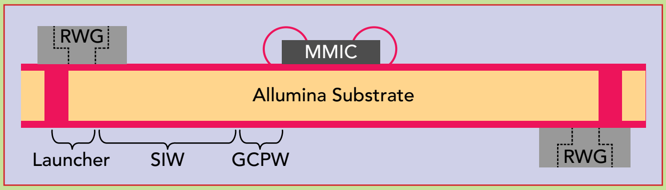


Fig. 1 Integrating a MMIC and waveguide passive circuits.

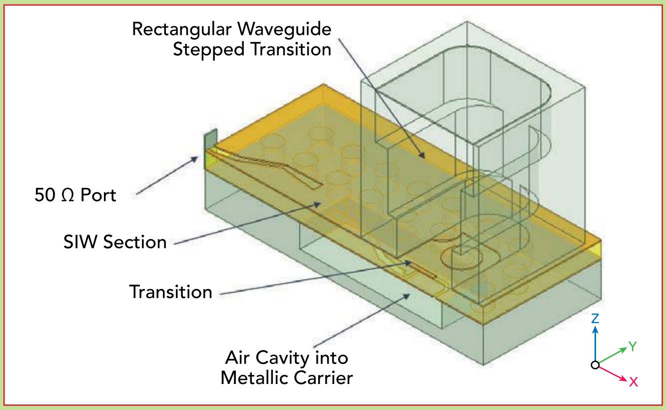


Fig. 2 3D cross-section of the proposed transition.

transition are attractive features.

Since the ceramic dielectric constant is nominally 9.9, an embedded quarter-wavelength back-short can be embedded in the 0.005 in.-thick substrate without any aperture cut. To complete the impedance matching, a stepped tapered-waveguide transformer is implemented. This structure, shown in ***Figure 2***, facilitates the transition between the air-filled waveguide and the high-permittivity substrate.

Layout

The transition involves a single alumina dielectric layer with top and bottom thin-film metal layers. The metal stack-up uses sputtered titanium and palladium, along with 3 µm galvanic-growth gold cladding. The resulting transition is 1.80 mm × 1.16 mm.

The operational principle is closely related to a standard microstrip-to-waveguide launcher. However, several design features improve the performance, add features and adapt the design to this basic stack-up. As shown in Figure 2, the design starts with the standard WR-06 waveguide transition. The standard waveguide interface allows the transition to interface with third-party devices and measurement instrumentation. The waveguide stepped transformer guarantees sufficient optimization capabilities. Figure 2 shows the two-step taper, implemented with rounded edges having a 0.2 mm radius as a by-product of CNC machining.

Figure 3 shows a lateral and top view of the detailed design with the optimized dimensions in micrometers. The S-parameters of the stand-alone transformer show a maximum insertion loss of 0.2 dB. ***Figure 4a*** shows a top view of the detailed geometry of the proposed D-Band transition and ***Figure 4b*** shows a close-up of the feeding architecture. The dimensions are in micrometers in both figures.

The work described in this article aims to develop a versatile transition that allows circuits to be placed on the top or bottom layer of the carrier board. This allows these circuits to avoid the 50 Ω GCPW or other structures that may be present. V-shaped slots have been introduced[13] that feed a quasi-TE_{10} mode along a short section of an SIW interconnection. This configuration makes it convenient to flip the input/output of the transition from one layer to the other. This feature increases loss by only a fraction of a dB, but it requires an air cav-

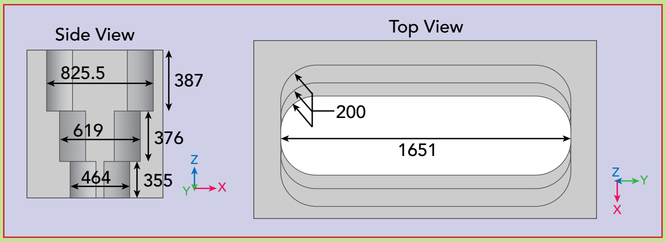


Fig. 3 Waveguide matching adapter for the transition.

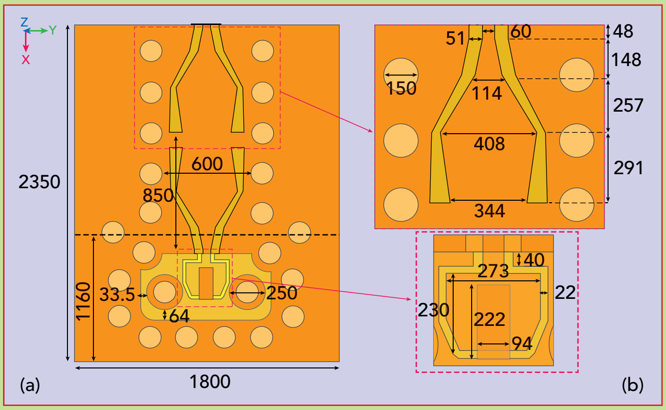


Fig. 4 (a) Transition top view. (b) Close-up of feed.

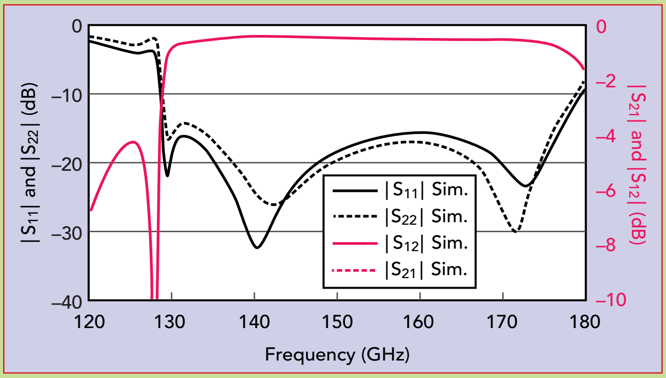


Fig. 5 Full-wave transition simulations.

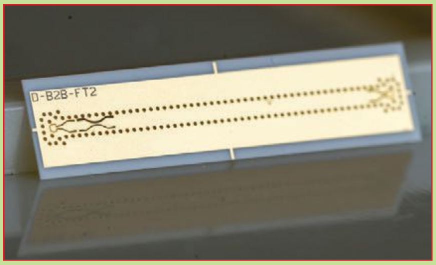
ity for the proper functionality of the etched slots.

Figure 5 shows the simulated S-parameters of the proposed design. It shows return loss values greater than 15 dB from 128.9 GHz to 176.9 GHz. With this 31.4 percent fractional bandwidth, the insertion loss is 0.43 dB at the center frequency, dropping only to 0.64 dB in the upper frequency corner. The simulation verifies that the design meets the D-Band loss flatness requirements, which are critical for very wideband signals.

Feeding Options

The proposed transition allows a MMIC to be placed on either side of a waveguide feed and connected to that MMIC. This is a key advantage of this technique and it is enabled by the V-shaped slot configuration, along with the excitation of the quasi-TE_{10} mode. This mode evenly distributes the currents between the bottom and the top metal layers. With a symmetric field distribution, the output can be on either layer with a 180-degree phase shift. This provides additional implementation possibilities:

- Basic configuration: 50 Ω feeding line and wave-



▲ Fig. 6 **Back-to-back D-Band flippable transition sample.**

guide transition are on the same side

- Flippable configuration: 50 Ω feeding line and waveguide transition are on opposite sides
- SIW fed configuration: Can exploit a single V-shaped slot for SIW feeding
- Planar configuration: If there is no advantage to connections on top and bottom, performance can be improved by eliminating the V-shaped slots.

PARAMETRIC STUDY

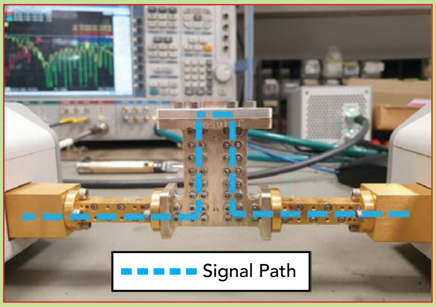
D-Band circuits involve very small features compared to standard RF and microwave applications. The resolution of the standard photo etching process may become a limiting factor for performance. This transition requires micrometer resolutions that are challenging up to 175 GHz. This section studies the effects of different manufacturing tolerances and assembly alignments of different parts can have on electrical performance. Design robustness is important for industrial readiness and component yield. This section investigates four design parameters.

Substrate Thickness

Unpredictable thickness variations can result from the lamination of the alumina substrate. The 0.005 in. alumina substrate may have a thickness tolerance variation of ±10 percent or 0.0005 in. Simulations show a frequency shift up to 10 GHz at the maximum substrate thickness variation. Even though return loss and insertion loss flatness do not change much, this is a significant change in frequency.

Dielectric Constant

The dielectric constant, ϵ_r, also has a tolerance. In this study, the di-



▲ Fig. 7 **Test circuit measurement setup.**

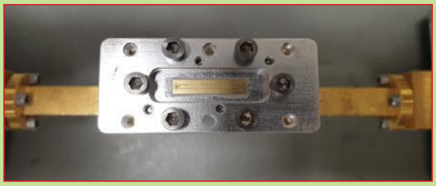
electric constant of alumina was allowed to change by ± 10 percent to assess design robustness. The frequency response shifts by 0.5 GHz for every 0.1 change in the dielectric constant. The loss patterns appear to be unaffected by this dielectric change.

Waveguide Alignment

The stepped transformer that matches the WR-06 connection to a custom-sized transition must be carefully positioned on the transition since misalignment influences performance. To investigate position sensitivity, the waveguide transformer has been incrementally shifted in 25 µm steps along X- and Y-directions. At shifts up to 50 µm, the matching is degraded, but the return loss is still less than 10 dB in the 130 to 175 GHz band. However, the insertion loss exhibits a deep notch at 156 GHz.

