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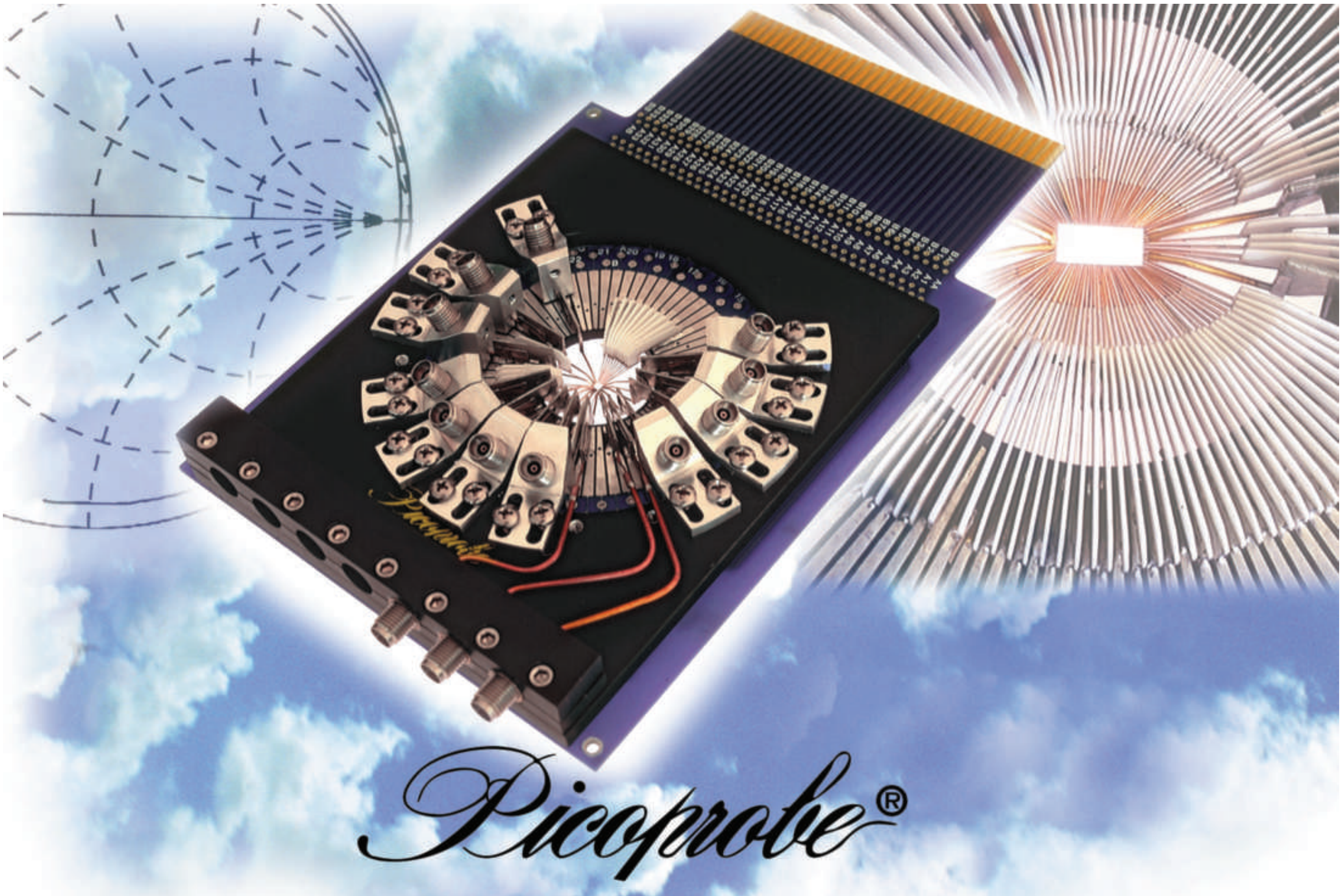

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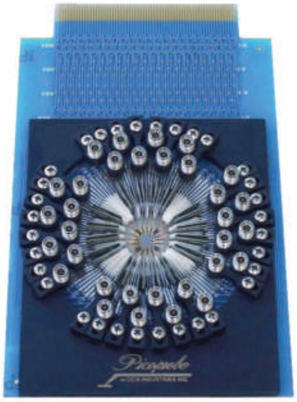

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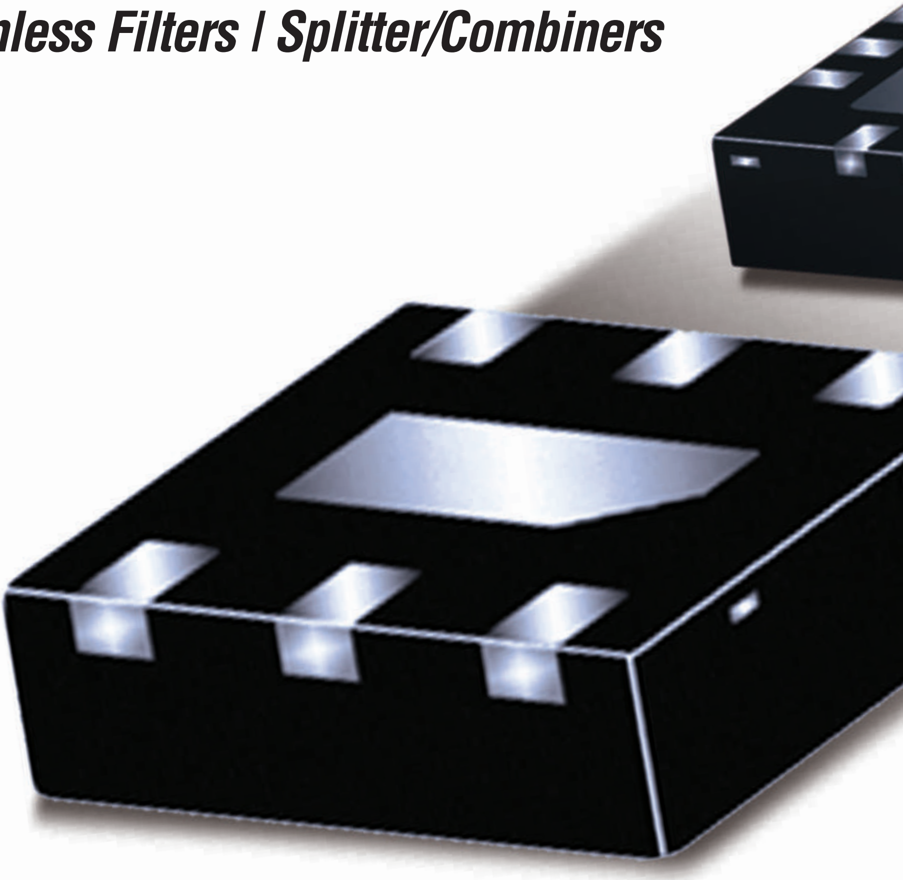

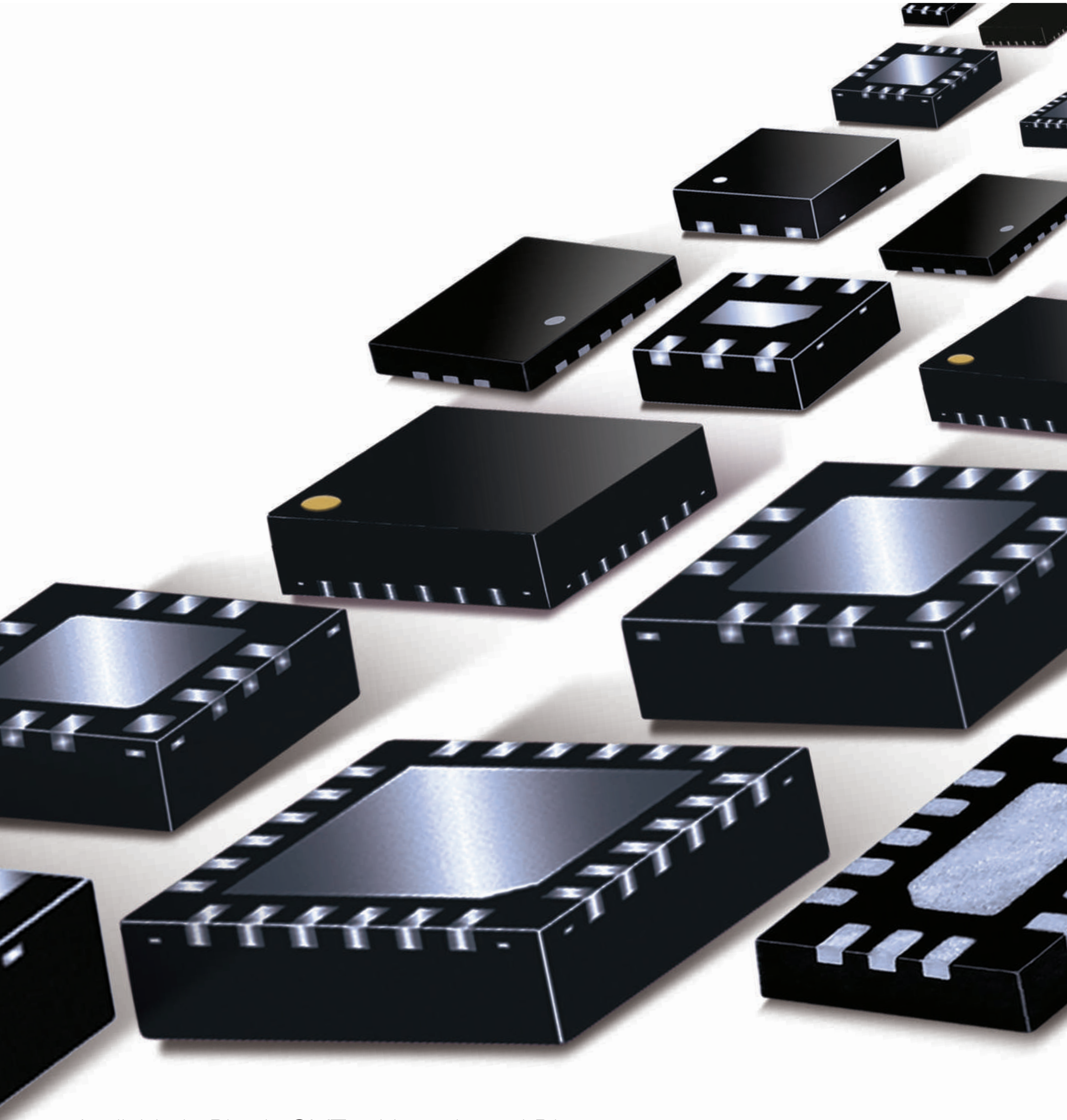

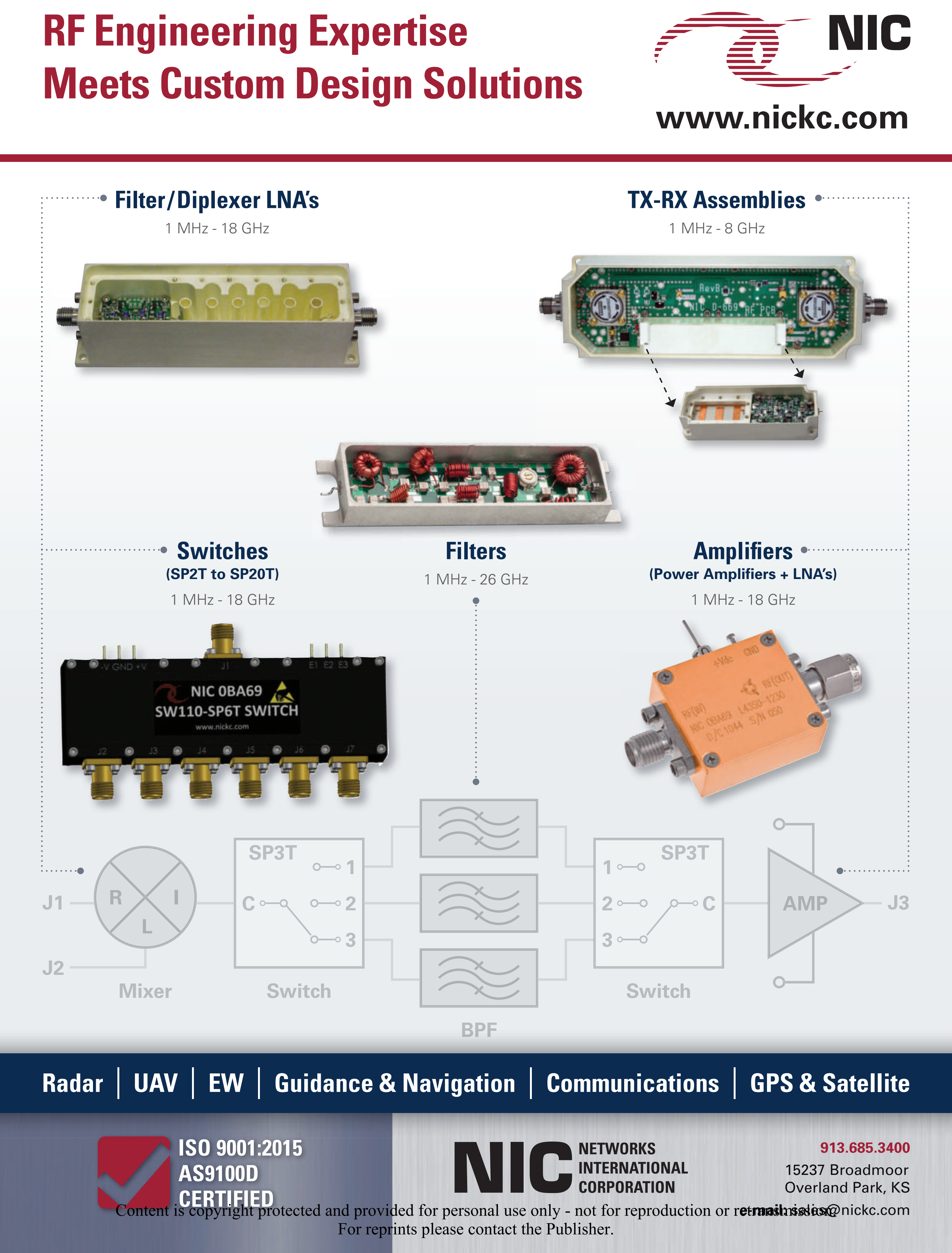
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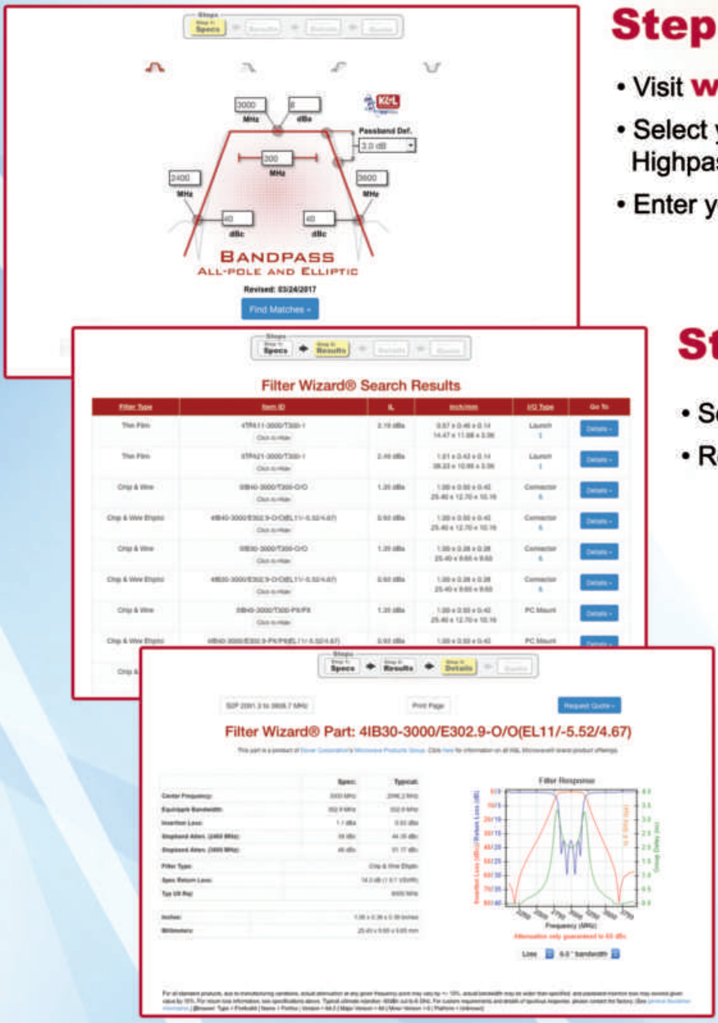