Via Hole Position

The metallized through-hole via location is crucial for controlling the operational bandwidth and the matching response. Even if they are laser drilled, vias have a poorer tolerance than photo-etched traces. The via position can shift by ± 25 µm and the inner metallization plating is not entirely controlled. Electromagnetic analysis indicates there are hole locations within the acceptable tolerances that will degrade the input matching of the transition. The overall trend will



▲ Fig. 8 **Top view of the measurement setup.**

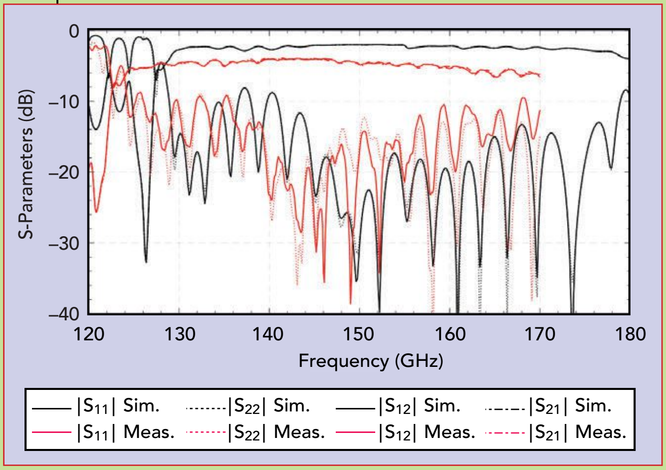
be to shift optimum S-parameter performance higher in frequency.

EXPERIMENTAL ASSESSMENT

The finalized single transition design was mounted in a back-to-back configuration to measure performance. Since the operational frequency is high, the back-to-back transition test fixture uses an SIW line to avoid radiation effects typical of microstrip lines in the mmWave spectrum. Several different combinations have been manufactured to represent all the mounting configurations described earlier. ***Figure 6*** shows a photograph of the most complex transition that implements two flippable transitions.

Measurements were performed with a four-port Rohde & Schwarz ZVA50 vector network analyzer (VNA) paired with two ZC170 mmWave converters. Each interface is a standard WR-06 waveguide section. This interface is also the reference plane for the TOSM calibration procedure.

The mmWave converters cannot directly connect to the transition, so a dedicated mechanical jig was designed and manufactured. ***Figure 7*** shows the measurement setup of the alumina test circuit. The VNA interfaces are connected



▲ Fig. 9 **Measured versus modeled results of the flippable D-Band transitions.**

to a mechanical jig that embeds two E-plane 90-degree bends. On top, a carrier supports the alumina test circuit and the waveguide interface with the stepped transformer. The signal flows through the H-plane 90-degree waveguide bends and is routed to the transition, not visible in Figure 7. ***Figure 8*** shows the transition positioned on top of the mechanical jig. A supporting carrier is placed between the waveguide assembly and the alumina test circuit. The carrier embeds the stepped waveguide tapers that complete the proposed transition. Positioning is critical to achieve the best performance and CNC-milled reference markers have been incorporated to enable fine alignment adjustments.

Figure 9 shows the results from the most challenging configuration of the proposed transition. The measurements are for the back-to-back transition test circuit. The waveguide assembly and all the sources of loss are taken into account. The simulation spans 120 to 180 GHz, but the ZC170 mmWave converters limit the measurements to 170 GHz.

The results are promising since the back-to-back transitions maintain better than 10 dB return loss from 130 to 170 GHz. Insertion loss flatness is also verified throughout the D-Band frequency range with only minor ripple. We believe this ripple is mainly due to the length of the back-to-back transition configuration.

The main discrepancy is related to the absolute value of the insertion loss. The measured result is 4 dB in the 140 to 150 GHz range versus 2 dB predicted by the simulations. This deviation becomes larger in the 160 to 170 GHz spectrum, where the measured insertion loss reaches 6 dB at the top edge of the operational frequency. Several factors contribute to the observed difference. From the manufacturing standpoint, inaccuracies and tolerances lead to an insertion loss penalty. However, the electrical properties of the materials will also contribute to the loss deviation. The simulations take these material-related loss mechanisms into account, but the absolute values depend on the electrical characteristics of the materials that have not been experimentally validated in the 170 GHz spectrum.

CONCLUSION

The proposed D-Band coplanar-to-waveguide transition answers several technical and industrial needs, providing high performance and design robustness to practical assembly manufacturing. The layout requires a single 0.005 in. standard thin-film alumina layer with CPW-to-SIW and SIW-to-rectangular waveguide transitions. The integrated launcher guarantees hermeticity without a backshort in all four configurations. The transition configurations described in this article accommodate different MMIC and waveguide port requirements and provide a solution for most practical cases. Simulations and sensitivity analyses have been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validated by back-to-back measurements, confirming a fractional bandwidth of about 30 percent with a 10 dB return loss. The proposed transition exhibits an average loss of 1.5 dB, de-embedded from the measurement fixtures, which is compatible with alternative, more complicated or less cost-effective solutions. The operation across the 130 to 170 GHz frequency range of D-Band makes this structure suitable as interconnection between MMICs and waveguide networks or antennas in next-generation wireless communication equipment. ■

ACKNOWLEDGMENT

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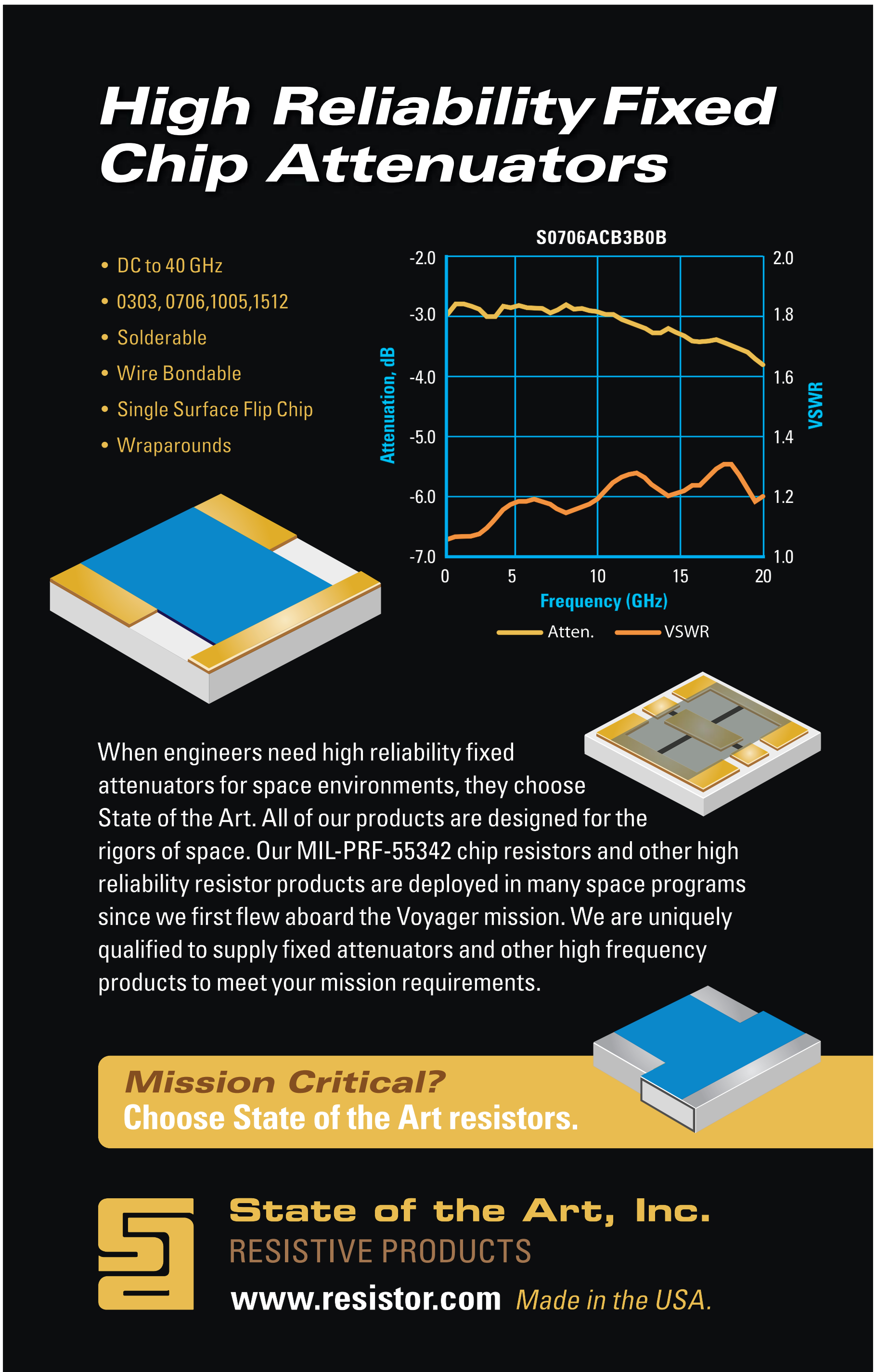