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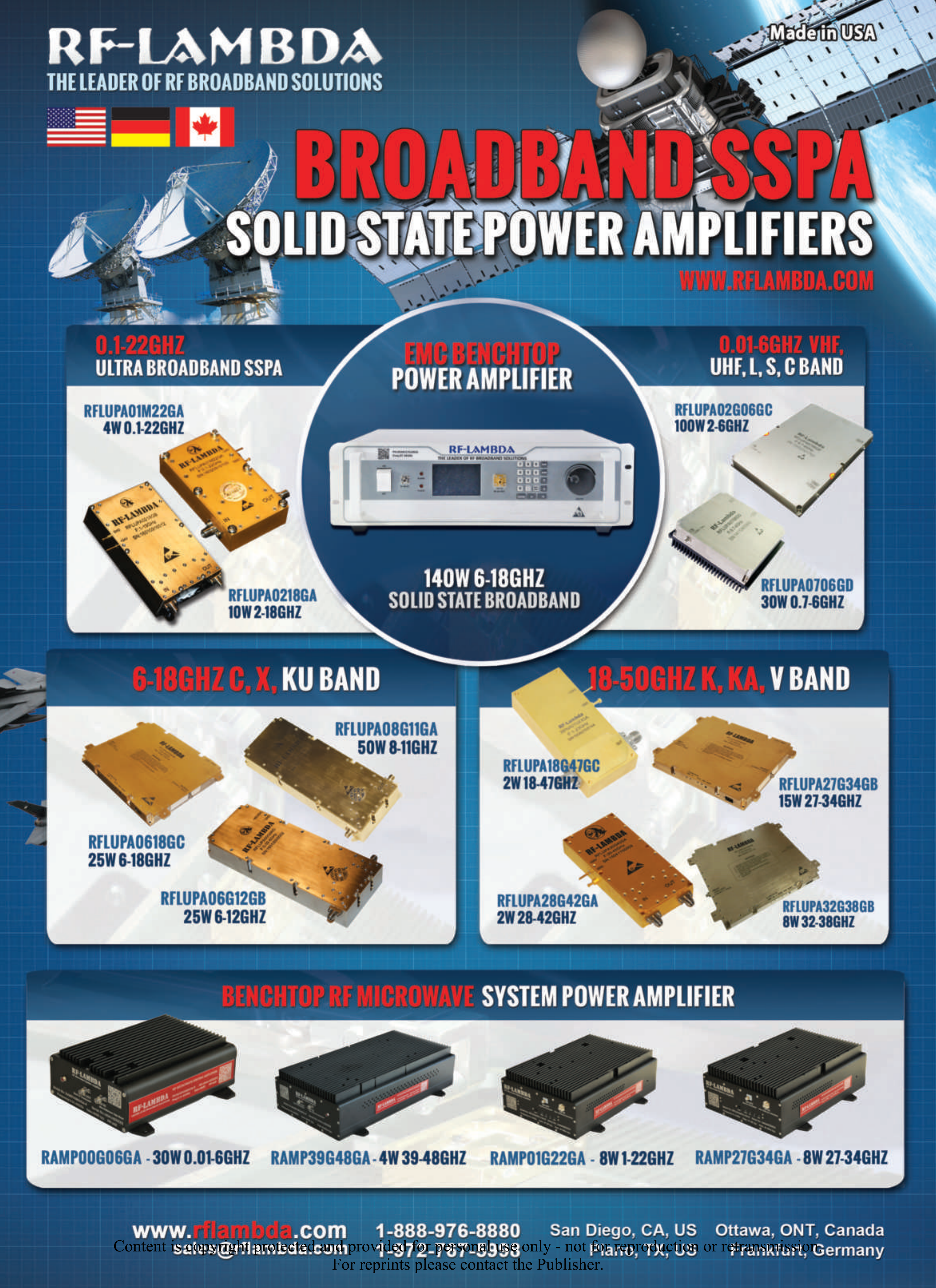
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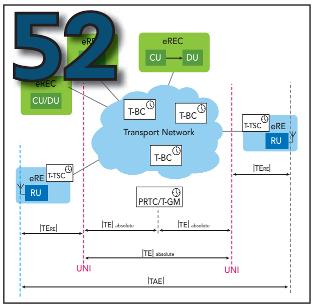

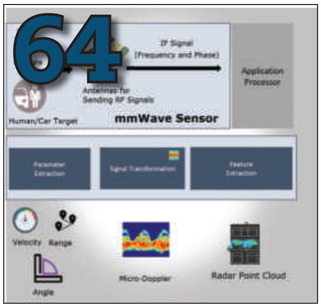

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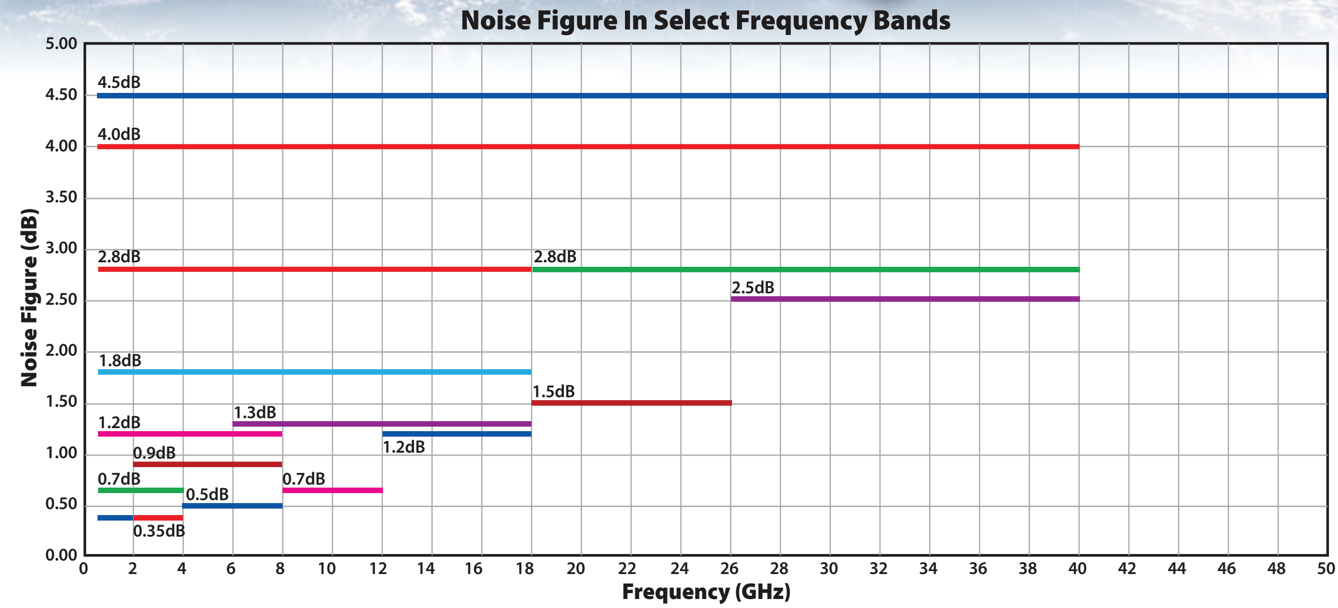

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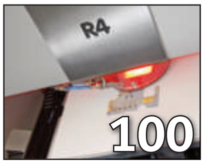

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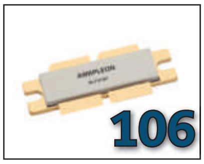

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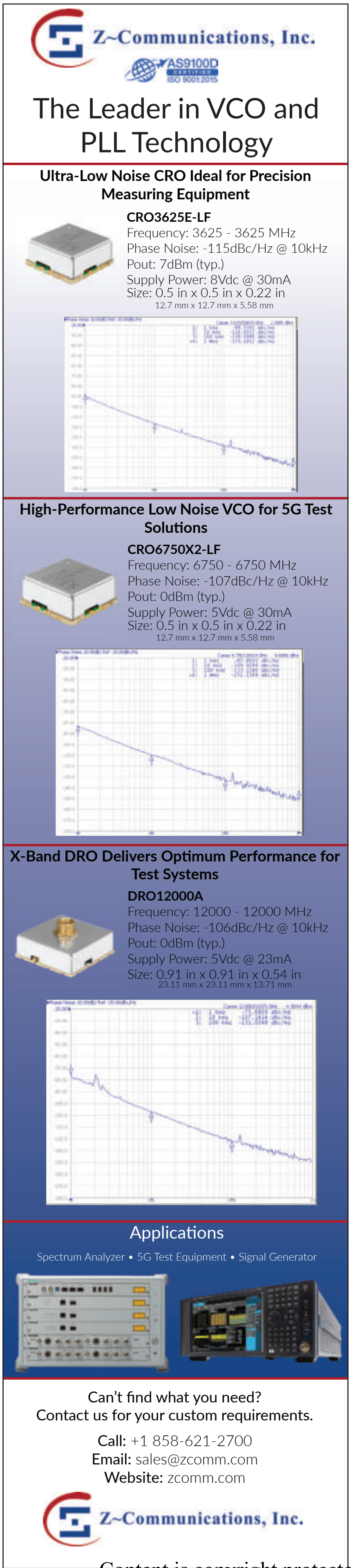

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How Drone Technology Will Revolutionize Satellite Antenna Testing

Joakim Espeland and Andrian Buchi
QuadSAT, Denmark

It is an exciting and dynamic time for the satellite industry. The number of satellites in orbit and satellite antennas on the ground is rapidly increasing. New constellations, geostationary orbit (GEO), low earth orbit (LEO) and medium earth orbit (MEO), new frequency bands and multiple uses of existing frequency bands (HTS, or high throughput satellites)—all contribute to a new frontier in satellite communications. Consequently, the potential for signal interference is a rising problem for the SATCOM industry.

Satellite operators partially address this problem with antenna performance requirements, such as the satellite operator's minimum antenna performance (SOMAP) requirements. This entails extensive antenna testing for manufacturers and service providers to be able to demonstrate and ensure performance. Antenna testing can be expensive and logistically difficult, so change is needed or it will restrict industry growth and innovation.

Using advanced drone technology coupled with advances in microwave technology, a new RF payload and unique pre- and post-flight software has been developed so that satellite antennas can be tested anywhere—easily and effectively (see ***Figure 1***). In recognition of this innovative new approach, the European Space Agency has awarded a contract to QuadSAT and its partners—the Global VSAT Forum (GVF) and the Danish Technological Institute—to evaluate this antenna test system.

This paper will explore the current challenges faced with satellite antenna testing and how drone technology can enable new cost-efficient testing models. It will elaborate on how this technology works, exploring both the drone technology and testing procedures, as well as mentioning some use cases.

IMPACT OF GROWING SATELLITE ENVIRONMENT

The number of satellites in orbit has steadily grown over recent years. With large constellations launching over the next few years, the satellite environment will become even more crowded. However, the satellite industry has experienced some slowdown and difficulties due to the COVID-19 pandemic. A survey by Northern Sky Research (NSR)[1] indicated that 44 percent of satellite companies have experienced a significant impact due to COVID-19 with 48 percent believing it will significantly impact the business in 2020-2021. The long-term prospects look more positive, with 40 percent believing that it will take six to 12 months for the satellite industry to recover. At the same time, the survey[1] also suggests that if a handful of companies succeed, the next decade will see more satellites put into orbit than all the satellites launched since Sputnik 1 in 1957.

Due to a larger number of satellites in orbit, there will be more ground infrastructure deployed too. In addition, large numbers of comms-on-the-move (COTM) antennas are being deployed, especially in maritime and aerospace markets. COTM antennas have increased the complexity with new architecture and tracking software. New

Fig. 1 QuadSAT Drone and testing equipment.

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antenna designs differ significantly from emerging antenna technology such as flat panel and electronically steerable antennas. Therefore, satellite operators need more test data to calculate link budgets. These changes lead to the requirement for more testing. Consequently, the leading satellite operators worked together to develop and introduce the SOMAP Requirements in 2017. The purpose of SOMAP is to ensure an industry-wide antenna qualification framework through an agreed minimum testing regime for COTM products.

For LEO, the way the antennas operate is very different from the ones used for GEO because they have different requirements. For example, since LEO satellites move faster than the Earth's orbit, antennas need to track the satellites (either mechanically or electronically) as they move across the sky. To serve seamless connectivity, LEO antennas handover satellites typically every five to 15 min.

Errors occur in any satellite network for many different reasons. Research conducted by the Satcoms Innovation Group a few years ago (as the Satellite Interference Reduction Group at the time) indicated that the highest percentage of interference was caused by human error, followed closely by equipment failure. Antenna flaws can cause serious errors for satellite communications, including mis-pointing, which may lead to satellite interference.

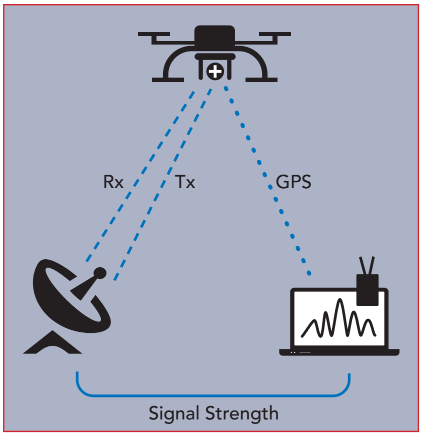
DETERMINING TESTING PROCEDURES

There are multiple test standards set out by governments or commercial bodies in terms of antenna testing. Current test ranges are at the core of these standards and many of the requirements have been set, based on their technical capabilities and limitations. The drone-based measurement method differs significantly from the traditional method and provides a new set of unutilized advantages.

ELEMENTS OF DRONE-BASED TEST RANGE

Over the past year, companies have extensively researched, tested and evaluated the necessary components and steps required for the development of a successful, portable and high precision drone-based antenna test range. A drone-based alternative must facilitate a wide variety of testing scenarios for antenna manufacturers, satellite operators and service providers.

A system is composed of four ele-



▲ **Fig. 2** Diagram of the drone-based measurement system.

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ments: an RF payload, a receiver system, a drone and a base station, as shown in ***Figure 2***. The RF payload comprises an antenna and a signal source. The signal source must be characterized by a stable frequency level and power output. The antenna must have a high level of cross-pol isolation and preferably have some gain and directivity to minimize the effect of interference coming from the environment. The ability to cover a broad frequency range is required to ensure that a wide range of different antennas can be tested. The purpose of the RF payload is to illuminate the antenna under test with a plane wave. The ability to precisely point the RF payload at the antenna under test is paramount.

A receiver system coupled to the antenna under test determines how much power is received by the test antenna. A spectrum analyzer or a power meter can be used. The receiver system also requires an amplifier to ensure that the signal is well above the noise floor in the measurement device.

The drone replaces the positioner in the standard antenna measurements and is accurately transporting the RF payload during the measurements. An advanced flight computer and pre-flight path planning software are required to create a spatial link between the system and ensures accurate control over the flight. It is crucial, that a flight path can accurately be replicated to provide measurement reproducibility. The flight sensors, onboard the drone, are vital for providing the necessary information to plot the conclusive results, as well as to compute the measurement uncertainty, which can subsequently be removed or quantified and documented.

A base station is required for real-time monitoring of the flight as well as other controlling functions that are key during the test, such as change of parameters or error correction with the position navigation and timing (PNT) system. Using a real-time kinematic (RTK) PNT base station allows for the drone to fly very accurately in the local reference system of the antenna under test. The RTK PNT used by QuadSAT ensures a drone position accuracy of 2 cm horizontally and 5 cm vertically. To put that into perspective, with this knowledge the drone will be able to maintain its position within a 30 × 30 × 30 cm box (see ***Figure 3***), even in high winds, up to 33 mph (54 km/h). This implies a pointing accuracy which is better than 0.01 degrees relative to the antenna, which rivals the accuracy provided by traditional, high performance, far-field test ranges.

PRACTICAL IMPLEMENTATION

Figure 4 illustrates the equipment, easily transported in a single case by

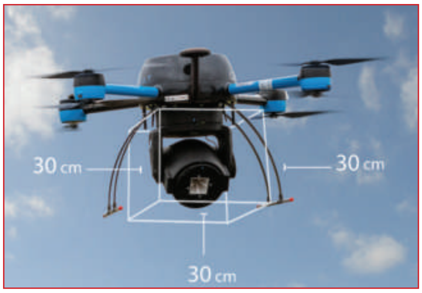

Fig. 3 Visual representation of the payload station positioning.

Fig. 4 From left to right: drone manual controller (used only for take-off and landing); drone equipped with a RF payload; base station.

a technician, needed for an antenna on-site test.

Setting up Before the Test: On-site base station set-up provides the reference position for the system, enabling the drone to know its exact location for performance of an accurate automated flight, and measurement of the antenna position with reference to the base station ensures that the antenna is at the center of all measurement flight paths. Preparation of the antenna under test (AUT) follows a specified step-by-step protocol, including the determination of Azimuth (Az) and Elevation (El) to ensure a clear line of sight (see ***Figure 5***).

Aligning and Identifying the Antenna Pointing: Following on from finding the initial and approximate Az and El pointing of the antenna, the drone performs a raster scan measurement to correctly identify the exact Az and El angles, with further verification to ensure optimal accuracy.

Performing the Test: Guided in flight in real-time, the drone can take any desired measurements, taking an Az cut or Raster scan, changing frequency and signal amplitude. The first test results show the directivity of the antenna and shape of the radiation pattern. Measurement of actual antenna gain is achieved using different methods determined by the final desired measurement accuracy. As illustrated in Figure 5, a pattern cut is performed in a preprogrammed test route, with the drone following a flight path that maintains a constant distance between the AUT (based on the main beam Az and El) and each data collection point. Drone and received signal status are constantly monitored and results generated can be graphically plotted for visual inspection. Alternatively they can be provided in data format.

The essential antenna tests are:

- Principal cuts in Azimuth, with a span of ± 20 degrees
- Principal cuts in Elevation, with a span of ± 10 degrees
- Raster scans, focusing on the vicinity of the main beam, at a span of ± 5 degrees both in Az and El, giving a highly visual 3D representation of the main beam

Figure 6 shows an example of such a measurement. All measurements are made in transmit and receive, and at three different frequencies (low, medium, high across the band) in both co- and cross-pol planes.

Drone testing conveniently enables antenna performance evaluation if the antenna is intended to operate with a radome. In such cases measurements with radome on and

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off are necessary. In ***Figure 7***, the antenna will meet the SOMAP Requirement (blue line) without radome (green line). Meanwhile with the radome on (red line) it will not

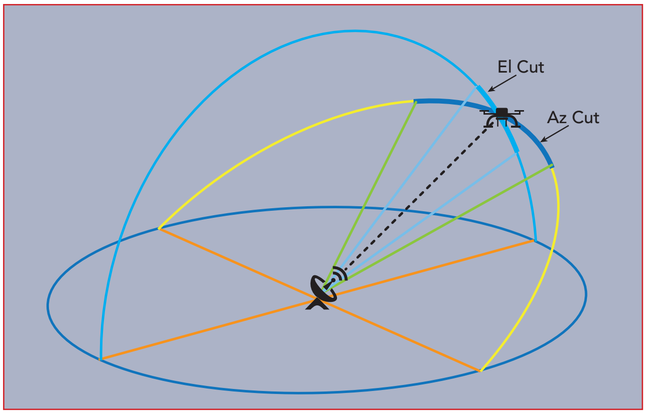


Fig. 5 Process diagram with azimuth and elevation cut.

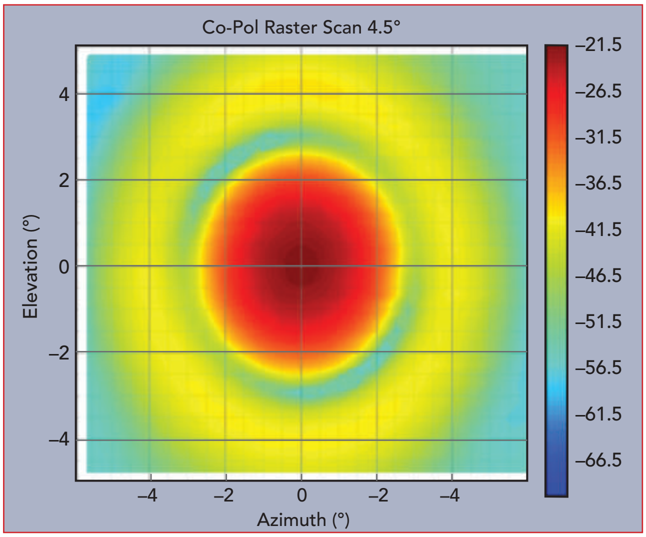


Fig. 6 Graphical representation of a raster scan performed with the drone-based measurement method.

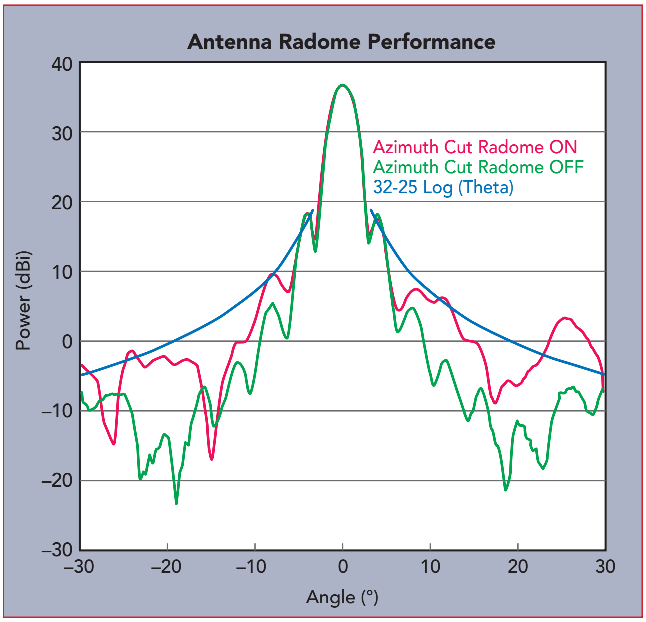
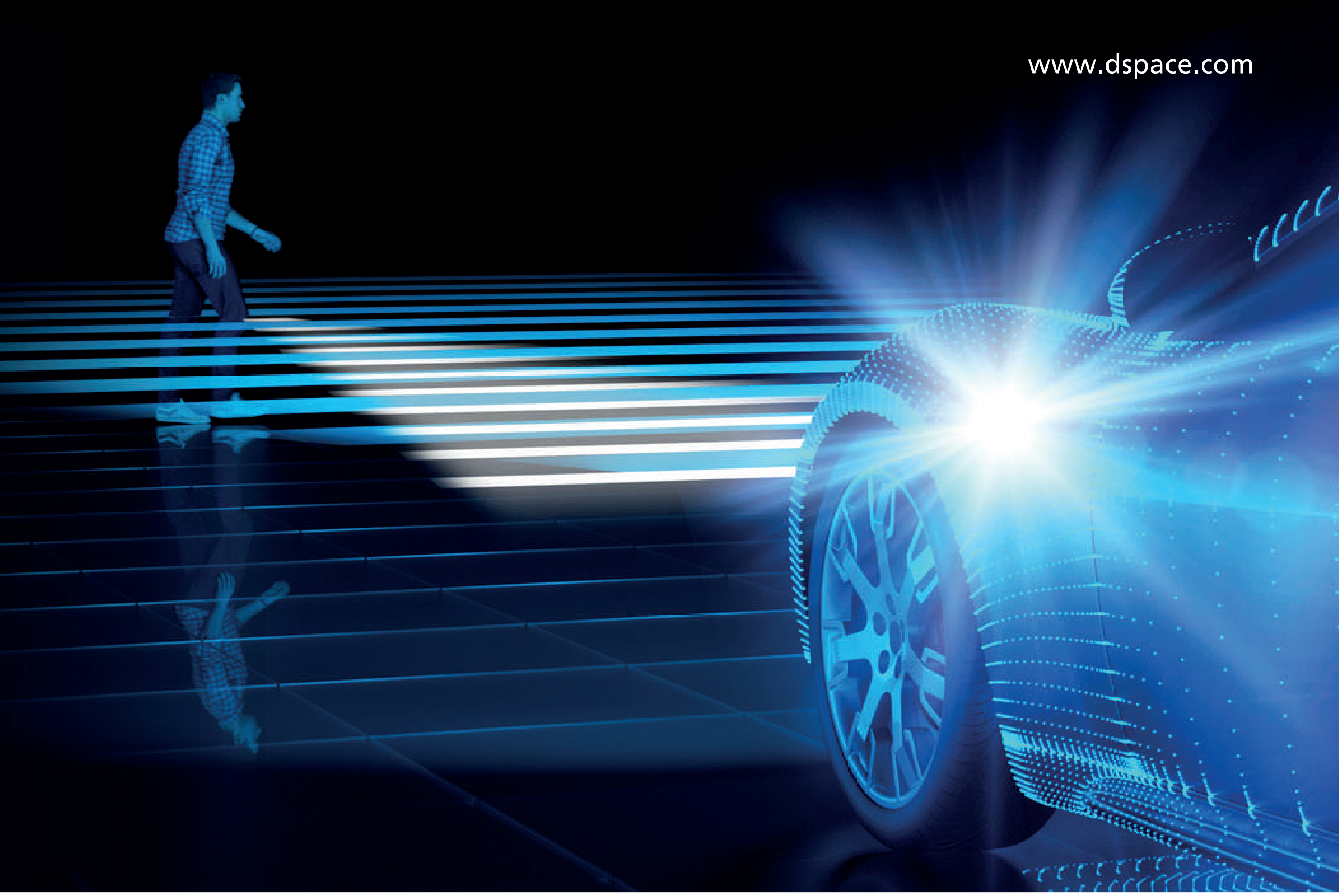


Fig. 7 Analysis of a radome that has operated at sea for several years on a pattern cut.



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comply with SOMAP Requirements, this is due to the large energy displacement of the radome.

REVOLUTIONIZING DRONE TESTING SYSTEM

Drone testing is providing a reliable method of identifying the transmit and receive Co-polarization and Cross-polarization off-axis components of a satellite antenna. It is designed to meet the needs of testing ground antennas, specifically with respect to pointing accuracy, radiation patterns and how the radome performance affects the radiation diagram.

The QuadSAT system is designed for X- and Ku-Band with intention to expand to Ka-Band antenna testing. It provides flexibility in assigning power levels, frequency choices and polarization adjustment. The product will be released in more frequency bands, modulations and customizations.

The company is working closely together with leading satellite operators and GVF to make sure industry standards are met. At the same time, considering the growth of LEO and MEO constellations, a similar method for evaluating and verifying the performance of tracking algorithms is being developed.

Drone positioning anywhere with reference to the AUT with comparable datasets allows a manufacturer to compare the performance of a new antenna model with the performance of the same model of antenna which has been operating under a radome for a period of time.

Satellite operators are at times experiencing under-performing antennas operating in their networks. Antenna manufacturers cope with logistically difficult, time consuming and expensive testing procedures and service providers have no viable means to measure the changes in antenna performance over time. Under-performing terminals have the potential to cause interference, with transmitting antennas causing interference on adjacent satellites.

Existing test methods use a positioning system to rotate the AUT to measure the radiation pattern as a function of the rotation angle. In the new drone solution, the antenna is kept at its location while the test is performed. The drone is equipped with an RF payload and flies a preprogrammed test route based on the desired measurement plane. The position of the drone is recorded in real-time with high precision which is coupled with the measurements performed by a receiver at the antenna's end.

Antennas operating in challenging environments are often covered by radomes for protection. These radomes must be manufactured for the frequency band of the antenna with great precision as even slight inaccuracies in the radome manufacturing process affects the performance of the antenna it covers. Exposure to the environment, such as sunlight, seawater, vibration, changing air pressure, or temperature, can change radome performance. The consequence can be antenna sidelobe degradation, beam deflection or depolarization, reducing the performance of the product combined

of both radome and the antenna it covers.

The size and shape of radomes complicate testing at current test ranges because they often do not fit onto the test-bench where the antenna is installed. These restrictions might have particular implications if the AUT is located on a large mobile platform such as an aircraft, a ship, or is used in a high speed rail application. These limitations do not impact a drone-based test range where the drone moves around the antenna (with or without radome), allowing for improved test data on radome effect, improving accuracy in link analyses as well as detecting a degradation in radome performance.

For satellite operators, drone technology means being able to facilitate a wide variety of testing scenarios to control the performance and quality of satellite antennas before they are introduced into their network. For antenna manufacturers, drone technology means being able to perform antenna measurements in-house conducted by their research and development teams. For service providers, drone technology means being able to conduct tests in the field, on-site after new installations or maintenance to ensure that their service meets customer expectations. Service providers will also see a dramatic reduction in the cost of installation and maintenance for COTM, as they can test without the need to move a ship, an airplane, etc. to verify the installation. Ultimately, drone-based antenna performance testing will make testing much more cost-effective, flexible and less time consuming.

SUMMARY

As more satellites are launched into various orbits, the number of antennas on the ground will increase rapidly. The desire of users to have smaller and lighter antennas leads to more complexity of the individual system. This will make adequate antenna performance testing more important, as COTM designs differ substantially in their design, which results in the need for increased flexibility in testing methods.