References

1. B. Tezergil and E. Onur, "Wireless Backhaul in 5G and Beyond: Issues, Challenges and Opportunities," *IEEE Communications Surveys & Tutorials 24.4* 2022, pp. 2579–2632. doi:10.1109/COMST.2022.3203578.
2. M. G. L. Frecassetti, A. Mazzanti, J. F. Sevillano, D. del Río and V. Ermolov, "D-Band Transport Solution to 5G and Beyond 5G Cellular Networks," *European Conference on Networks and Communications (EuCNC)*, 2019, pp. 214–218, doi: 10.1109/EuCNC.2019.8802033.
3. A. O. Watanabe, M. Ali, S. Y. B. Sayeed, R. R. Tummala and M. R. Pulugurtha, "A Review of 5G Front-End Systems Package Integration," *IEEE Transactions on Components, Packaging and Manufacturing Technology,* 2021, pp. 118–133, issn: 2156-3985. doi: 10.1109/TCPMT.2020.3041412.
4. R. Quaglia, V. Camarchia, M. Pirola, *Electronics for Microwave Backhauling*, Artech House, 2016.
5. A. U. Zaman, V. Vassilev, P.-S. Kildal and H. Zirath, "Millimeter Wave E-Plane Transition From Waveguide to Microstrip Line With Large Substrate Size Related to MMIC Integration," *IEEE Microwave and Wireless Components Letters 26,* 2016, pp. 481–483. issn: 1558–1764. doi: 10.1109/LMWC.2016.2574995.
6. E. S. Li, G.-X. Tong and D. C. Niu, "Full W-band Waveguide-to-microstrip Transition With New E-plane Probe," *IEEE Microwave and Wireless Components Letters 23,* 2013, pp. 4–6. issn: 1558-1764. doi: 10.1109/LMWC.2012.2235176.
7. C. Wang, Y. Yao, J. Wang, X. Cheng, J. Yu and X. Chen, "A Wideband Contactless CPW to W -Band Waveguide Transition," *IEEE Microwave and Wireless Components Letters 29,* 2019, pp. 706–709. issn: 1558-1764. doi: 10.1109/LMWC.2019.2945242.
8. S. Jameson and E. Socher, "A Wide-Band CMOS to Waveguide Transition at mm-Wave Frequencies With Wire-Bonds," *IEEE Transactions on Microwave Theory and Techniques 63,* 2015, pp. 2741–2750. issn: 1557-9670. doi: 10.1109/TMTT.2015.2461160.
9. Y.-C. Leong and S. Weinreb, "Full Band Waveguide-to-microstrip Probe Transitions," Vol. 4, Anaheim, Calif., U.S., IEEE, 1999, 1435–1438, isbn: 0-7803-5135-5. doi: 10.1109/MWSYM.1999.780219.
10. Y. Ishikawa, K. Sakakibara, Y. Suzuki and N. Kikuma, "Millimeter-Wave Topside Waveguide-to-Microstrip Transition in Multilayer Substrate," *IEEE Microwave and Wireless Components Letters 28,* 2018, pp. 380–382, issn: 1558–1764, doi: 10.1109/LMWC.2018.2812125.
11. S. Moscato, M. Oldoni and S. C. Mejillones, "Substrate Integrated Waveguide Components on Alumina for E-band Applications," *Microwave Mediterranean Symposium,* 2022, pp. 1–4. doi: 10.1109/MMS55062.2022.9825525.
12. Y. Zhang, D. Zhao and P. Reynaert, "A Flip-Chip Packaging Design With Waveguide Output on Single-Layer Alumina Board for E-Band Applications," *IEEE Transactions on Microwave Theory and Techniques 64,* 2016, pp. 1255–1264, issn: 1557–9670, doi: 10.1109/TMTT.2016.2536602.
13. S. R. Zahran, S. Moscato, A. Fonte, M. Oldoni, A. A. Traversa, D. Tresoldi, P. Ferrari, G. Amendola and L. Boccia, "Flippable and Hermetic E-Band RWG to GCPW Transition With Substrate Embedded Back-short," *IEEE Transactions on Microwave Theory and Techniques 71.6,* 2023, pp. 2582–2593, doi: 10.1109/TMTT.2022.3228619.

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- Harmonics and subharmonics: -60 dBc
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- Reference input/output: 10/100/3000 MHz, including a 3 GHz clock for phase-coherent synchronization among multiple devices
- Dimensions and weight:
  - Single-channel model: 232 × 393 × 97 mm (half-width of 19 in.); weight: < 10 kg
  - Multi-channel model: 19 in. and 2 HU rack-mountable module; weight: < 18 kg
- Power consumption: 80 W (single channel)
- Communication ports: ETHERNET, USB, GPIB.

Figure 1 shows the APHSP signal generator phase noise performance across several frequencies up to 100 MHz offset. This outperforms all other analog signal generators currently on the market. Beyond the 1 MHz offset, the APHSP maintains agility with a switching time below 5 µs due to avoiding a phase-locked loop (PLL) for noise suppression. This characteristic is shared with other models in our analog signal source lineup.

INNOVATIVE DESIGN MEASURES

The APHSP signal generator architecture is based on fully direct synthesis, so it uses a PLL only for synchronization with external reference sources. The PLL has been central to high spectral-quality frequency synthesis for many decades thanks to its narrowband filtering capability. However, addressing the excessive noise inherent to PLL systems has been a persistent challenge, often at the cost of increased system power consumption and expense. While AnaPico has traditionally adhered to conventional frequency synthesis principles, it continuously innovates. Achieving a new qualitative level in microwave generation often necessitates choosing between direct and indirect synthesis. Recent advancements in direct digital synthesis chips, frequency dividers and high rejection microwave filters have created new opportunities to develop efficient and compact direct-frequency synthesizers.

The APHSP series utilizes direct digital synthesis in the UHF range, where the signal spectrum quality is inherently high and the frequency switching time and step are intrinsically minimal. This UHF range is then up-converted in steps over an octave, maintaining low non-harmonic components and phase noise. This synthesis approach leverages the noise performance of high frequency oven-controlled crystal oscillator (OCXOs) without significant degradation. However, generating a system reference signal with minimal phase noise presents a new challenge. AnaPico addresses this with a proprietary solution that produces the 3 GHz reference signal shown in ***Figure 2***, which can be used in frequency synthesis and is accessible via the rear panel. This solution includes low noise frequency multipliers and custom-designed oscillators, such as a 100 MHz OCXO. Maintaining the noise potential of quartz at microwave frequencies below -180 dBc/Hz is notably challenging when using commercial off-the-shelf OCXOs.

The synthesized frequency range is extended from 1 kHz to 51 GHz using multipliers and frequency dividers. Then, power amplification, harmonic suppression and output level stabilization are performed across the entire frequency and temperature ranges.

The PLL is retained only for synchronization with external reference signals, ensuring the specified noise performance regardless of the external reference source quality. When a high-quality external signal (e.g., a

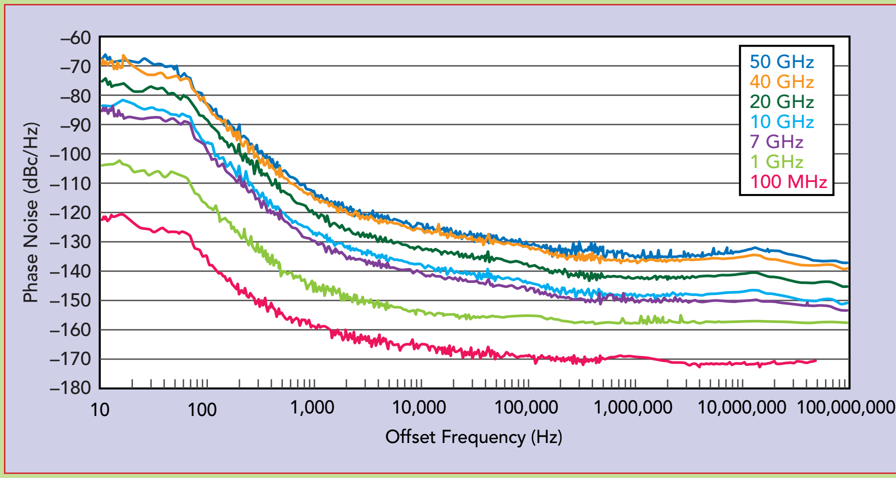


Fig. 1 **APHSP SSB phase noise at 10 dBm P_{out}.**

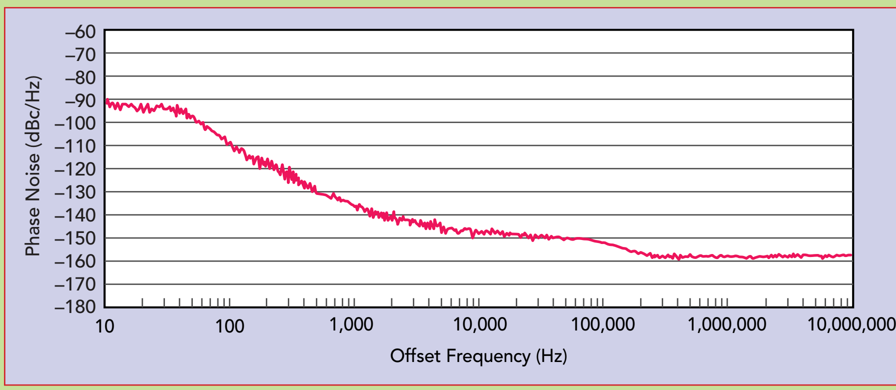


Fig. 2 **Phase noise of 3 GHz reference clock.**

10 MHz generator with the LN option) is used, standard settings of 10 or 100 MHz can be used, implementing a PLL bandwidth of about 50 Hz. For synchronization with a stable but noisy source like an Rb oscillator, the VREF option is more suitable, offering a bandwidth of less than 1 Hz. The installed LN option eliminates the need for users to seek a low noise oscillator, providing the best available phase stability. The VREF option allows for enhanced accuracy and long-term frequency stability using atomic frequency standards without compromising phase noise. The combination of VREF and LN options achieves a reference PLL bandwidth of 0.05 to 0.1 Hz.

APPLICATIONS

Phase-coherent single- and multi-channel analog signal generators with ultra-low phase noise, very high spectral purity and fast-switching capabilities have a wide range of potential applications. Some applications that are enabled by sophisticated multi-channel signal generators with high spectral purity and excellent phase coherence include:

- MIMO and beamforming networks in wireless communication systems
- Radar and electronic warfare systems that drive arrays or jam and deceive enemy systems
- Quantum computing and research that are exploring qubit control and quantum protocols
- Fundamental scientific research and metrology to enable interferometry, spectroscopy and timing systems
- Medical imaging and diagnostics to improve MRI and ultrasound imaging capabilities
- Test and measurement equipment that enables the evolution of RF and microwave components
- Navigation and satcom opportunities in aerospace and defense that depend on precise, high-quality signal generation
- Advanced driver-assistance systems and vehicle-to-everything opportunities in automotive where radar and communications systems are becoming critical
- Industrial and environmental monitoring to expand measurement capabilities
- Education and training to enable the next generation of academic and industrial advances.

In summary, single- and phase-coherent multi-channel analog signal generators with ultra-low phase noise, high spectral purity and fast-switching capabilities are invaluable in any application where precise, reliable signal generation is essential. They enable advancements in technology and research, ensuring high performance and accuracy in a wide range of critical and cutting-edge applications.

VENDORVIEW

AnaPico AG
Glattbrugg, Switzerland
www.anapico.com

SSG-44G-RC (100 MHz TO 44 GHz)

Wideband Sig Gen

High Quality, Cost-Effective Millimeter Wave
Signal Generator for Your Test Bench or ATE

Features

- 100 MHz to 44 GHz, -40 to +17 dBm
- Low phase noise & excellent harmonic rejection
- CW & pulsed outputs with 0.5 µs pulse width
- Automated sweep & hop list sequences
- Compact package with Ethernet & USB control
- SSH secure Ethernet communication

Common Applications

- 5G FR1, FR2 & FR3, millimeter wave radio
- Semiconductor burn-in & life testing
- Automated production test systems
- Benchtop signal generator
- Wideband LO source

Complete Series:

Model Number	Frequency	Output Power
SSG-6000RC	25 MHz to 6 GHz	-65 to +14 dBm
SSG-6001RC	1 MHz to 6 GHz	-70 to +15 dBm
SSG-15G-RC	10 MHz to 15 GHz	-50 to +16 dBm
SSG-30G-RC	10 MHz to 30 GHz	-47 to +23 dBm
SSG-30GHP-RC	10 MHz to 30 GHz	-47 to +28 dBm
SSG-44G-RC	100 MHz to 44 GHz	-40 to +17 dBm

mmWave Horn Antennas for T&M Applications

Pasternack, an Infinite Electronics brand and a leading provider of RF, microwave and mmWave products, has announced its new series of mmWave horn antennas. These antennas were designed to meet evolving needs and achieve precision in test and measurement applications. The new line includes a variety of waveguide probe antennas and dual-polarized horn antennas, offering enhanced flexibility and performance in the 22 to 170 GHz frequency range.

The mmWave horn antennas, which range in size from WR-6 to WR-34, are equipped with U-round, U-square, U-mod and U-cover flanges. They deliver a nominal gain of 6.5 dBi for probe antennas and 15 dBi for dual-polarized antennas, ensuring high precision in characterizing antennas and wireless systems. Precision machining guarantees consistent gain versus frequency and VSWR less than 1.3:1. These performance attributes improve accuracy and reliability in test and measurement tasks.

The antennas offer a wide selection of frequency options and a rectangular waveguide interface for optimal performance. They are constructed from high-grade copper with a gold plating finish. They provide linear/circular polarization, ensuring versatility for various testing scenarios.

Pasternack's mmWave horn antennas are in stock and available for same-day shipping. For inquiries, please call +1 (949) 261-1920.

A leader in RF products since 1972, Pasternack is an ISO 9001:2015-certified manufacturer and supplier offering the industry's largest selection of active and passive RF, microwave and mmWave products available for same-day shipping. Pasternack is an Infinite Electronics brand. Infinite operates a global portfolio of leading in-stock connectivity solution brands. The brands provide products, solutions and real-time support for customers. Infinite's brands serve customers across various industries with a broad inventory selection, same-day shipping and 24/7 customer service.

VENDORVIEW

Pasternack, an Infinite Electronics brand
Irvine, Calif.
www.pasternack.com
+1 (978) 682-6936 for inquiries

Real-Time Spectrum Analysis

Integrating Wi-Fi, Bluetooth or other RF technologies into a design can be challenging. To make the evaluation and characterization of complex RF systems easier, RIGOL's RSA5000 real-time spectrum analyzers add the dimension of time to RF analysis. The RSA5000 combines high performance swept analysis and real-time performance with options for EMI pre-compliance, vector network analysis and vector signal analysis. Depending upon the model, the RSA5000 supports a frequency range for all measurement modes of 9 kHz to 3.2 GHz or 6.5 GHz.

RIGOL's RSA5000 Spectrum Analyzer allows the user to debug and analyze complete RF modules and systems. Complex signals, including 802.11b and GSM, can be demodulated and analyzed, radiated emissions measured and basic S-parameters characterized. The RSA5000 Series combines high performance swept analysis and real-time performance with specialized optional measurement modes like EMI mode for EMI pre-compliance testing, VSA Mode for complex demodulation analysis, and AMK for advanced measurements, including channel parameters. The RSA5000N models include vector network analysis capabilities. VNA Mode includes S11, S21 and distance-to-fault (DTF) measurements.

In addition to supporting a frequency range up to 6.5 GHz, RSA5000 spectrum analyzers offer specifications that include 1 ms full span sweep, 1 Hz minimum resolution bandwidth, real-time bandwidth up to 40 MHz, 7.45 μs 100 percent POI, and DANL as low as -165 dBm (with optional pre-amplifier). For advanced analysis, the RSA5000 provides real-time visualization modes, including combinations of normal, density, spectrogram and power-versus-time modes. The triggering capabilities of the RSA5000 enable users to identify specific signals of interest with frequency mask and power triggers or use external triggers to time-correlate digital signals for additional analysis.

RIGOL
Portland, Ore.
www.rigolna.com/products/spectrum-analyzers/rsa5000/

3H Communication Systems
Dual Bandpass Filter with LNA
VENDORVIEW

The 3H L-Band Filter assembly is used for satellite uplink communications with one input and one output. It offers low insertion loss of < 2.0 dB over three passbands with > 80 dB rejection 40 MHz away from band edge, with an absolute group delay of < 10 Ns. 3H custom designed miniature filters, duplexers and multiplexers offer the lowest insertion loss in the smallest packages available on the market. 3H filter products are designed and manufactured for commercial and military applications from DC to 50 GHz.
www.3hcommunicationsystems.com

Analog Devices
Power Amplifier
VENDORVIEW

The ADPA1116 is a 0.3 GHz to 6 GHz power amplifier with a saturated output power of 39.5 dBm, power-added efficiency of 40 percent and a power gain of 23.5 dB typical from 0.5 GHz to 5 GHz at an input power of 16.0 dBm. The RF input and RF output are internally matched and AC-coupled.
www.analog.com

Cernexwave
Thermoelectric Refrigeration Cooling/Heating System
VENDORVIEW

Cernexwave's thermoelectric refrigeration cooling/heating system is a great solution to bring your components to the optimum temperature for testing. They have a temperature control range of -45°C to +120°C with fast temperature change speed and high accuracy. The large cooling/heating plate dimensions and small overall footprint allow these units to be used for a great range of components in labs of any size.
www.cernexwave.com

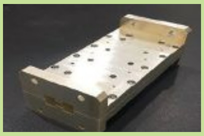
Empower RF
Compact Module
VENDORVIEW

Ideal for CUAS and EW, the 1208 is a compact module operating from 500 to 2700 MHz while delivering over 100 W. This field-proven, high volume product is tactically deployed disrupting unmanned systems and communications. The module utilizes GaN on SiC semiconductor technology for high efficiency, wide dynamic range and low distortions.
www.empowerrf.com

Eravant
PNA Extenders
VENDORVIEW

Using dual downconverters fed by independent LO signals, models STI-05-10-S1 and STI-05-10-S2 phase noise analyzer frequency extenders accept signals from 75 to 110 GHz. The S1 model is compatible with AnaPico APPH equipment (12 to 18 GHz LO), while the S2 model operates with Holzworth HA7062 series PNAs (6 to 9 GHz LO).
www.eravant.com

Exceed Microwave
Waveguide Bandstop Filter with Wide Passband
VENDORVIEW



BSF-W-00053 is a WRD750 waveguide bandstop filter with > 40 dB rejection between 8.835 to 9.105 GHz. This filter does not have a spurious notch and the passband is 7 to 8.69 GHz on the low end with the high side starting from 9.23 GHz all the way up to 18 GHz. It has return loss >15 dB. Contact Exceed Microwave for custom designed waveguide and coaxial filters.
www.exceedmicrowave.com

Exodus Advanced Communications
1.0-2.5 GHz, 8 KW Pulse Solid-State LS-Band Amplifier
VENDORVIEW

Exodus Advanced Communications' AMP2074P-LC-8 KW pulse amplifier is designed for Pulse/HIRF, EMC/EMI Mil-Std 461/464 and radar applications. Providing superb pulse fidelity 1.0 to 2.5 GHz, 10 KW typical and up to 100 µs pulse widths. Duty cycles to 6 percent with a minimum 69 dB gain. Available monitoring parameters for forward/reflected power in Watts and dBm, VSWR, voltage, current, temperature sensing for outstanding reliability and ruggedness in a compact configuration.
www.exoduscomm.com

Fairview Microwave
RF Fixed Attenuators and Terminations
VENDORVIEW

Fairview Microwave launched its latest range of RF fixed attenuators and terminations, capable of supporting frequencies up to 18 GHz. These precision components meet the rigorous demands of high frequency applications, making them ideal for use in telecommunications, aerospace and test and measurement environments. The newly released products feature RF fixed attenuators that come in a variety of power ratings, including 2 W, 10 W and 50 W and are available with SMA, N-type, BNC and TNC connectorized designs.
www.fairviewmicrowave.com

LadyBug Technologies
LB5967L RF Power Meter
VENDORVIEW

LadyBug's LB5967L power meter provides accurate measurements from 9 kHz to 67 GHz. The sensor's wide frequency range, high dynamic range and fast measurement speed make it ideal for source calibration, eliminating multiple sensors often used to cover this frequency range. The RMS responding diode-based sensor accurately measures signals with any modulation bandwidth. Interfaces: USB HID, USBTMC, Optional LAN (HiSLIP) with PoE, SPI and I2C. Includes LadyBug's multi-threaded software package.
www.LadyBug-Tech.com

MIcable Inc.
1.5-3 GHz 400 W Drop-in 90° Hybrid
VENDORVIEW

MIcable released the new 1.5 to 3 GHz high power surface-mount 90-degree hybrid. It has low insertion loss (0.25 dB maximum), excellent VSWR (1.30:1 maximum), extremely good amplitude unbalance (±0.5 dB maximum) and phase unbalance (±5 degrees maximum), high isolation (18 dB minimum) and 400 W power handling capability with excellent stability and heat dissipation ability in a small package. It is suitable for power amplifier, power combining network, antenna feed network, modulator and phase shifter applications.
www.micable.cn