A new industry tailored test method that consists of a drone, a base station, an RF payload and a receiver system has been developed. As the drone solution evolves in accordance with the industry's needs, it will gradually eliminate the requirement to transport antennas to dedicated test ranges. The absence of size restrictions will accommodate antenna testing of a COTM system underneath its radome and thus provide valuable insight into its performance. This new drone solution will transform antenna performance measurement into a flexible, simple, quick and cost-effective method that has the potential to increase the overall quality of antenna terminals used in satellite communication, revolutionizing testing in this industry.■

Reference

1. Northern Sky Research, "COVID-19 Impact Survey Results: Satellite & Space," April 2020, https://www.nsr.com/wp-content/uploads/2020/04/NSR-April-2020-COVID19-Survey-Results.pdf.

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OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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DefenseNews

Cliff Drubin, Associate Technical Editor

Hypersonics Testing Accelerates

The March 19 test of a hypersonic glide body at the Pacific Missile Range Facility in Hawaii was just the start for the Defense Department, the assistant director for hypersonics in the Office of the Undersecretary of Defense for Research and Engineering said, and after ample flight testing, the department will move toward developing weapons from the concepts it has been testing.

"Over the next 12 months really what we will see is continued acceleration of the development of offensive hypersonic systems," Michael E. White said during an online panel discussion hosted by Defense One.

Hypersonic weapons move faster than anything currently being used, giving adversaries far less time to react, and they provide a much harder target to counteract with interceptors. White said DOD is developing hypersonic weapons that can travel anywhere between Mach 5 and Mach 20.

The recent test successfully demonstrated a capability to perform intermediate-range hypersonic boost, glide and strike, he said. That test, White added, begins a "very active flight test season" over the next year, and beyond, to take concepts now under development within the department and prove them with additional tests.

"Part of the department's efforts is the defense against adversary use of hypersonic missile threats—and that may involve space," said Navy Vice Adm. Jon Hill, director of the Missile Defense Agency. "Land-, silo- or air-launched hypersonic weapons all challenge the existing U.S. sensor architecture," Hill said, and so new sensors must come online. "We have to work on sensor architecture," Hill continued. "Because they do maneuver and they are global, you have to be able to track them worldwide and globally. It does drive you toward a space architecture, which is where we're going."

DOD is now working with the Space Development Agency on the Hypersonic and Ballistic Tracking Space Sensor to address tracking of hypersonics, the admiral said. That system is part of the larger national defense space architecture. "As ballistic missiles increase in their complexity...you're going to be able to look down from cold space onto that warm earth and be able to see those," he said. "As hypersonics come up and look ballistic initially, then turn into something else, you have to be able to track that and maintain track. To transition from indications and warning into a fire control solution, we have to have a firm track and you really can't handle the global maneuver problem without space."

Source: U.S.A.F. Photo

Hill said that the department already has had a prototype of such satellites in space for some time, and is collecting data from it. In the early 2020s, he added, additional satellites will also go up to demonstrate tracking ability.

Long-Range Communications Without Large, Power-Hungry Antennas

Establishing long-range tactical communications for U.S. troops in remote locations currently requires giant parabolic dishes, tall pole-mounted antennas, large antenna domes and high-power amplifiers. Besides their significant weight, power and cost (SWAP-C), these antennas present large visual and RF signatures, are vulnerable to jamming and constitute a single point of failure.

To break this dependence on big antennas and amplifiers, DARPA recently announced the Resilient Networked Distributed Mosaic Communications (RN DMC) program. RN DMC aims to provide long-range communications through "mosaic" antennas composed of spatially distributed low SWaP-C transceiver elements or "tiles." This approach replaces high-powered amplifiers and large directional antennas with mosaics of dispersed tile transceivers. Transmit power is distributed among the tiles, and gain is achieved through signal processing rather than by a physical antenna aperture to concentrate energy.

"This is a fundamentally different way to think about long-range tactical communications that supports DARPA's Mosaic Warfare concept of busting monolithic systems and distributing capability for greater resilience at less expense," said Paul Zablocky, program manager in DARPA's Strategic Technology Office. "RN DMC seeks to develop a mobile, self-forming, self-healing mosaic antenna comprising numerous low-cost and low-power transceiver tiles that can be placed aboard ships, vehicles, unmanned and manned aircraft and satellites, as well as individual squad members."

The antenna mosaic concept could prove more robust against failure or attack since tiles are distributed across air, ground and sea assets. Tiles also promise to be lower cost—targeted at $1,000 or less apiece—making individual tiles expendable without losing the mosaic antenna functionality.

"Powerful signal processing in a small, inexpensive form factor is the key enabling mosaic antenna technology," Zablocky said. "We will leverage small form factor software-defined radios and RF systems on a chip as well as previous DARPA research and development efforts that have validated the feasibility of basic distributed coherent radio transmissions."

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RN DMC includes three focus areas: system design, experimental performance validation and operational architecture definition. The effort is divided into three planned phases, totaling 45 months.

Stormbreaker Completes First Guided Release from Super Hornet in U.S. Navy Flight Test

Raytheon Missiles & Defense, a Raytheon Technologies business, completed the first guided release of a StormBreaker® smart weapon from an F/A-18E/F Super Hornet, which will become the second fighter jet to add the weapon when the program reaches initial operational capability later this year. The U.S. Air Force's newest weapon, StormBreaker®, has a unique tri-mode seeker that enables pilots to hit moving targets in adverse weather or low visibility. Integration is progressing on several U.S. fighter jets including the F-15E and now the F-18 Super Hornet.

"StormBreaker is the only weapon that enables pilots to hit moving targets during bad weather or if dust and smoke are in the area," said Cristy Stagg, StormBreaker program director. "Super Hornet pilots will be able to use poor visibility to their advantage when StormBreaker integration is complete."

Source: Raytheon Technologies

During the U.S. Navy flight test, StormBreaker safely separated from the jet and successfully received guidance data from the plane, enabling it to be directed to its target while in flight. StormBreaker features a revolutionary tri-mode seeker that uses imaging infrared and mmWave radar in its normal mode. The weapon can also deploy its semi-active laser or GPS guidance to hit targets.

The F-15E Eagle is the first platform to add StormBreaker; it is also being integrated on the F-35 Joint Strike Fighter.

CommercialMarket

Cliff Drubin, Associate Technical Editor

5G Continues Progress Despite COVID-19

According to 5G Americas, 5G progress in connections and deployments continues despite the COVID-19 pandemic and resulting economic downturn. According to data from Omdia, there are now over 63.6 million 5G connections globally as of Q1 2020, which represents 308.66 percent growth over Q4 2019.

5G Americas President Chris Pearson said, "Globally, 5G remains the fast-growing generation of wireless cellular technology ever, even as the world is gripped with a pandemic. In North America, we are seeing consistent, strong uptake of new 5G subscribers as new devices have been released that can take advantage of low-band and mmWave frequencies. At the same time, new network capabilities are being added."

Globally, there are now 82 5G commercial networks, a number which is expected to more than double to 206 by the end of 2020, according to data from TeleGeography. In addition, there are now over 100 commercial 5G device models available globally, according to the Ericsson Mobility June 2020 Report, with increasing support for low-band, mid-band and mmWave frequency bands.

Despite global strength in the number of 5G network rollouts, regional differences are beginning to emerge due to the localized impacts of the COVID-19 pandemic. According to Vice President of Latin America and Caribbean at 5G Americas, Jose Otero, "The impact of COVID-19 is finally being felt Latin America's and Caribbean's telecom industry. The decrease in remittances arriving from Europe and North America together with the mandatory lockdowns imposed by many regional governments decreased the purchasing power of a large percentage of the population."

Regionally by the end of Q1 2020, North America had 1.18 million 5G connections and 494 million LTE connections. This amounted to 100 percent growth in 5G, a gain of 591 thousand 5G connections over the quarter and 2.34 percent growth in LTE, a gain of 11.3 million LTE connections over the quarter. For Latin America and the Caribbean, Q1 2020 saw 3,004 5G subscriptions (142.85 percent Q4 2019 to Q1 2020 growth) and 372 million LTE subscriptions (3 percent Q4 2019 to Q1 2020 growth), respectively.

Looking ahead, Omdia projects 5G connections will reach 238 million globally by the end of 2020, of which North America will account for 10 million connections. According to Senior Analyst at Omdia, Kristin Paulin, "We expect growth to pick up in the second half of the year, following the easing of lockdowns as well as continued 5G network expansion and the availability of more 5G devices." Latin America and the Caribbean will account for an additional 270 thousand connections by the end of the year. Global 4G LTE connections remain strong and are expected to reach 5.7 billion, of which 506 million 4.8 percent annual growth, will come from North America and 404 million (11.8 percent annual growth) will come from Latin America and the Caribbean.

To minimize the impact of the pandemic, some governments in Latin America and the Caribbean have adjusted communications services taxes and terms. In addition, Otero said, "The lack of devices due to global logistic obstacles has resulted in negative subscriber growth and slower uptake of newer technologies. It is expected that until the situation normalizes all spectrum assignment processes would be delayed and that no new networks would be launched during this period."

3GPP Finalizes Latest 5G Spec

Standards body 3GPP signed-off on the COVID-19 (coronavirus) delayed release of the latest 5G specifications, but warned its next standards were at risk of further hold-ups due to continued restrictions on physical meetings.

Release 16 specifications were finalized at an online meeting on July 3, 2020, having been delayed by three months when the organization suspended in-person meetings in March. At the time, it also shifted the timeline for the subsequent Release 17 protocols by the same period to December 2021.

However, in its latest statement it noted Release 17 was "at a high risk of being delayed" further due to the continued need for online gatherings rather than physical ones. The issue is set to be discussed at a meeting in September.

The Release 16 protocols cover the use of a range of technologies to improve 5G mobile broadband and specify standards to support several vertical applications.

Updates include enhancements of massive MIMO; protocols for access to unlicensed spectrum; and standards covering vehicle-to-everything, industrial IoT and ultra-reliable low-latency communication.

In a statement released following the virtual meeting, attended by more than 600 representatives, Huawei noted the latest standard would "provide a high performance and full-service support well into the future."

COVID-19 Accelerates the Adoption of Civil Drone Shipments

Like many technologies, the future of robotics is being complicated by COVID-19. But more than any other technology, robotics developers have visibly demonstrated the value of more flexible automation to meet the enormous chal-

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> Governments are turning to drones for emergency, health and law enforcement.

lenges being placed on businesses and governments. While shipments in autonomous last-mile delivery and commercial cleaning robot shipments will be bolstered by the pandemic, drones for civil use-cases will see the most immediate and long-term growth. Civil drone shipments will nearly double from 2020 pre-pandemic forecasts to reach 13,400 and nearly 80,000 shipments will take place in 2025, stated ABI Research.

In its new whitepaper, *Robotics and Covid-19: Challenges and Opportunities*, ABI Research reveals how COVID-19 has been the catalyst for change in the robotics industry and explores how the industry is well-placed to accelerate its deployments by enabling both corporations and governments to tackle this crisis.

"Having over a quarter of the world under lockdown would have been a mad prediction the start of 2020," said Rian Whitton, senior analyst at ABI Research. "Now, with a stay at home orders being relaxed, and gatherings limited, governments are turning to drones for emergency, health and law enforcement."

"Drones are essentially acting as a platform for various cameras for facial recognition and crowd control. Some are equipped with infrared cameras to measure temperature. In fact, we've seen some infrared camera manufacturers' orders skyrocket because businesses want to check employee's temperature before they come to work," said Whitton. Many drones are deployed with loudspeakers to enforce curfews and surveil areas for security purposes, which poses a big opportunity for aerospace and drone companies to increase sales to government agencies. Delivery drones have also become more prominent during the crisis. In China, delivery drones have made more than 3,000 trips carrying 11 tons of supplies to Wuhan. In early February, the U.S. Federal Aviation Administration began creating safety standards for specific delivery drone models, accelerating testing and eventual commercialization in the U.S. ABI Research expects the small drone delivery market will reach US$10.4 billion by 2030.

Drone manufacturers received US$281 million in investment in 2019 and drone services received US$497 million. "While the industry has been wracked by the commodification of consumer drones and major incidents affecting the presumed safety of large-scale drone operations, the value of commercial services is not in doubt and the industry will receive significant increases in orders from law enforcement agencies as a result of COVID-19," Whitton concluded.

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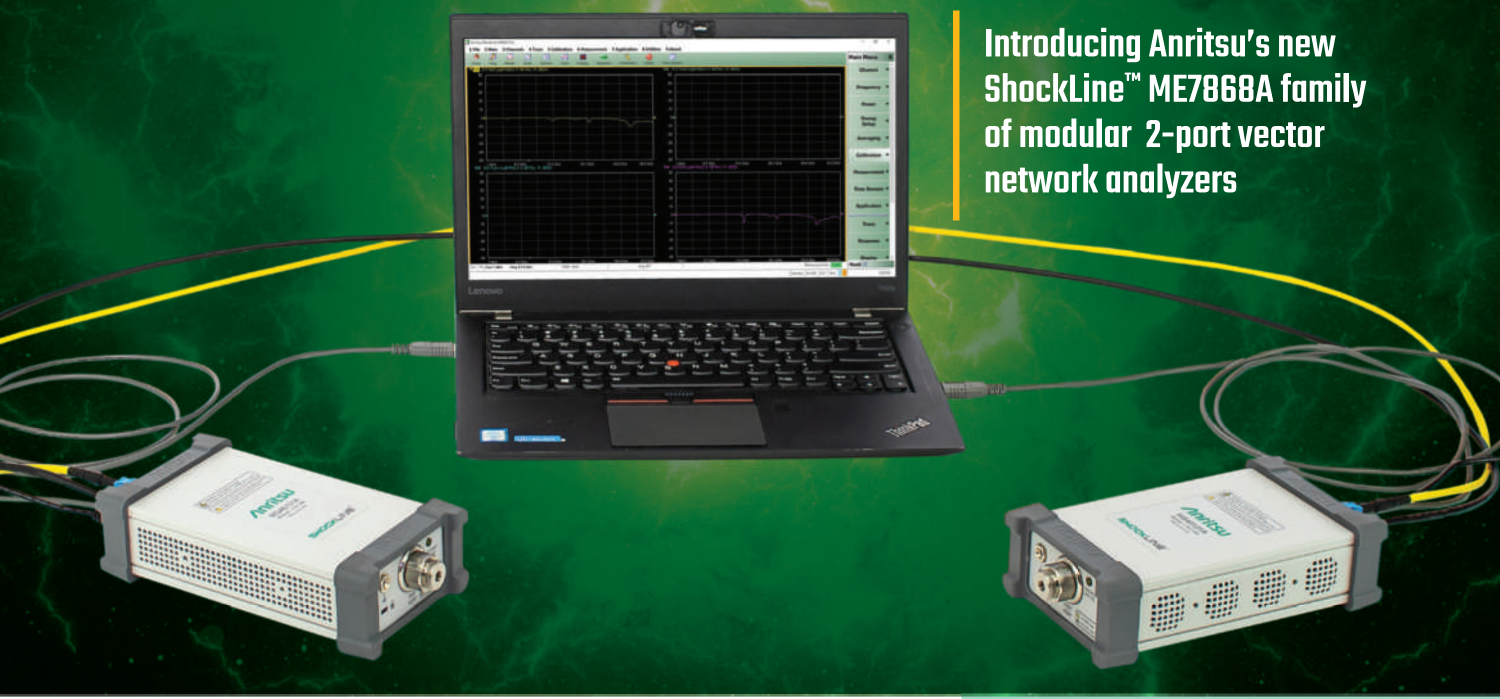

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Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Analog Devices Inc. and **Maxim Integrated Products Inc.** announced that they have entered into a definitive agreement under which ADI will acquire Maxim in an all stock transaction that values the combined enterprise at over $68 billion. The transaction, which was unanimously approved by the Boards of Directors of both companies, will strengthen ADI as an analog semiconductor leader with increased breadth and scale across multiple attractive end markets. Under the terms of the agreement, Maxim stockholders will receive 0.630 of a share of ADI common stock for each share of Maxim common stock they hold at the closing of the transaction. Upon closing, current ADI stockholders will own approximately 69 percent of the combined company, while Maxim stockholders will own approximately 31 percent. The transaction is intended to qualify as a tax-free reorganization for U.S. federal income tax purposes.