Millibox
Complete Solution for mmWave and sub-THz Radar OTA Performance Testing

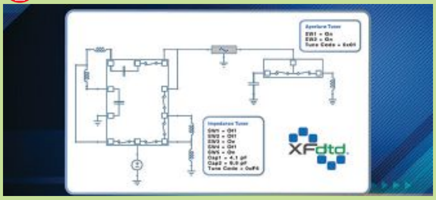
MBX33R is a readily available complete OTA radar test setup which includes: MBX33: 2 m benchtop chamber for designs between 18 GHz and 330 GHz, GIM04-300x: 30 cm wide 3-axis DUT positioner with Python controller, WLL09: accessorized wall, for mounting up to nine fixed or moving radar targets and LIN04: software programmable linear actuator for trihedral corner reflector.
www.millibox.org

Pasternack
High Performance RF Angled PCB Connector
VENDORVIEW

Pasternack launched its new line of RF angled PCB connectors. This includes several connectors in different series that are specifically designed to meet the rigorous demands of RF applications. The new product line features 1.85 mm, 2.4 mm and 2.92 mm PCB and panel connectors, enhancing Pasternack's existing portfolio, which traditionally included only straight or edge-mount connectors. The RF angled PCB connectors comply with industry-standard interfaces, ensuring compatibility and reliability across a wide range of applications.

www.pasternack.com

Remcom
XFdtd 3D Electromagnetic Simulation Software
VENDORVIEW



The new optimization capability calculates and reveals the ideal component property values and operating modes that fulfill user-defined matching network design goals, eliminating a potentially overwhelming task for very complex systems containing multiple switches and capacitors by providing a software-generated solution. The release also includes subcircuit analysis in the schematic editor and the ability to retrieve tune codes based on desired switch states.
www.remcom.com

Southwest Microwave
High Performance Connector

Southwest Microwave introduced their newest high performance connector. The 0.8 mm is an innovative and advanced thread-in connector that maintains optimal signal integrity while providing the industry's lowest VSWR, RF leakage and insertion loss. Features include compatibility with IEEE 287 and IEC 61169-64 standards, DC to 145 GHz and field replaceable and reusable.
www.southwestmicrowave.com

WAKA Manufacturing
Cable Assembly

WAKA Manufacturing has introduced a new cable assembly featuring a 1.0 mmW connector and rigid armor. This assembly ensures a balance between durability and flexibility by utilizing semi-rigid internal cables to maintain phase stability even when bent. It supports frequency up to 110 GHz and offers customizable lengths starting from a minimum of 100 mm, adjustable in 1.0 mm increments. Its high performance low reflection characteristics are achieved through WAKA's innovative soldering technology. A release of 1.85 mm armored cable is planned.
www.waka-manufacturing.com

Maximizing RF Performance with Custom Laminates

WavePro®, A Garlock Brand
Palmyra, N.Y.

MADE-TO-ORDER LAMINATES

Laminates are used extensively in microwave and mmWave circuits. The applications of these laminates range from simple microstrip patch antennas to complex multi-layer stack-ups. Besides application and performance specifications, choosing a laminate often begins with dielectric constant (Dk).

Laminates with a Dk value in the range of 2 to 4 are widely available, with selective commercial availability up to a Dk value of 13. The laminate's thickness, another design factor that affects RF performance, is generally limited to a handful of options. But what if you could specify laminate Dk, thickness and copper cladding according to your precise requirements? With more variables under your control, fewer design tradeoffs and compromises would be needed to maximize bandwidth, reduce size and weight or improve gain. ***Figure 1*** shows three laminates with different dielectric constants, panel thicknesses and copper claddings from WavePro.

▲ Fig. 1 **Laminates can have different dielectric constants, panel thicknesses and copper claddings.**

CUSTOMIZATION OPTIONS

WavePro® ceramic-filled PTFE laminates are manufactured to your specifications. Available as standard 24 in. × 18 in. flat panels, the following parameters can be customized:

Dk: from 2.0 to 20.4 (in increments of 0.1)

Panel thickness: 1.5, 2, 4, 8 and 10 mm

Cladding: electrodeposited or rolled copper foil, 0.5/1/2 oz., surface roughness LP/VLP/ULP.

Laminates are manufactured locally at our facility located in New York. Lead times may vary depending on the laminate specifications and order quantity.

THE FOUNDATION: A HIGH-QUALITY DIELECTRIC MATERIAL

Due to its low loss and excellent dielectric properties, high purity PTFE is the basis for

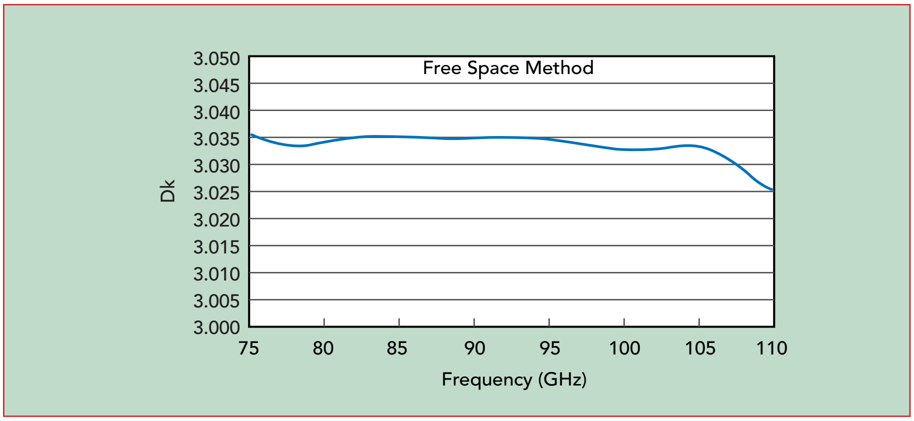


Fig. 2 Substrate dielectric constant, 75 to 110 GHz (WP030).

Fig. 3 Spiral Wi-Fi extender antenna.

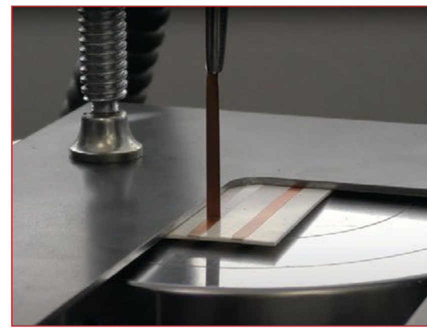


Fig. 4 Copper peel strength test.

WavePro dielectric materials. Ceramic fillers are added to the host PTFE matrix to control the dielectric constant, loss tangent and coefficient of thermal expansion of the composite material. The formulation of fillers varies, as one ceramic may be used to enhance or mitigate the effects of another. Formulations are calibrated to maintain consistency within and between production batches.

Testing and characterizing the material's dielectric properties is essential to the quality assurance process. WavePro products are tested to the following industry standards:

- ASTM D2520: cavity resonator method for unclad dielectrics
- IPC-TM-650-2.5.5.5: stripline method for laminates
- Free space transmittance/reflectance: techniques for mmWave/THz frequencies.

High purity ingredients, precise formulations and a stringent quality assurance process yield an engineered dielectric with reliable, stable properties. ***Figure 2*** shows the variation of the dielectric constant with frequency for WP030 (Dk = 3.03 at 5 GHz). Even at 110 GHz, the Dk is within 0.2 percent of its nominal value.

HIGH DK, THICK LAMINATES

The custom manufacturing process for WavePro allows the production of laminate panels up to 10 mm (0.394 in.) thick, with a dielectric constant of up to 20.4. Miniaturization is one key driver for the use of high Dk laminates. As Dk increases, the wavelength decreases. Since many passive components are dimensioned to one-quarter or one-half the operating frequency wavelength, this effect can be leveraged to design hardware with reduced size and weight. Ultra-high Dk materials also exhibit increased capacitance, which benefits power integrity.

One limitation of traditional microstrip antenna elements is their narrow bandwidth. As wideband designs grow in demand, the use of thicker substrates will help overcome bandwidth limitations. However, as substrate thickness approaches or exceeds the electrical wavelength, care must be taken to avoid the excitation of higher-order modes. ***Figure 3*** shows an example of a spiral Wi-Fi extender antenna fabricated with WavePro laminate material.

FABRICATION PROCESS

Custom laminates are manufactured using a two-step process. First, the unclad dielectric panel is fabricated to the specified Dk and thickness. The substrate is then placed between the specified copper foils (i.e., dual-cladded) and fusion bonded at high temperature and pressure. Proper adhesion of the copper foil to the dielectric substrate is essential, especially when the laminate undergoes multiple high temperature heating cycles during processing. WavePro custom laminates are tested following the IPC-TM-650-2.4.8 methodology. Results indicate an average copper peel strength of 16.0 lbs./in. for very low profile (VLP) copper foil. A photograph showing an example of the IPC-TM-650-2.4.8 copper peel strength test is shown in ***Figure 4***.

OPTIMAL RF DESIGNS

WavePro custom laminates offer two distinct advantages for RF and antenna designers:

- Customized panels manufactured to specifications. This enables the adaptation of existing designs for performance optimization
- Extended range for high Dk (up to 20.4) and panel thickness (up to 10 mm). This enables new designs previously unattainable with laminates and potential space and weight reductions.

About WavePro

WavePro is a brand of Garlock, a manufacturer specializing in engineered materials and products with a history dating back over 130 years. Visit WaveProAntenna.com to request free samples and learn more about our laminates, unclad dielectrics and material specifications.

WavePro®
A Garlock Brand
WaveProAntenna.com

Bridging the Terahertz Gap

Micro Harmonics
Fincastle, Va.

THz-capable isolators are looking to resurrect the "dead zone," a region of the electromagnetic (EM) spectrum between what is commonly used for electronic and optical applications. This band, often called the "terahertz gap," resides between 100 GHz and 30 THz. Recently, IMRA, a research and innovation organization that develops essential technologies for industrial use, overcame many of the issues associated with the THz regime when working at frequencies above 300 GHz.

Researchers at the Colorado-based laboratory were looking to use molecules as stable frequency references that could potentially be used to develop molecular clocks. During their research of alternatives to the current state-of-the-art optical atomic clocks operating at several hundreds of terahertz,[1] IMRA researchers encountered the common issue of standing waves, also referred to as signal reflections or mismatches. These undesirable waves, or ripples, can attenuate power output, distort the information on the carrier and, in extreme cases, damage internal components.

Engineers rely on Faraday rotation isolators, more commonly referred to as isolators, to alleviate the problem of standing waves at lower microwave frequencies. An isolator is a two-port component that allows EM signals to pass in one direction but get absorbed in the opposite direction. The challenge is that traditional isolators fail to deliver at higher frequencies within the THz regime.

Under a NASA-awarded contract, Micro Harmonics Corporation (MHC) produced a line of mmWave isolators capable of operating between WR-28 and WR-2.8 (26.5 to 400 GHz). Examples of these devices are shown in ***Figure 1***.

These commercial-off-the-shelf components had to be completely redesigned to deliver in five critical categories:

ISOLATION

The distance between components in mmWave systems often exceeds a wavelength, causing reflected signals to be out of phase. This can perturb the operating point of the upstream component. Sweeping frequencies causes phase changes that create nulls, dips and degraded performance. An isolator inserted between components will absorb the reflected signal and the problem will disappear.

Isolation measures how much of the signal traveling in the reverse direction passes through the isolator. The highest possible isolation occurs when the reverse wave is rotated exactly 45 degrees into the plane of the isolator's resistive layer. Isolation can degrade by as much as 10 dB when the signal rotation is off by just 1 degree. MHC fully characterizes each isolator on a vector network analyzer rather than spot-checking at a couple of frequencies in the band to ensure total compliance.

INSERTION LOSS

While isolation is paramount, suppressing the reverse wave in an isolator cannot come at the expense of forward input signal attenuation. For traditional isolators, insertion loss is low in the microwave bands, but the loss becomes increasingly problematic at mmWave and THz frequencies. In the WR-10 band (75 to 110 GHz), the insertion loss can exceed 3 dB, meaning half of the signal power is lost. The loss in the WR-5.1 band (140 to 220 GHz) climbs to more than 5 dB. Because of high losses, traditional isolators were often precluded from use in mmWave systems.

Faraday rotation isolators use ferrite discs to rotate the signal. However, the traditional manufacturing method involves tuning the magnetic bias field of ferrites substantially longer than the minimum required length to achieve optimal performance. This delivers good isolation but at a much higher insertion loss.

To minimize loss, the goal is to reduce the ferrite length as much

Fig. 1 26.5 to 400 GHz isolators.

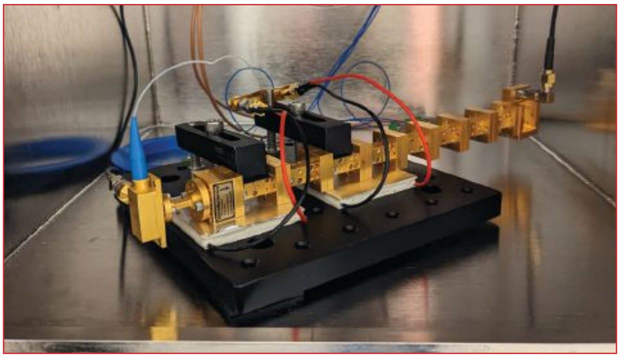


Fig. 2 Terahertz oscillator developed by IMRA.

Fig. 3 MHC WR-3.4 isolator.

as possible. The MHC design saturates the ferrite with a strong magnetic bias field, enabling the ideal 45 degrees of rotation in the shortest possible ferrite length. This reduces insertion loss to less than 1 dB at 75 to 110 GHz and only 2 dB at 220 to 330 GHz.

LOW PORT REFLECTION

A good isolator must also have low port reflections. The importance of low port reflections is often overlooked. An isolator with high port reflections creates an alternate set of standing waves. The adjacent components are still adversely impacted by out-of-phase signals reflected into their ports. High isolation and low insertion loss are of little value if the port reflections are large. A good VSWR at mmWave frequencies is 1.5:1 or less.

HIGH POWER RATING

Power in the reverse signal is absorbed in the isolator, resulting in heat. Handling more heat requires a higher power rating. Historically, heat was not an issue with very little transmit power available at mmWave frequencies. However, as higher power sources become available at mmWave frequencies, the importance of power ratings increases.

To handle the problem of high heat loads, some newer isolators already incorporate diamond heat sinks into their design. Diamond is the ultimate thermal conductor, approaching 2200 W/m•K, more than 5x higher than copper. Diamond effectively channels heat from the resistive layer in the isolator to the metal waveguide block, lowering operating temperatures for improved reliability.

SMALL FOOTPRINT

Minimizing the size and weight of mmWave components is especially important in wireless applications. A standard traditional-style isolator in the WR-10 band is about 3 in. long, with a center cylindrical section diameter of about 1.3 in. However, the MHC design is rectangular and can be as small as 0.75 in. per side and 0.45 in. thick.

EXAMPLES

Building upon a firm understanding of the principles and the development of the components is allowing researchers and manufacturers to start to close the terahertz gap. ***Figure 2*** shows an experimental DKS microcomb THz oscillator and spectroscopy of N_2O. ***Figure 3*** shows a Micro Harmonics WR-3.4 isolator operating in the 220 to 325 GHz band. With this isolator providing 30 dB of attenuation, IMRA researchers could talk to N_2O molecules in the test setup of Figure 2. ■

Reference

1. J. Greenberg, B. M. Heffernan and A. Rolland, "Terahertz Microcomb Oscillator Stabilized by Molecular Rotation," APL Photonics, January 2024, Web: pubs.aip.org/aip/app/article/9/1/010802/3012375/Terahertz-microcomb-oscillator-stabilized-by.

Micro Harmonics
Fincastle, Va.
540.473.9983
MicroHarmonics.com

MLDD Power Divider Operates to 7.125 GHz

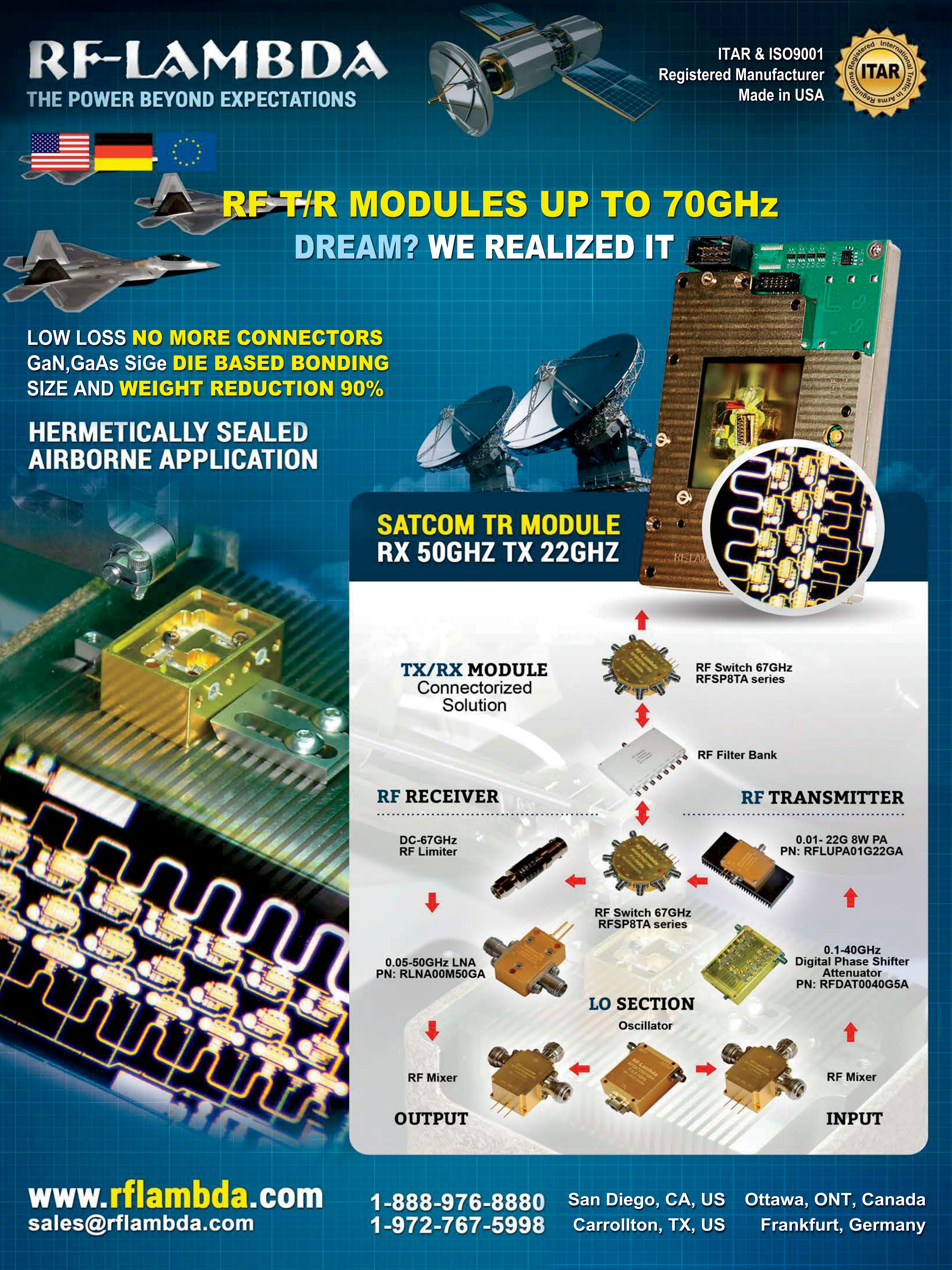
KRYTAR, Inc. announces a new matched-line directional divider (MLDD) two-way power divider in a compact package that operates in the L-Band through the C-Band frequency range. The new power divider offers a solution for emerging designs and test and measurement applications, including mmWave, 5G, radar, satellite communications and more. The 600407125 model operates from 0.4 to 7.125 GHz with more than 15.0 dB isolation and ±0.2 dB of maximum amplitude tracking. The maximum phase tracking over this frequency range is ±3 degrees. The two-way divider exhibits an insertion loss of less than 1.0 dB across the entire frequency range. Maximum VSWR is 1.6:1 and the input power rating is 10 W specified into a maximum load VSWR of 2:1. The package measures 7.75 x 1.00 x 0.52 in. and it weighs only 7 oz. The 600407125 comes with standard 3.5 mm coaxial female connectors.