Keysight Technologies has acquired **Eggplant** from The Carlyle Group, in a transaction valued at $330 million. Eggplant, with revenue of $38 million in 2019, provides software test automation that uses artificial intelligence and analytics to automate test creation and test execution. Eggplant will extend Keysight's automated software test capabilities across the physical and protocol layers and into the application layers. Eggplant's Digital Automation Intelligence platform can test any technology on any device, operating system or browser at any layer, from the user interface to application programming interfaces to the database.

Modelithics has acquired the ProbePoints™ substrate fixture assets from **Jmicro Technology**, including test fixtures and probing accessories for testing semiconductor devices and packaged products. The popular ProbePoint alumina substrate fixtures enable RF wafer probes to test devices without ground-signal-ground probe pads. With the legacy Jmicro ProbePoint fixture products, Modelithics plans to offer other standard and custom microwave and mmWave test fixtures and calibration standards, using its 20-year experience with fixturing and calibration. Designers can obtain test fixtures and accessories through Modelithics, a company known for precision measurements and trusted models.

OneWeb announced that it has entered into an agreement with a consortium led by **HMG** and **Bharti Global Limited** for the acquisition of the OneWeb business in connection with its court-supervised sale process. The bid is designed to capitalize the company sufficiently as a going concern to effectuate the full end-to-end deployment of the OneWeb system. Following a competitive process, the consortium's winning bid represents a strong offer that will enable OneWeb to successfully emerge from the Chapter 11 process with a robust foundation on which to continue its progress towards commercial operations and secure OneWeb's position as a global leader in low latency connectivity.

COLLABORATIONS

Soitec (Euronext Paris), an industry leader in designing and manufacturing innovative semiconductor materials, announced a business agreement with **Qualcomm Technologies Inc.** on the supply of piezoelectric-on-insulator (POI) engineered substrates for 4G and 5G RF filters. Soitec's POI substrate brings strong value proposition to smartphones' 5G filters for mass markets. After multiple years of collaboration with Qualcomm Technologies, Soitec has concluded an agreement to bring POI wafers production to high volume manufacturing to be used for Qualcomm Technologies' RF filters going to smartphones RF front end modules. POI is an innovative substrate manufactured thanks to Soitec's proprietary Smart Cut technology in 150 mm.

Infineon Technologies AG announced that its Silicon Valley Innovation Center has entered a new agreement with **Blumio** to co-develop a wearable, non-invasive blood pressure sensor based on Infineon's XENSIV™ radar chipset by 2021. The new sensor has the potential to disrupt the USD 45 billion market for wearable cardiovascular monitoring devices by enabling continuous and precise measurement without a cuff. Upon successful completion, a kit combining Infineon's radar chipset and development board with Blumio's software and algorithms would be released to consumer and medical wearable device makers to integrate into their blood pressure monitoring devices.

Qualcomm Technologies Inc. and **Infinite Computer Solutions** announced a strategic collaboration to promote the widespread adoption of smart cities solutions and deliver Internet of Things as a Service (IoTaaS) for plug and play deployment. The collaboration creates an end-to-end, fully managed solution that facilitates digital transformation for smart connected spaces across government, healthcare, construction, entertainment, transportation, manufacturing, retail and logistics. The IoTaaS offering connects companies in the Qualcomm® Smart Cities Accelerator Program using Infinite's intelligent engagement platform—Zyter® SmartSpaces™—to enable a streamlined, full suite of offerings that address the complexities around developing secure, smart, connected spaces across vertical industries, worldwide.

NEW STARTS

National Instruments is rebranding, renaming itself simply **NI**—as it has long been known—and adopting the tag line "Engineer Ambitiously™," reflecting a campaign to recognize the contributions of engineers to society. To share the stories of engineers whose work

DUAL or SINGLE LOOP
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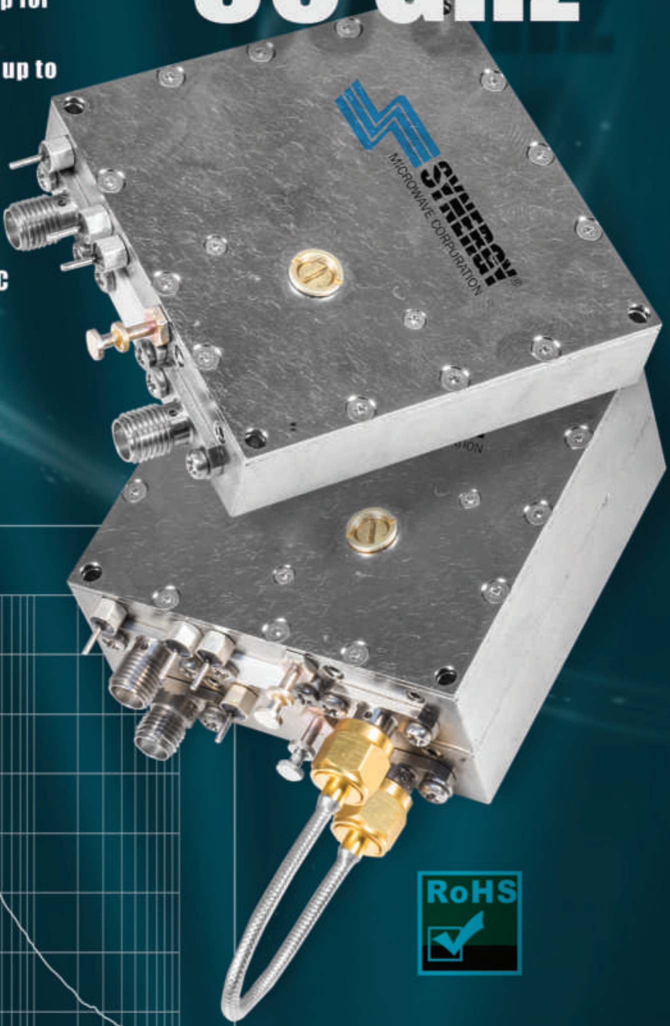

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- Output frequencies from 100 MHz locked crystal to 30 GHz
- Available with reference clean up dual loop, or single loop for very low noise reference
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- Reference input range 1 MHz to 1.5 GHz
- Dual RF output or reference sample output available
- +12 dBm standard output power +16 dBm available
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Applications:

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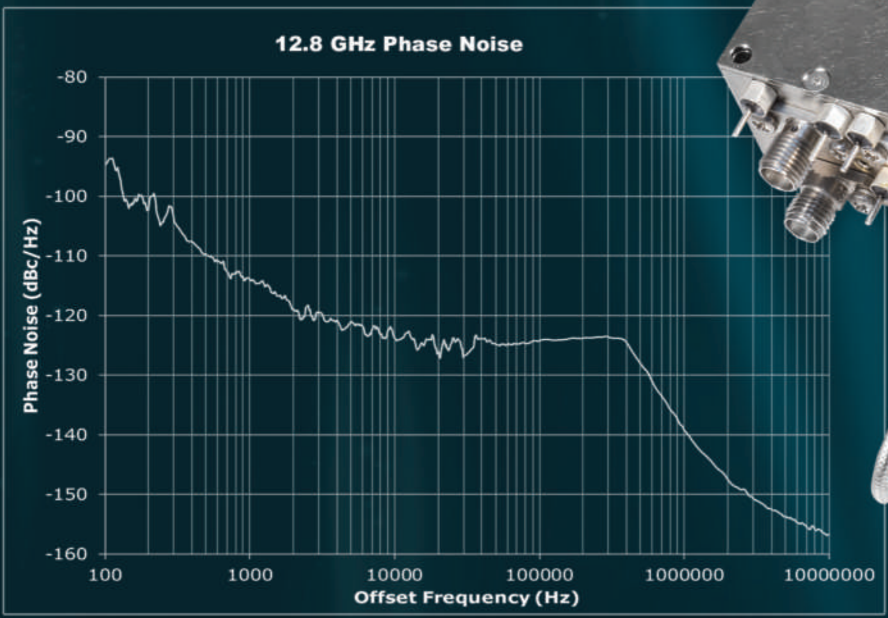

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reflect a commitment to ambitious accomplishments, NI is launching Perspectives, a web portal to share their work and how NI's equipment and software is helping to enable it. NI is inviting engineers to submit their stories and will publish one each week for the next 100 weeks.

ACHIEVEMENTS

R. Dale Lillard, president of **Lansdale Semiconductor Inc.**, announced that the company was honored for the seventh consecutive year by **Raytheon Integrated Defense Systems** for Supplier Excellence. This year, Lansdale achieved Raytheon's highest 5 Star Award for the second time in two years. Raytheon's Integrated Defense Systems business instituted the annual Supplier Excellence Awards program to recognize suppliers who have provided outstanding service and partnership in exceeding customer requirements. Award candidates are judged on certain criteria, including overall quality, on-time delivery and demonstrated commitment to continuous improvement.

Cinch Connectivity Solutions, a Bel group company, and a global leader in delivering reliable connectivity solutions, awarded **Powell Electronics** with the inaugural President's Award for the 2019 calendar year. The President's Award is given annually based on excellence in sales growth, service, customer satisfaction and engagement. Powell Electronics was presented Cinch Connectivity Solutions 2019 President's Award, recognized for exceptional POS growth, new design wins and consistent engagement with Cinch field sales teams and independent manufacturer's reps across the country. Traditionally, these awards are presented at the EDS Summit in Las Vegas, Nev. This year, with the COVID-19 pandemic, Bel held virtual celebrations to congratulate the Powell team.

Northrop Grumman selected **Haigh-Farr** as an Outstanding Supplier supporting the OmegA rocket, which will launch national security missions for the U.S. Space Force. OmegA is on track for its first launch in spring of 2021. In order to achieve the high data rate capabilities the OmegA rocket required; Haigh-Farr created an antenna system specifically for their mission profile. This system includes a series of four antennas, each individually selectable, providing full RF power via a directed and focused antenna pattern.

CONTRACTS

Raytheon Missiles & Defense, a **Raytheon Technologies** business, has received a $2.3 billion production contract from the **U.S. Missile Defense Agency** for seven GaN-based AN/TPY-2 radars, part of a foreign military sale to the Kingdom of Saudi Arabia. The mobile AN/TPY-2 missile defense radar is part of the Terminal High Altitude Area Defense (THAAD) system, designed to protect against incoming ballistic missile threats. Of the 14 AN/TPY-2 radars produced, seven are fielded with U.S.-operated THAAD systems, five operate in forward-based mode for the U.S. and two are part of foreign military sales.

Cubic Corp. announced its **Cubic Mission Solutions** business division was awarded a $950 million ceiling indefinite delivery/indefinite quantity (ID/IQ) contract for the **U.S. Air Force's Advanced Battle Management System**. The Air Force will use the contract for the maturation, demonstration and proliferation of capability across platforms and domains, leveraging open systems design, modern software and algorithm development in order to enable Joint All Domain Command and Control (JADC2). This contract is part of a multiple award, multi-level security effort to provide development and operation of systems as a unified force across all domains (air, land, sea, space, cyber and electromagnetic spectrum) in an open architecture family of systems that enables capabilities via multiple integrated platforms.

Mercury Systems Inc. announced it received a $25 million follow-on order from a leading defense prime contractor for integrated RF and digital subsystems for an advanced naval electronic support application. The order was booked in the company's fiscal 2020 fourth quarter and is expected to be shipped over the next several quarters. Mercury is accelerating innovation for its customers as the company bridges the gap between commercial technology and defense applications to meet the industry's current and emerging needs.

Top ten global design firm, **Stantec**, has been awarded a $20 million (USD), five-year indefinite delivery/indefinite quantity (IDIQ) contract to complete water resource and floodplain projects within the Continental United States (CONUS) and Outside the Continental United States (OCONUS) by the **US Army Corps of Engineers (USACE)**, New Orleans District. Stantec will provide a broad array of engineering services to the USACE, including, but not limited to, structural, civil, hydraulic, geotechnical and environmental, as well as surveying, landscape architecture and project management. In alignment with the mission of the Department of Defense, projects under the USACE New Orleans District IDIQ are expected to move forward despite the COVID-19 pandemic.

Comtech Telecommunications Corp. announced that during its fourth quarter of fiscal 2020, its Santa Clara, Calif.-based subsidiary, **Comtech Xicom Technology Inc.**, which is part of Comtech's Commercial Solutions segment, received a contract valued at more than $1.5 million for 500 W Ka-Band traveling wave tube amplifiers for a tracking, telemetry and command applications. These amplifiers will ship later this calendar year and will be deployed globally by a major satellite service provider for a new Ka-Band network.

Sensor system supplier **HENSOLDT** has been awarded a contract by **Airbus Defence and Space** to develop and produce a new active electronic scanning array radar for the German and Spanish Eurofighter fleets. The project is jointly financed by the Eurofighter partner nations Spain and Germany, who will also be the first users of the radar in their fleets. Following budget approval

by the Spanish government and most recently by the German Bundestag in mid-June, the contracts worth over 1.5 billion euros have now been signed.

During Armed Forces Week, **BAE Systems** and the **Royal Navy** announced a £3.2 million autonomous boat contract that will increase Navy's capabilities while protecting sailors' lives. The autonomous capabilities of BAE Systems' Pacific 24 (P24) rigid inflatable boat (RIB), a staple in the Royal Navy surface fleet, could significantly enhance the Royal Navy's ability to protect its sailors at reach, as the upgraded sea boat is able to execute its own missions without crew and be run from a warship. Such missions could include anti-piracy operations, border control, persistent intelligence gathering, maritime security and force protection, all while keeping a sailor safe from harm.

L3Harris Technologies launched the latest in a demonstration series of end-to-end small satellites as part of a **U.S. Air Force** constellation the company is responsible for developing. As the prime contractor for the firm fixed-price development space mission, L3Harris is designing, developing, building, testing and deploying the satellites. The company will task, command and control the satellite system, as well as perform on-board processing of data to deliver imagery products directly to warfighters on tactical timelines.

PEOPLE

▲ *James Martin*

MixComm announced the appointment of **James "Jay" Martin** as vice president of business development. Martin will drive growth in 5G and related markets for the mmWave startup. He brings to MixComm an extensive background in wireless business development, design and engineering management with a history of building successful and deep technical relationships with customers in the RF and mmWave industries. With 25 years of experience, he has led significant value creation through new opportunity identification and customer engagement.

▲ *Carl Novello*

NXT Communications Corp. (NXTCOMM) announced the appointment of **Carl Novello** as its chief technology officer (CTO). He leads NXTCOMM's product development efforts to bring transformational flat panel antenna solutions to mobility markets. Novello brings two decades of advanced satellite communications, system and RF antenna design and test expertise to his role. Novello is bringing transformational antenna solutions to aviation and other mobility markets. He oversees product engineering, design and development for NXTCOMM's line of advanced electronically steered antennas that will deliver unprecedented broadband connectivity to mobile platforms.

▲ David Díez & Francisco Canales

ERZIA Technologies announced that it has selected **David Díez** and **Francisco Canales** as the managing directors of the company effective July 1. Mr. Luis García, CEO and founder of ERZIA, will no longer be both CEO and MD; he is handing over this last responsibility to two key members of the organization. Díez will be focused on the aerospace and defense business and the RF and microwave technology areas. Canales will concentrate his energy on operations and finance as well as the VSAT/MSS businesses of ERZIA. Díez holds a master's in Engineering specializing in telecommunications, with broad experience in engineering, management and business development. Canales holds a master's degree in Business Administration and has been ERZIA's financial director for almost 17 years.

▲ Bryan Ingram

Anokiwave Inc. announced the appointment of two prominent wireless industry executives to its Board of Directors. Expanding to nine directors is one of several strategic investments Anokiwave is making to achieve its aggressive growth objectives. **Bryan Ingram**, formerly senior vice president and GM of Broadcom's Wireless Semiconductor Division, and

▲ Michael T. Murphy

Michael T. Murphy, formerly senior vice president and GM of MACOM's RF and Microwave Business, have joined Anokiwave's Board. These recent additions bring more than 50 years of combined operational expertise, a track record of success with development and production of high-growth, high volume RF and handset products and industry relationships that are both broad and deep.

The Satcoms Innovation Group (SIG) has announced that **Bob Potter** of Kratos Defense and Security Solutions has been appointed a director of the group. Potter joins existing directors Andreas Voigt of Eutelsat and Mark Steel of Inmarsat, led by recently appointed Managing Director Helen Weedon. Potter has been heavily involved with SIG for many years, during which time he has spoken regularly at the group's events and conferences. His experience in RF systems design and measurement techniques extends back more than 25 years. Potter has held several senior-level and executive positions from CTO to president over the years.

▲ Bob Potter

Around the **Circuit**

REP APPOINTMENTS

For over 40 years, **AR RF/Microwave Instrumentation** has played a major role in the success of companies in China. AR provides total RF test solutions by offering customers RF test instrumentation, RF test systems, EMC test software and chambers. In addition to the complete array of products comes world-class customer service and application support. From calibration and regular maintenance, to troubleshooting and repairs, you can depend on AR. Its local representative for China is **Yifeng Tech Co., Ltd**. Representing AR for Sales & Service is Alvin Li, GM/CEO.

Modelithics, an RF and microwave simulation model provider, welcomes **Silicon Supplies**, a solution based provider of Silicon Discrete and IC (Integrated Circuit) bare die for use in niche trailing edge and leading edge applications, into the Modelithics Vendor Partner (MVP) Program at the Strategic level. As a Strategic MVP, Silicon Supplies is supporting RF and microwave designers by sponsoring free extended 30-day trials (with approval) of all Modelithics models available for Silicon Supplies components, as well as collaborating with Modelithics to develop new design data and models for selected components.

Richardson Electronics Ltd. announced a new distribution agreement with **DAPU Telecom**, a leader in frequency control and timing solution products. The agreement aligns with both companies' commitment to providing the highest reliability and quality products into various applications including RF and microwave communications, industrial, wired and wireless transmission, radar and test equipment. DAPU Telecom proudly offers a broad range of timing devices, including OCXO and TCXO, clock and timing modules and ICs. Recent introductions include real time clock ICs, clock buffers, IEEE 1588v2 chipsets, PLL ICs, circulators and isolators.

Richardson RFPD announced that it has entered into a global franchise agreement with **LICAP Technologies, Inc.** LICAP manufactures supercapacitors (also known as ultracapacitors and electric double layer capacitors) that provide peak power and backup power (typically less than 60 seconds) for a wide range of applications. LICAP offers a variety of standard supercapacitor modules that are easy to integrate into any electrical power system that requires high performance, long life and high reliability energy storage. The core technology enabling LICAP's high performance is patented activated dry electrode material, which is developed and manufactured at LICAP U.S. headquarters in Sacramento, Calif. Supercapacitor product R&D and production are conducted at LICAP's facility in Tianjin, China.

INVITED PAPER

The Growing Importance of Oscillators With 5G

Pasternack
Irvine, Calif.

Normally, the most talked about aspects of 5G in the RF front-end are the deployment and functionality of massive MIMO (mMIMO), mmWave transceivers for small cells and the power density requirements of power amplifiers (e.g., silicon versus GaN). However, the key performance indicators of 5G impact other components in the RF front-end transmit/receive chains, particularly oscillators, where timing and synchronization requirements drive the need for more precise oscillator design and fabrication.

Cooperative radio techniques such as inter- and intra-band carrier aggregation (CA), MIMO, downlink coordinated multi-point (CoMP) transmission and reception and uplink CoMP require much tighter synchronization than traditional 4G technologies. The entire synchronization chain, including the air interface at the remote radio unit (RRU) and introduced errors from fiber, switches and routers at various nodes must be considered. The end-to-end (E2E) latency for time-division duplex (TDD) 5G networks is 1.5 μs; this, however, is only a foundational latency requirement that gets progressively tighter with cooperative radio techniques. The newly introduced enhanced Common Public Radio Interface (eCPRI) protocol has made provisions for this, which makes official the increasing importance of a stable source for an effective 5G network.

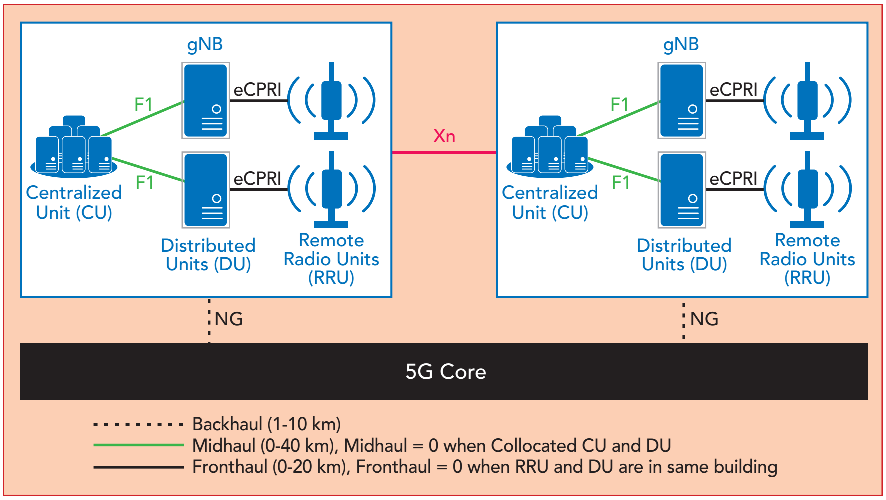


Fig. 1 5G Location of fronthaul, midhaul and backhaul in the network.

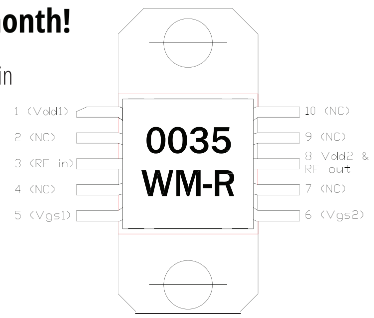
5G XHAUL: CPRI CONSTRAINTS

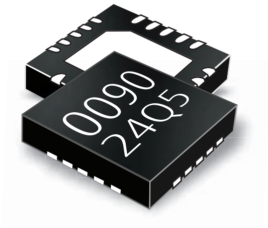
Previous generation cellular base stations comprised a baseband unit (BBU) and remote radio head (RRH) connected to the antenna through a run of coax. The RRH handled the conversion between the digital and RF signals, while the BBU handled the bulk of the processing by providing the physical interface between the base station and the core network.

The LTE base station (eNodeB) improved this with an integrated antenna and RRH connected to the BBU through an optical fiber using a CPRI signal, eliminating RF cable loss and interference. The 3GPP new radio architecture now consists of a centralized unit (CU), distributed units (DU) and RRUs, where the 4G BBU functions are split into the DU and CU. This network architecture (see ***Figure 1***) includes fronthaul, midhaul and backhaul infrastructure to handle the capacity, latency and reach requirements

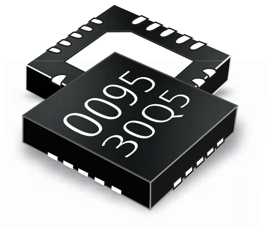
One of our best selling MMICs will be available in QFN packaging next month!

AMCOM's AM003536WM-BM/EM/FM-R is an ultra-broadband GaAs MMIC power amplifier. It has 22 dB gain and 36dBm output power over the 0.01 to 3.5 GHz band. This MMIC is in a ceramic package with both RF and DC leads at the lower level of the package to facilitate low-cost SMT assembly to the PC board. When mounting directly to the PCB, please see application note ANB700 for instructions. Because of high power dissipation, we strongly recommend to mount these devices directly on a metal heat sink. The AM003536WM-EM is a Copper Tungsten drop-in package with straight leads. The AM003536WM-FM-R is the AM003536WM-BM-R mounted on a gold-plated copper flange carrier. There are two screw holes on the flange to facilitate screwing on to a metal heat sink. Both parts are RoHS compliant.





AM009024WM-QN5-R
is an ultra-broadband GaAs MMIC power amplifier. It has 22dB gain, and 24dBm output power over the 0.05 to 9GHz .



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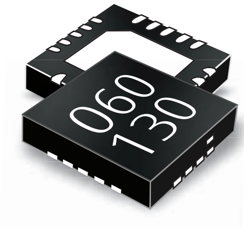

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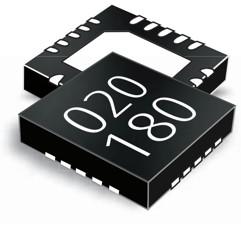
is a broadband GaAs MMIC which operates between 6 and 13 GHz with 28 dB gain and 33 dBm output power.



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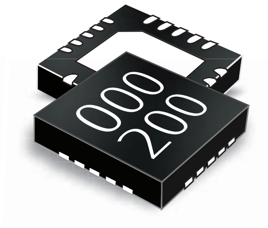

AM00020026WM-QN5-R
Broadband GaAs MMIC Distributed Power Amplifier which operates between DC and 20 Ghz with 13 dB gain, and 26 dBm output power.

AMCOM AM004020LN-P1 is a broadband Low Noise Amplifier module. It is designed for general purpose applications. It operates from 20 MHz to 4000 MHZ with Noise Figure of 2 dB and small signal gain of 24 dB.

AMCOM AM108020LN-P1 is a broadband Low Noise Amplifier module. It is designed for general purpose applications. It operates from 1 GHz to 8 GHz with mid-band Noise Figure of 2 dB and small signal gain of 22 dB.

AMCOM AM056020LN-P1 is a broadband Low Noise Amplifier module. It is designed for general purpose applications. It operates from 500 MHz to 6000 MHZ with mid-band Noise Figure of 2 dB and small signal gain of 20 dB.

AMCOM AM07014020LN-P1 is a broadband Low Noise Amplifier module. It is designed for general purpose applications. It operates from 7 GHz to 14 GHz with mid-band Noise Figure of 2 dB and small signal gain of 17 dB.

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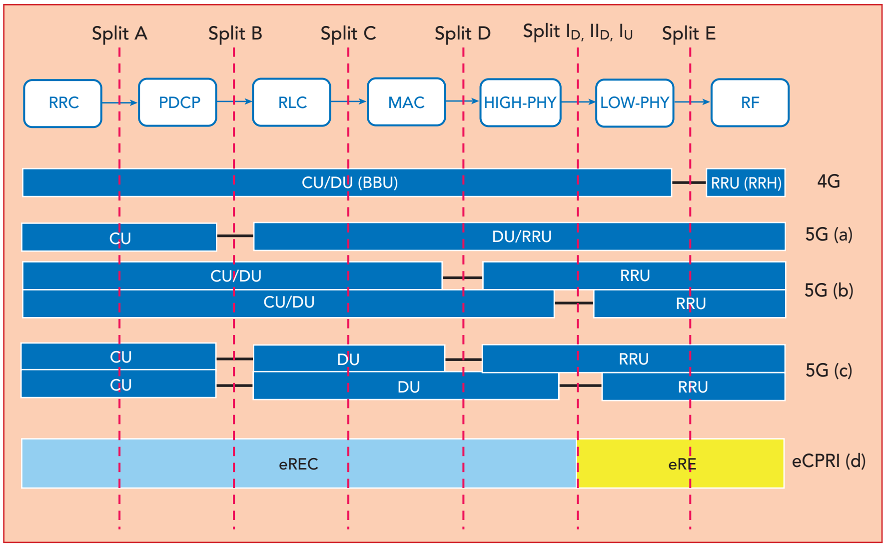

Fig. 2 CU, DU and RRU functions in high layer (a), low layer (b) and cascaded split points (c), with the corresponding intra-PHY eCPRI split (d).[1, 2]

TABLE 1

MAXIMUM ONE-WAY FRAME DELAY[1]

eCPRI CoS	Latency Class	Maximum One-Way Frame Delay	Use Case
High	High 25	25 µs	Ultra-low Latency (Fast User Plane)
	High 100	100 µs	Full E-UTRA or NR (Fast User Plane)
	High 200	200 µs	Lengths of Fiber in 40 km Range (Fast User Plane)
	High 500	500 µs	Large Latency Installation (Fast User Plane)
Medium	—	1 ms	Slow User Plane Fast C&M Plane
Low	—	100 ms	C&M Plane

of 5G. Instead of the CPRI interface between the BBU and the RRH in 4G, 5G fronthaul architectures will likely leverage the eCPRI interface between the DU and the RRU. The eCPRI protocol, however, is not limited to fronthaul; it can service connections between the CU and DU.

Wireline Solutions: CPRI vs. eCPRI

The CPRI protocol is a standard digitized format mainly used to transfer point-to-point data over fiber to separate the radio equipment (RE) from the radio equipment control (REC). This enables the 4G eNodeB configuration with a BBU (REC) separate from the RRU (RE), which is often integrated with the antenna. However, CPRI does not scale well with base stations that have a functional decomposition—specifically, a functional split within the physical layer (intra-PHY split). The intra-PHY split is necessary in 5G, enabling high data rate functions such as CA, network MIMO, downlink CoMP and uplink CoMP. This led to the release of eCPRI, with the goal of "decreasing data rate demands between eREC and eRE via a flexible functional decomposition."

Figure 2 shows the functional split in various 5G architectures described in ITU-T GSTR-TN5G, as well as the intra-PHY downlink splits (ID, IID) and uplink split (IU) specified in eCPRI.[1] More often than

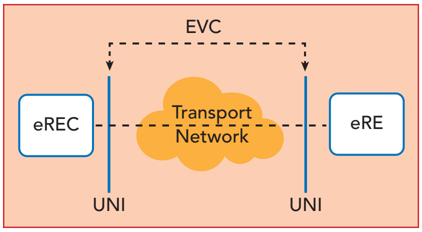

Fig. 3 The UNI is the physical point defining subscriber/service provider responsibility. (*Source:* eCPRI).

not, an eRE corresponds to an RRU, while the eREC includes the CU and DU functions.

eCPRI Latency and Synchronization

This flexible functional decomposition is accomplished by laying the eCPRI protocol layer above the packet-based transport network layer, which could be IP- or Ethernet-based. The new eCPRI protocol also comes with updated timing requirements for handling multiple REs. Where the CPRI quality of service requires a maximum overall round-trip link latency of 5 µs (R-26), the asymmetry of eCPRI calls for more variation in this requirement. The eCPRI standard includes various classes of service where the maximum one-way frame delay can go as low as 25 µs for ultra-low latency performance (see ***Table 1***). The one-way frame delay must include both the fiber propagation delay from ingress and egress of various user network interfaces (UNI) as well as the switching delay from the transport network (see ***Figure 3***). The Ethernet virtual connection can contain several UNIs.[2] This causes much more stringent delay requirements on the switches and routers within the transport network, in addition to the already strict air interface requirements on the eRE. Typically, the eREC or CU/DU, does not require the same stringent synchronization and timing requirements that an eRE or RRU needs, since the eRE will generate the frequency for air transmission locally.