KRYTAR's new power divider offers full frequency coverage in a single package and provides superior performance targeting broadband electronic warfare systems and complex switch-matrix applications. KRYTAR has used its proprietary design to produce a wide assortment of MLDDs with excellent performance over a wide range of bandwidths and operating frequencies. Units with tighter amplitude and phase tracking specifications can be supplied upon request.

For nearly 50 years, KRYTAR, Inc. has specialized in the design and manufacture of broadband mmWave, microwave and RF components and test equipment. The KRYTAR product line covers DC to 110 GHz and it includes directional couplers and detectors, 3 dB hybrids, MLDD power dividers/combiners, terminations, coaxial adapters, bias tees, beamformers, a power meter and power sensors.

VENDORVIEW

KRYTAR
Sunnyvale, Calif.
www.krytar.com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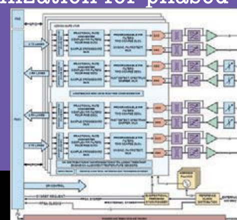


Intelliconnect Celebrates Opening of New Base

Intelliconnect (Europe) Ltd opened their new base for sales, marketing and engineering in Witham, Essex, with a celebration of their innovation, achievements and future aspirations. The new 4300 sq. ft. facility will also be available for other Trexon group companies to use as European base.

Intelliconnect

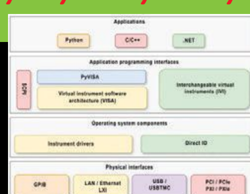
www.intelliconnectgroup.com

Why Instrument Control is Crucial in Test and Measurement

Check out this blog by Keysight for an overview of instrument control aspects in the field of electronic test and measurement.

Keysight Technologies

www.keysight.com/blogs/en/tech/educ/2024/instrument-control



QSPICE: Accelerate Your Development with New Features

Accelerate your development time with QSPICE! Watch Mike Engelhard's video showcasing the latest enhancements.

Qorvo

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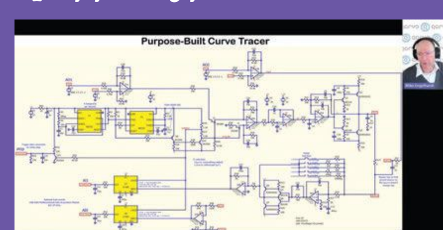

Introducing Modelithics Models for Single-Layer Capacitors, Part 1

In Part 1 of this two-part blog series, learn all about the new scalable equivalent-circuit models for SLCs and how they offer a great deal of flexibility.

Modelithics

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Quantic Croven Celebrates 70 Years of Innovation in Precision Quartz Crystal Resonators

Quantic Croven (Croven Crystals) celebrates 70 years of innovation and exceptional service to the RF and microwave industry. Since its founding, the company has continually pushed boundaries in quartz crystal resonator technology, supporting a wide array of mission-critical defense and space applications.

Quantic Croven

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Amphenol RF expanded their AUTOMATE Mini-FAKRA cable assembly portfolio with additional pre-configured cable assemblies. These assemblies are available in straight single, dual or quad port mini-FAKRA jack to jack configurations and are designed on flexible RG-174 cables. AUTOMATE assemblies support data transmission rates up to 20 Gbps, which makes them ideal for automotive and industrial IoT applications that require high data transfer rates to communicate information for safety, performance and entertainment without lag.

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Ansys Perceive EM is a groundbreaking API solver technology set to revolutionize radar systems and wireless communications design. With unprecedented performance and scalability, it delivers high fidelity results and enables on-demand synthetic data generation for artificial intelligence/machine learning applications. In addition to speed and accuracy, Perceive EM handles highly detailed environments. Engineers can model radar systems and RF channels in real-world, dynamic conditions, including movements of objects, subscribers and access points, extending to scenarios beyond line-of-sight sensing, where traditional methods may fall short.

www.ansys.com

JFW Industries

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4-Channel USB Attenuator

VENDORVIEW

JFW has a new 50 Ω 4-channel USB attenuator to help automate your RF testing. JFW model 50P-2089 SMA operates from 200 to 6000 MHz with attenuation range 0 to 95 dB by 1 dB steps. All four attenuators are individually controlled. Test software is provided with the USB attenuator. If you would like to integrate the USB attenuator into your script testing, we offer a JFW Python library upon request.

www.jfwindustries.com

KRYTAR, Inc.

Directional Couplers

VENDORVIEW

KRYTAR, Inc., a leader in the design and production of ultra-broadband microwave components and test equipment, announced a family of five new directional couplers operating in the frequency range of 0.4 to 7.125 GHz (UHF through C-Bands) offering nominal couplings from 6 dB to 30 dB in compact packages. These couplers offer the ultimate solution for emerging designs and test and measurement applications including mmWave, 5G, satellite communications (SATCOM), radar and more.

www.krytar.com

Luff Research, an Ironwave Technologies company

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Luff Research, an Ironwave Technologies company, introduces phase-locked dielectric resonator oscillators (PLDROs) as microwave frequency sources tailored to be used in high performance communication systems. The PLDROs generate spectrally

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clean signals that are phase locked to an external or internal reference. There is an option that when the external reference is not provided, the unit automatically switches to an oven-controlled high stable internal reference. PLDROs are very versatile and adaptable to specific requirements. Not only are these units small, operate on a single 5 V DC input, have excellent signal quality, these units offer excellent value and lead time.

www.luffresearch.com

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MPG offers a wide range of manually and digitally controlled tunable cavity filters in both bandpass and band-reject configurations. Options are available from 1 MHz to 8 GHz with filter tuning ranges typically covering one octave. MPG has many catalog options available and those are listed on its website. MPG also offers custom tunable filter solutions designed to meet specific customer requirements. Please browse the website for standard catalog options or contact MPG's sales team for a custom quote.

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www.passiveplus.com

Qorvo

5 – 1218 MHz 75 Ω 25 dB CATV Amplifier

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The QPL7425 is a GaAs pHEMT single-ended RF amplifier IC featuring 25 dB of flat gain and low noise. This IC is designed to support HFC and fiber to the home applications from 5 to 1218 MHz using a single supply operating from 3 V to 8 V. QPL7425 offers low noise and distortion plus high gain in a 3x3 QFN package for convenient layout and design in set top and infrastructure projects for 75 Ω CATV and satellite applications.

www.qorvo.com

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Reactel will feature its full line of filters, multiplexers and multifunction assemblies covering up to 67 GHz at EuMW 2024 in Paris. Supporting military, commercial, industrial and research needs, Reactel can design the right unit for you. From small, lightweight units suitable for flight or portable systems to high power units capable of handling up to 25 kW, connectorized or surface-mount, large or small quantities – Reactel's talented engineers can design a unit specifically for your application. Visit stand 701C to discuss your requirements.

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RFMW

Oven-Controlled Oscillator

VENDORVIEW

The SIT7101 is a 10 MHz, ruggedized MEMS oven-controlled oscillator (OCXO) that boosts the resilience of PNT systems and other equipment such as radar and radios, satellite communications (SATCOM) terminals and avionics against spoofing, jamming and other disruptions in global positioning system (GPS) signals. Available in a 9.0 × 7.0 mm SMT package, now at RFMW.

www.rfmw.com

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Richardson RFPD

RLF and XLF Lowpass Filters

VENDORVIEW

Richardson RFPD, Inc., an Arrow Electronics company, announced the availability and full design support capabilities for two families of lowpass filters from CTS Corporation. The RLF and XLF series are optimized to support 3GPP standards that require harmonic suppression through fifth-order harmonics. Both series provide complete solutions for harmonic rejection for wireless infrastructure applications. The

New**Products**

RLF family offers extremely low insertion loss (3 to 5 dB, maximum) and superior close-in rejection/attenuation. They are suitable for up to 20 W of average power and 200 W of peak modulated power.
www.richardsonrfpd.com

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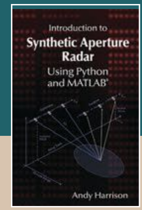
MICRO-ADS

2024 SHOW COVERAGE

For complete coverage of the EuMW 2024 conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at mwjournal.com/eumw2024.

Reviewed by: Katerina Galitskaya



Bookend

"Introduction to Synthetic Aperture Radar Using Python and Matlab"

By Lee Andrew (Andy) Harrison

"Introduction to Synthetic Aperture Radar Using Python and Matlab" by Andy Harrison is a valuable resource for both newcomers and seasoned professionals in the field of synthetic aperture radar (SAR). The author's clear writing style and well-structured content make this book an excellent choice for anyone seeking to understand SAR imagery generation. One of the book's strengths lies in its practical approach: readers get access to both Python notebooks and Matlab live scripts, allowing them to customize each tool for unique applications and get hands-on knowledge on the topic. These tools are built to analyze SAR performance, manipulate imagery and predict outcomes for various scenarios. Each chapter builds upon the foundational knowledge established at the beginning of the book, progressing from basic SAR imaging principles to more advanced topics such as interferometric SAR and 3D imaging. The inclusion of problems to solve after each chapter ensures that readers can apply what they learn in real-world scenarios. Furthermore, Andy Harrison provides sets of examples at the end of each chapter, making the learning experience smooth and helping to reinforce key concepts. The book is suitable for students taking courses in SAR, as well as for professionals looking to improve their skills or transition into the field. The book also benefits from the author's collaboration with industry partners, such as ICEYE, Umbra Lab and Lincoln Laboratory, whose contributions provide valuable datasets and imagery for practical exercises. In conclusion, "Introduction to Synthetic Aperture Radar Using Python and Matlab" by Andy Harrison is a comprehensive guide that effectively balances theoretical explanations with practical applications. Whether used for academic study or professional development, this book provides readers with the knowledge and tools necessary to navigate the complexities of SAR imaging with confidence and proficiency.

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390 pages
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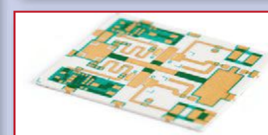
FABS and LABS

Remtec: The Power of Possible

The phrase "The power of possible" appears in Remtec marketing material. It encapsulates the ability to grow and shape the future. As the company celebrates the opening of a newly-renovated facility, it is worthwhile to see how Remtec is turning that phrase into reality.