Two kinds of time errors are specified for eCPRI timing accuracy: absolute and relative time error.

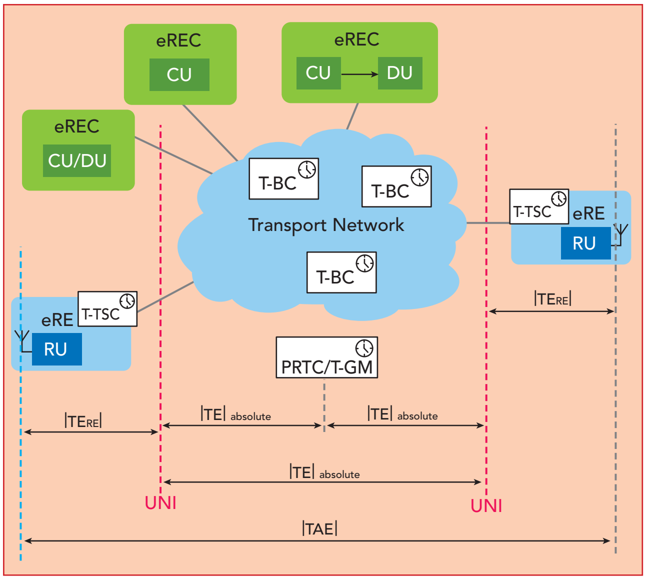

Fig. 4 Various clocks in the synchronization path, illustrating the timing accuracy requirements shown in the tables.

TABLE 2

ECPRI TIME ERROR REQUIREMENTS[1]

Category	3GPP Feature	Case	TE at UNI (|TE|Relative or |TE|Absolute)	3GPP TAE at Antenna
A+	MIMO or Tx Diversity (LTE and NR)	• T-TSC is not integrated in eRE • T-TSC provided by 1PPS or similar interface	20 ns (relative)	65 ns
A	Intra-Band Contiguous CA (LTE, NR BS Type 2)	• Enhanced Integrated T-TSC (TEabs = 15 ns) • Link Delay Asymmetry Included	60 ns (relative)	130 ns
		• T-TSC Not Integrated in eRE • T-TSC Provided by 1PPS or Similar Interface	70 ns (relative)	
B	• Intra-Band Non-Contiguous CA (LTE) • Inter-band CA (LTE)	• Integrated T-TSC with Defined Error and Noise Requirements (T-TSC Class B) • Link Delay Asymmetry Included	100 ns (relative)	260 ns
		• Enhanced Integrated T-TSC (TEabs = 15 ns) • Link Delay Asymmetry Included	190 ns (relative)	
		• T-TSC Not Integrated in eRE • T-TSC Provided by 1PPS or Similar Interface	200 ns (relative)	
C	• Intra-Band Non-Contiguous CA (NR) • Inter-Band CA (NR) • TDD (LTE + NR) • Dual Connectivity (LTE + NR) • CoMP (LTE + NR)	• Integrated or Separate T-TSC	1100 ns (absolute)	3 µs

Absolute time error ($|TE|_{absolute}$) is the difference in time between the primary reference time clock (PRTC) and the local clock (see ***Figure 4***). Relative time error ($|TE|_{relative}$) is the difference in time between UNIs of a local cluster, which can be as low as 20 ns to adequately provide the time alignment error (TAE), or time error between transmitter antenna ports as required by 3GPP (see ***Table 2***).[2] Ethernet- or IP-based transport network synchronization can be accomplished via several standard protocols, such as synchronous Ethernet (SyncE) or precision time protocol (PTP), so long as the timing accuracy between UNIs is met.

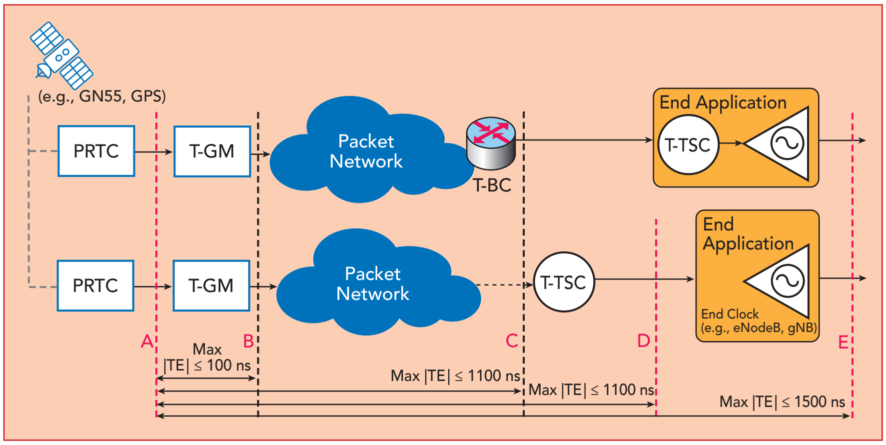

Fig. 5 Time synchronization with maximum absolute time error per ITU-T G.8271.1/Y.1366.1.[3]

Network Synchronization Chain

Depending on the architecture of a wireless network, there are generally three main clocks for time synchronization of packet-based time and phase synchronization methods (i.e., NTP, PTP, SyncE standards): the PRTC, the packet master clock and the packet slave clock. The synchronization chain synchronizes the highly stable master clock with the slave clocks down the line. The ITU defined PTP telecom profile renames these clocks as the PRTC, the Telecom Grand Master Clock (T-GM), the Telecom Boundary Clock (T-BC), the Telecom Transparent Clock (T-TC) and the Telecom Time Slave Clock (T-TSC). Timing support is typically accomplished in intermediate nodes (e.g., switches and routers) through the T-BC. As shown in Table 2, the T-TSC can either be integrated into the end application (e.g., the eRE or RRU) or be external, delivering a phase/time reference to the end application via a synchronization distribution interface (e.g., 1PPS or ToD) as shown in ***Figure 5***. Timing requirements are much tighter where the PTP termination is at the UNI, or when the T-TSC is separate from the end application clocks. The maximum TE at the UNI listed for category C is the same as the maximum TE at reference point C or D. This is to meet the 5G TDD requirement of 1.5 µs E2E latency. Requirements become tighter with cooperative radio techniques where the maximum relative TE requirements exist within a cluster, when multiple RRUs are connected to the same DU.

WHAT THIS MEANS FOR OSCILLATORS

In the ITU-T G.8271.1/Y.1366.1 report,[3] the network limits up to reference point C (see Figure 4) involve two types of noise generation from the PRTC, T-GM, T-BC or T-TC, which are constant and dynamic in nature. Noise generation is expressed in terms of TE, where the constant TE (cTE) is produced by the chain, and the dynamic TE (dTE) is attributed to the low and high frequency noise components of the chain. The low frequency dTE components, defined as below 0.1 Hz, can be measured with maximum time interval error


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(MTIE) and time deviation, while the high frequency dTE components, which are above 0.1 Hz, can be measured with peak-to-peak TE.

The master-slave synchronization chain relies upon the PRTC, the timing from the protocol itself and the holdover clock, which is meant to maintain phase/time information when the T-BC loses its input phase and time references. The holdover clock can consist of either a stable internal local oscillator (LO) or receive an assist from a primary reference clock traceable signal. Wander generation, or the slight differences in clock signals in a network over time, occurs intrinsically with white and flicker frequency modulation, as well as extrinsically through random walk frequency modulation from aging, power supply variations, temperature, vibration/shock and frequency drift during a switchover period to a holdover mode. Meeting the holdover requirements for the various classes of T-TSC and T-BCs in ITU-T G.8273.2 is necessary to ensure overall TAE requirements.

Oscillator Constraints for Local Clusters

Phase noise and MTIE requirements beyond reference point C (see Figure 4) are also vitally important to maintain timing within a local cluster of RRUs. The various 5G radio techniques rely on clean and stable RF sources with tight individual phase noise requirements over the cluster. Some of these radio techniques and their respective effects on oscillators are discussed below and summarized in ***Table 3***.

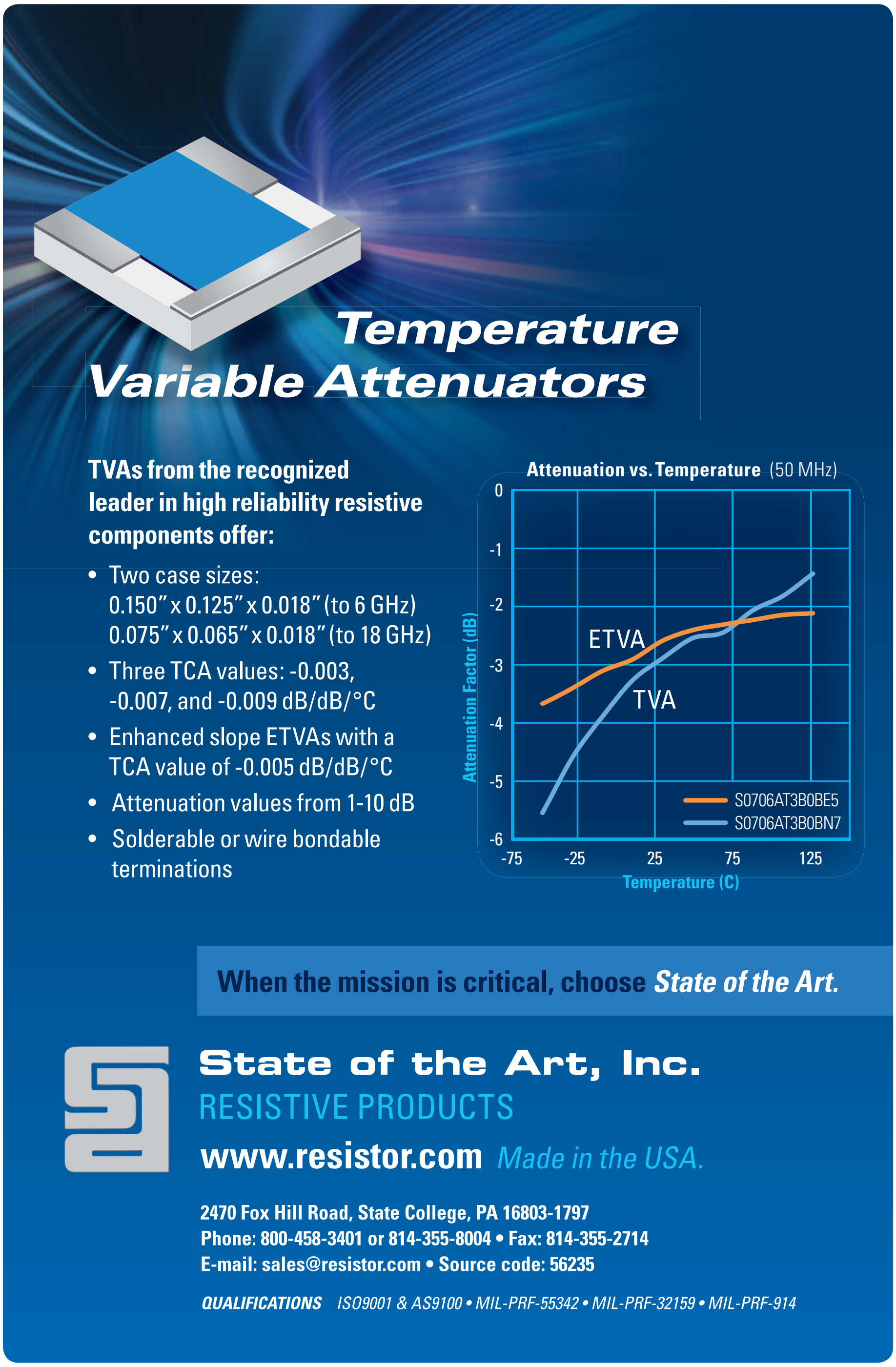
MIMO Systems — Phase noise is known to negatively impact channel state information (CSI)—information on the propagation path for a signal from transmitter to receiver, including scattering, fading and power decay parameters—and cause channel aging for multi-user (MU) MIMO systems. CSI is especially important for systems relying on linear precoders to mitigate the effects of MU interference. Any difference between the estimated CSI and the real transmit path (e.g., from channel aging) is detrimental to system performance. Phase noise can cause a time-varying and random phase difference between the oscillators at the base station and the user equipment, with unpredictable rotations of the transmitted data symbols. This will invariably affect future installations of mMIMO with synchronous or asynchronous frequency generation, where there may be motivation to use low-cost local oscillators.

TABLE 3
5G OSCILLATOR REQUIREMENTS

Technology	Oscillator Impact
MIMO	Phase noise degrades channel aging, impacting linear precoding and ultimately performance.
High Order QAM	Requires low jitter to meet QAM noise requirements.
mmWave	May require reference oscillators at higher frequencies.

High Level QAM Systems — Orthogonal frequency division multiplexing (OFDM) enables similar data rates and bandwidth compared to single-carrier modulation schemes, while offering more immunity to severe channel conditions. Often, OFDM systems use a high order quadrature amplitude modulation (QAM) for each subcarrier. Next-generation cellular installations continuously expand the symbol set to increase bandwidth efficiency. This increase in constellation size and, subsequently, decision points becomes more sensitive to the effects of forward path impairments such as phase noise, which often manifest as slight shifts in the position of the constellation points. Ultimately, poor phase noise performance of the LO impairs the signal bit error rate (BER).

5G mmWave Systems — Small cells relying on non-line-of-sight or line-of-sight microwave backhaul have particularly difficult synchronization problems due to the nature of packet timing. These problems are exacerbated using mmWave signals, as more small cells are needed to adequately cover an area. This, in turn, tightens the latency and synchronization requirements because of the increasing number of intermediate nodes for backhaul. Phase noise also generally increases with carrier frequency; for example, frequency multiplication increases the phase noise, and high frequency crystals have lower Q. This adds another layer of complexity to the already complex latency and synchronization needs of 5G.



CONCLUSION

Network timing and noise sources are major considerations with 5G installations, as the transport network and air interface must work in tandem for reliable latency and synchronization. The intrinsic and extrinsic wander and jitter of RF sources in the timing chain require serious consideration. Aside from latency, phase noise may directly affect the BER of a wireless installation and degrade its reliability. Using cost-effective sources, stable over temperature and vibration, is essential to the performance of the 5G air interface and xhaul. In some cases, a phase-locked loop may be necessary to stabilize the phase noise, although with the penalty of cost and complexity. Stable oscillators and frequency synthesizers for commercially viable mmWave communications add another level of complexity to meet the needs of 5G.■

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INVITED PAPER

Interactive Radar Sensors for a Holistic Cabin Experience

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Infineon Technologies AG, Munich, Germany

New sensor technologies facilitate innovation in driver assistance systems, vehicle automation, vehicle connectivity and mobility services. With higher levels of driver automation, exterior assistance systems are enhanced by the reshaping of interior systems to provide a holistic driving experience. In this article, we outline how short range radar sensors enable several vehicle in-cabin sensing applications, namely driver monitoring systems and occupancy monitoring systems.