Remtec was founded in 1990 to serve the electronics industry's growing need for advanced ceramic packaging technology, primarily for applications requiring high power, high circuit density and a broad operating frequency range. The following year, engineers developed Remtec's proprietary Plated Copper on Thick/Thin Film (PCTF®) ceramic metallization technology that is still central to the company's product and capabilities portfolio. With that differentiating technology, Remtec established production and manufacturing capabilities to design and fabricate metalized ceramic substrates, surface-mountable hermetic and non-hermetic ceramic packages, chip carriers and specialty components for electronic applications.

Over time, Remtec realized that the "possible" was enabled by resources and capabilities. They acquired a plating company and moved to a new facility. As they turned "possible" into reality, the business grew and their target market applications expanded, necessitating an expansion of the footprint and capabilities of that facility.

That brings the story to the present and Remtec's June 5 ribbon-cutting ceremony for its newly-renovated 55,000 sq. ft. facility in Canton, Mass. In the nearly 35 years that have transpired since its founding, Remtec has realized the power of being a U.S.-based, onshore supplier of ceramic substrates and packaging solutions for microelectronics, RF, high-power and high-density interconnects and circuits. The company points to studies showing a precipitous drop in the share for U.S.-based PCB, substrate and advanced packaging capabilities and production. Realizing the importance of onshore production for many core customers and markets, Remtec has been ISO 9001:2015 registered since 2005. They have been RoHS-compliant since 2006, along with being ITAR-compliant and registered with the Directorate of Defense Trade Controls. This makes it possible to support and enable the needs of their most demanding customers.

From this new Massachusetts facility with enhanced capabilities, Remtec fabricates electronic circuits and component boards using screen printing, etching and firing techniques. They provide Ag, Au, Cu, ENIG and AuSn plating suitable for high-density circuits and high-power handling components. The company supplies alumina, aluminum nitride and beryllium oxide ceramic materials, along with high-DK barium titanate substrates, to a broad range of low-power, mixed-signal, high-power, RF and microwave applications.

With this impressive set of processes, material capabilities and more than 500 years of collective experience in the flow from design to manufacturing, Remtec is well-equipped to address challenging and novel packaging, substrate and interconnect solutions. They use a wide range of metallization techniques to offer ceramic/metal hermetic packages, leadless chip carriers, surface-mount hermetic packages, ceramic lids and interposers at the chip and PCB levels. All these packages and substrates can be engineered for high RF power, high voltage and challenging thermal dissipation applications.

This set of capabilities, products and experience is enabling current applications like MEMS, wireless TR modules, navigation systems, X-ray and scanning, UV curing, imaging systems, IoT and automotive systems. Remtec is clearly focused on the future, with activities in 2.5 and 3D heterogeneous integration and pushing the frequency capabilities of their products and processes well into the mmWave range. With the new facility, processes and expertise, coupled with the roadmap and vision to navigate that path, Remtec is enabling the "power of possible" for itself and the electronics industry.

https://remtec.com/

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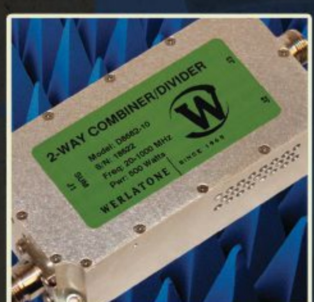

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LEARN MORE

Jason Breitbarth, Founder of Saetta Labs, discusses his background, what led him to found Saetta Labs, how the company's products differentiate from competitive products and the future efforts of Saetta Labs.

Q: You started Holzworth Instrumentation in your garage in 2004 after a bit of time in the test and measurement industry. You were there until the company was acquired in 2020 and then you founded Saetta Labs in 2023. Can you tell us a bit about your background and your entrepreneurial journey?

A: You might say someone who starts and grows a company is compelled to do it. I wanted to start/own my own company as far back as my undergrad. There is a certain sink-or-swim mentality surrounding the process that attracts me. I also like to wear a lot of hats and work with like-minded people. In a small company, especially starting, it's a unique, fast-moving, team-oriented attitude and it's very inspiring.

The Holzworth journey was one of personal and collective growth. I was quite young when I founded it and was uneducated in the business world; it was quite a rapid education. I had two excellent partners, Joe and Leyla, and we were all in. The lack of business education turned out to be an advantage at the time. We were trying to launch our first product in 2007 and 2008 when funding was non-existent, so we bootstrapped. This led to efficiencies in design and manufacturing that continue to this day. The culture of the company grew organically, and no single person was responsible for it; we all contributed. I can't sugarcoat the difficulty of starting and growing a company for everyone involved, but for those who enjoy that environment, it's extremely rewarding. It was a journey of many, not one.

Saetta Labs is a new company that is continuing the journey, but it is substantially easier the second time around. The idea is to learn from previous experience while maintaining flexibility for new challenges. I started Saetta Labs because I enjoy working with people, advanced technology and sharing the experience.

Q: What was the driver for you to start Saetta Labs? What are the biggest challenges and opportunities when you start a company?

A: After selling Holzworth, I once again had time to read and learn about new technological possibilities. I'm not interested in business for the sake of business; I want to be involved with new technology and push what's possible. I believe if you do quality work that adds value, the business naturally follows. The driver to start Saetta Labs was to advance oscillator technology and work with motivated and inspired people.

Each type of company has its unique challenges. In the case of Saetta Labs, we had to build the knowledge base of the sapphire technology and the environment to create it. It took an entire lab of equipment, not just a laptop and software license. We had to extend our capabilities in multiple disciplines to solve the engineering challenges. We brought in multiple types of machining, the ability to work with sapphire, vacuum equipment and temperature chambers, as well as all the typical microwave test equipment. We now have a whole ecosystem to prototype and manufacture oscillators on-site in a vertically integrated company.

Q: Holzworth Instrumentation became a very successful company and you ultimately sold it to Wireless Telecom Group, now part of Maury Microwave. What differentiates your work at Saetta Labs from the work you were doing at Holzworth?

A: Our primary focus at Holzworth was creating low phase noise synthesizers and analyzers by developing better architectures with existing technology. However, the phase noise was limited by the available frequency references (quartz OCXO). To build a better synthesizer (or radar), you need a better reference. Saetta Labs was formed to develop sapphire oscillator references from the ground up to extend the state of the art. Sapphire oscillators do not lend themselves to on-chip solutions or stuffing PCBs; they are a true 3D structure designed using multiple engineering disciplines.

Q: Can you describe some "metrics" (number of employees, square footage of facilities, locations, number of products, etc.) that would give our readers a better sense of Saetta Labs?

A: We are a small, focused company. We have a single facility in Boulder, Colo. and are in our first year of delivering product. This is a growth year for us, but we will still be at less than 10 people by year's end. This can be both a pro and con for our customers. On the positive side, we can respond quickly to demanding specifications, but we understand working with a small company also has inherent risks to larger programs. We are actively evaluating manufacturing partnerships for larger volumes to help mitigate this risk for our customers as well as organic growth.

Q: Your oscillators are sapphire-loaded. What can you tell our readers about the advantages of sapphire and the advantages of the "whispering-gallery" mode that you use in your oscillators?

A: Resonator Q-factor is the single biggest determinant of oscillator phase noise. Quartz and SAW oscillators have dominated the low phase noise market because of their high Q, but they operate relatively low in frequency and are acoustic-electric. The phase noise degrades as it's multiplied as well as being susceptible to vibration.

Our oscillators use sapphire as the resonator element with a whispering-gallery mode. The whispering-gallery mode is a pure microwave resonance and operates fundamentally at X-Band (4 to 20 GHz). The difference between the whispering-gallery and the TM and TE modes used in most DROs is it uses the dielectric boundary condition between sapphire and air (or vacuum) to contain the resonance. TM and TE modes use the metal walls of the cavity as the boundary condition. The metal walls are losses, degrading Q-factor. Our sapphire-based resonators have Q factors in excess of 200,000 at 8 GHz. Sapphire has an extremely high-power handling with no 1/f degradation, again differentiating it from quartz resonators.

Q: What are the core competencies and technologies that differentiate you from your competitors?

A: The current trend in our field is to only move forward with a design that can be put on a chip or stuffed on a board. We threw that premise out immediately. First, we developed closed-form expressions for the whispering-gallery modes and can create any microwave oscillator frequency. The design and manufacturing of the sapphire oscillator is vertically integrated and the sapphire ground on-site to the exact frequency. Sapphire oscillators are inherently 3D, and we developed the know-how and manufacturing capability to produce them completely in-house.

Q: What is your market focus and how do you see that changing in the next five years?

A: There are two markets the sapphire oscillator feeds into quite easily: instrumentation and radar. Instrumentation is obvious, where performance dominates. The other is radar, especially ground-based targeting radar for incoming targets. Current radars are limited by quartz technology from about 10 kHz to 200 kHz offsets. Sapphire excels in this range, giving the designers new degrees of freedom and improving existing radars with a "drop-in."

In the next five years, the sapphire oscillator can improve any system utilizing new direct RF DACs and ADCs that sample in the X-Band and above, regardless of the application. The latest and in-development DACs and ADCs have lower phase noise than quartz references and only sapphire can utilize their full potential.

Q: Where is your development focus? What applications, products and markets have you excited for the future?

A: We are going to stay solely focused on high-frequency and ultra-low phase noise sapphire oscillators and related components. We will release components that help our customers integrate sapphire references, including regenerative frequency dividers and distribution amplifiers. There are so many applications that could benefit from sapphire technology that we will just have to wait and see.

Q: What is your vision for Saetta Labs in the future? What will be your biggest challenge to make that vision a reality?

A: Saetta Labs was founded on technology by engineers for engineers. The biggest challenge is education and customer support to bring this level of ultra-low phase noise to the system level. Measuring devices at this noise level is very challenging, as is maintaining it throughout the signal chain. We must be adaptable and supportive to our customer's needs.

Q: What else would you like our readers to know about Saetta Labs?

A: Looking at things a bit more philosophically, we believe each person at a company is much more than a resource on a spreadsheet. Advanced technology is successful by the contributions of individuals working together. We are excited to continue working with existing and new customers and curious about future applications we haven't thought of.