Human-machine interface (HMI) is becoming a domain where automotive manufacturers seek to differentiate. Dating back to 2015, automotive HMI began with simple gesture sensing using IR cameras and MEMS haptic feedback systems. Today we see it trending toward completely personalized, elongated and digital displays such as Byton's M-Byte 48 inch co-driver display and Daimler's MBUX. Such automotive clusters will revolutionize human-vehicle interaction.

Sensor advancements in miniaturization, in-dashboard processing, power efficiency and ease-of-integration are enabling newer and sophisticated technologies like radar and time-of-flight sensors. In addition, sensor fusion concepts foretell the future, e.g., combining voice with gesture for robust intended action prediction, illuminating display buttons as a user reaches and differentiating between driver and passenger inputs. The information needed, aesthetic design, environmental factors and cost of computation will define the technology for a specific use case. There are numerous use cases including, but not limited to, comfort applications like gesture sensing and passive safety applications.

According to the World Health Organization, about 1.3 million people die in road accidents almost every year,[1] and 73 percent of these accidents are attributed to human error. Per National Highway Traffic Safety Administration statistics, more than 50 children die annually due to hyperthermia after being left in a car.[2] Steps have been taken to introduce child presence detection and driver monitoring systems by Euro and Asean New Car Acceptance Programs. The Alliance of Automobile Manufacturers signed a voluntary agreement in Sept. 2019 for rear seat reminder systems,[3] while seat belt reminder and restraint systems functional criteria for the EU, Japan and others are extensively described by United Nations Economic Commission for Europe Regulation 16.[4] Hence, driven by regulation or legislation, innovative in-cabin passive safety applications are making a difference for safety on the road.

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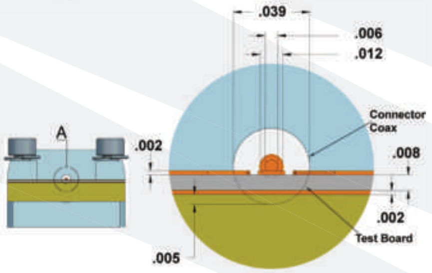
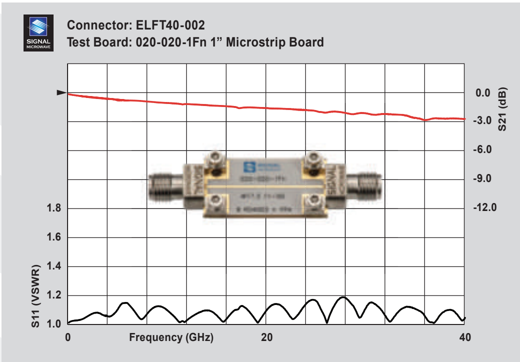


DETAIL A; 8 mil Test Boards and Connector Cross Section



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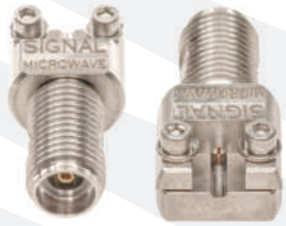

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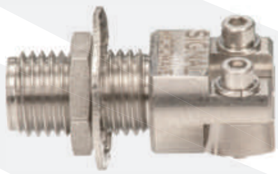

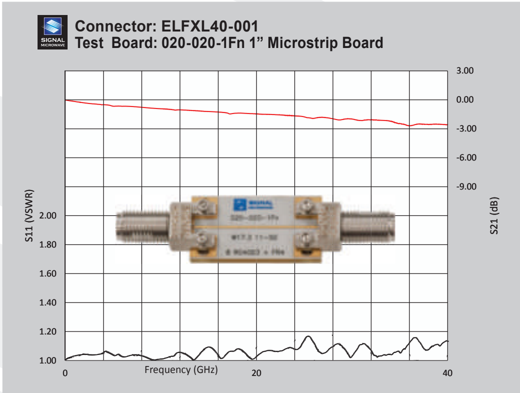

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RADAR PROCESSING – A NEW TRANSFORMATION

Radio detection and ranging (radar) works via electromagnetic radiation where a high frequency waveform travels through space, interacts with an object and returns an echo or reflected signal back to its source. Most of the information about the object is encoded in the phase and frequency of this received signal. Basic parameters like range, angle and velocity to localize the object can be easily extracted. Further information can be obtained by 2- and 3-dimensional signal transformations such as range-Doppler or micro-Doppler to provide minuscule body motion or even chest movements due to heart and breath rate (see ***Figure 1***). For classification, radar point cloud can also be leveraged.

The ability of radar to aesthetically sense objects agnostic to lighting conditions, maintain data privacy through inherently encoded information and operate in both line-of-sight and non-line-of-sight conditions are some of its unique advantages. Its application, however, depends on the specific use case. Some examples are discussed.

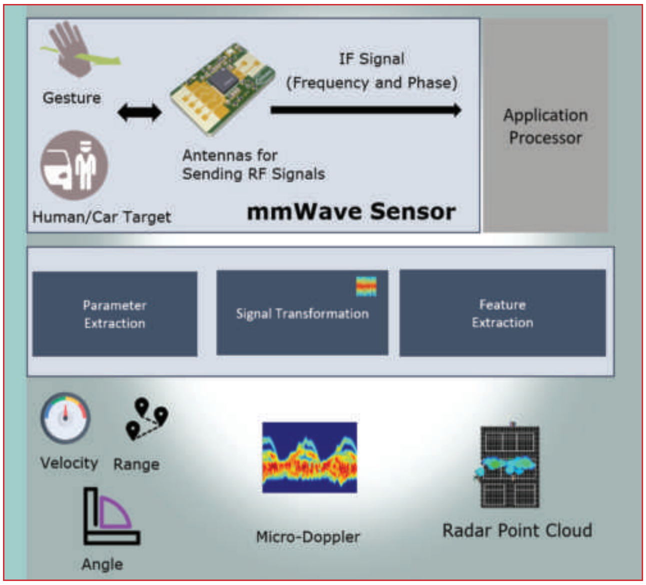
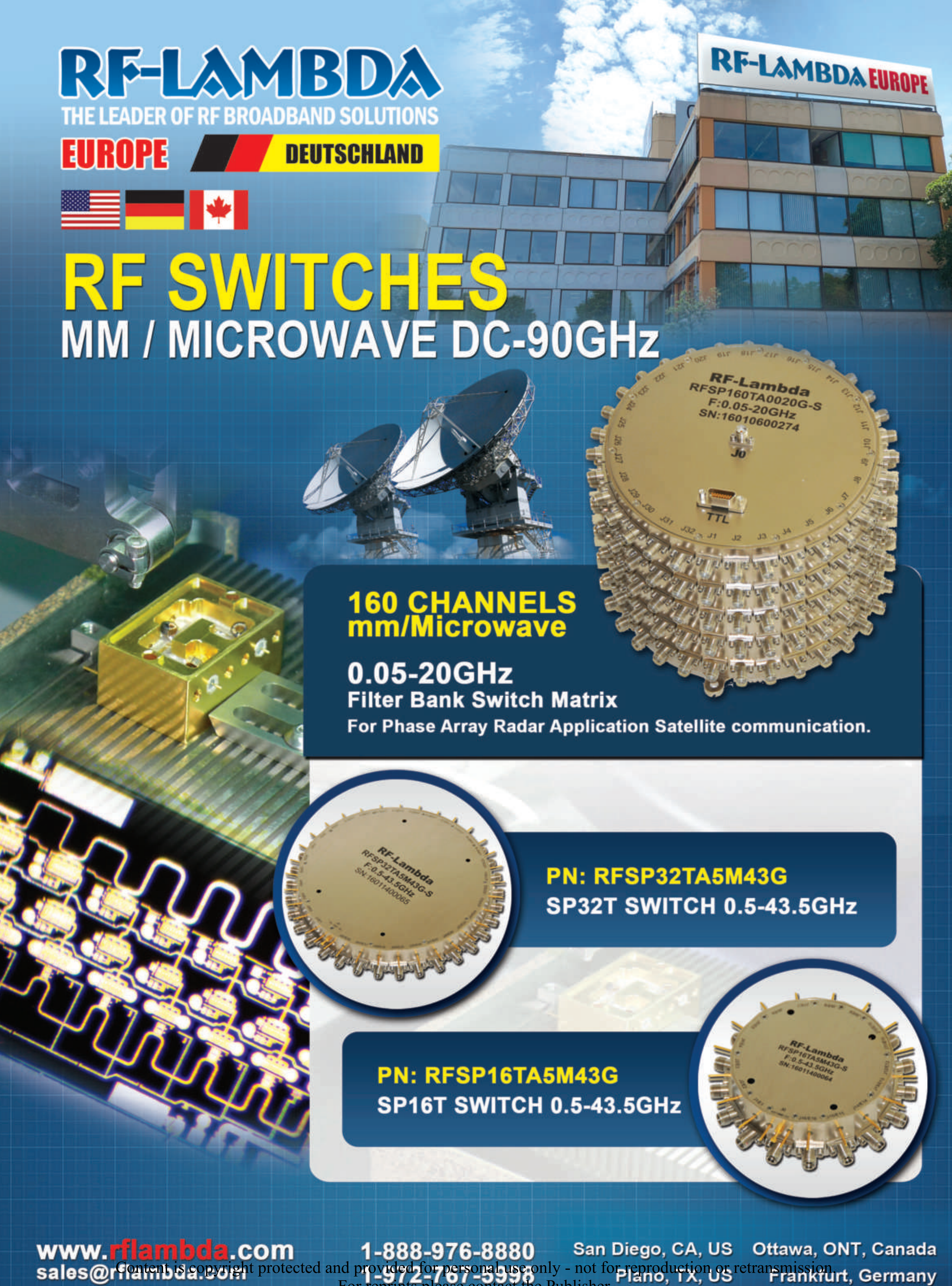


Fig. 1 Radar signal processing blocks.

TABLE 1

BENEFITS OF RADAR FOR DRIVER MONITORING AND ACTUATION

Use Case	Sensor Type	Radar Benefits	Actuation Examples
Driver Presence	• Radar • Ultrasound • Weight	Robust Detection: Micro-Motion of Body	• Seat Adjustment • Infotainment and Sound Adjustment
Identification and Authentication: Facial, Fingerprint Recognition	• Facial: 2D Camera, Time-of-Flight (ToF) Sensor • Fingerprint: Radar, Optical	In Fusion Systems: Radar Activates ToF or 2D Camera Systems (Power Optimized) and Acts as Secondary Authentication Sensor for Fingerprint[5]	• Multi-Layer Authentication for Theft Prevention • Personalization of Dashboard Mirrors, Seat Functions
Drowsiness or Inattention: Iris Tracking, Head/ Body Position	• 2D Cameras • ToF		• Automatic Seat, Side Mirror, Rear Mirror Adjustment and Personalization • Speed Recommendation • Dashboard Warning • e-call System
Stress Level or Physiological Fitness to Drive: Vital Sign Recognition	• Radar • RGB Camera with Thermal Imager	Radar Offers Smaller and Cost-Effective Module for Vital Sign Monitoring Fusion with ToF or Camera for Holistic Driver Monitoring	• e-call System • Air Conditioning • Recommendations on Dashboard for Nearby Stops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Driver Monitoring Systems

The current state-of-the-art sensor technologies for driver monitoring systems are 2D cameras. These are generally installed directly in front of the driver on the steering wheel or instrument panel close to the speedometer and tachometer. A multi-sensor approach for level 2 autonomy and higher may be required where a holistic physiological understanding of a driver's wellbeing is important, for example, in a traffic jam assist scenario. ***Table 1*** summarizes some approaches for different use cases.

The standard radar vital sign signal processing pipeline involves a radar interferometry technique to monitor the phase of the detected target over time.[6, 7] Following a range fast Fourier transform (FFT), potential targets are selected either through a conventional 1D CFAR technique followed by a peak search on the range spectrum or by using a peak-to-average power ratio (PAPR) metric, i.e. ratio of peak-to-average power across the slow time of each potential target range bin. For a stationary target, the peak FFT value is close to the average/mean of the FFT spectrum along the slow time; where in the case of a vibrating source, such as a beating heart or breathing, the average/mean value is low, resulting in a high PAPR.

Following target range bin preselection, a vital sign Doppler detection is performed by either estimating the standard deviation of the IQ data across slow time and checking if it lies within a prescribed value or using a spectral metric if there are no energy peaks within the vital sign frequencies (0.2 to 3.3 Hz). Doppler detection is an important step before passing the signal through bandpass filters to eliminate static target bins since white noise will lead to validating an incorrect signal.

After vital sign detection, IQ data for the range bins that pass the above criteria is fitted with an ellipse reconstruction algorithm to compensate for offset, phase and amplitude imbalances due to hardware imperfections. Ellipse reconstruction helps to remove these amplitude and phase offsets by mapping the ellipse onto a unit circle.[8] ***Figure 2*** is the output of the ellipse reconstruction algorithm for the case of a high quality vital sign target (see Figure 2a) and the case where random body movement perturbs the reconstructed IQ signal (see Figure 2b).[9]

The resulting signal phase is then passed through a phase unwrapping block to reconstruct the original true phase of the wave from its multiples of 2π values. This is done by adding or subtracting 2π for phase jumps larger than $-\pi$ or $+\pi$, respectively. The unwrapped phase contains the displacement signal:

$$\Delta d(t) = \lambda / 4\pi \, \text{unwrap}(\phi(t)) \qquad (1)$$

where λ is the carrier wavelength and $\phi(t)$ is the extracted phase over slow time.

The resultant displacement signal contains the superposition of both the breathing signal and the heart rate signal. The displacement signal is passed through bandpass filters, with start and stop frequencies of 0.2 Hz and 0.4 Hz, respectively, for breathing rate estimation and 0.8 Hz and 3 Hz for heart rate estimation.[10] There are several approaches for breathing/heart rate estimation, for example:

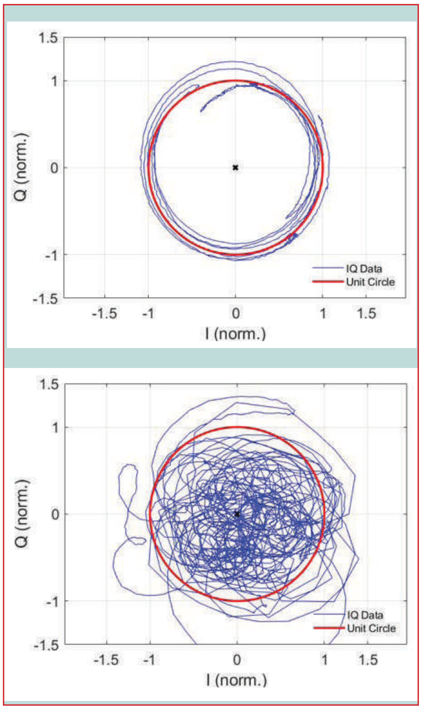

Fig. 2 Normalized I/Q plots vs. unit circle, showing high quality vital sign data (a) and data corrupted by random body movement (b).

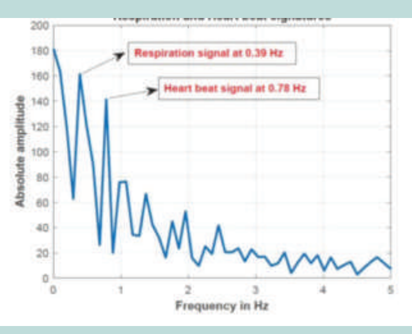

Fig. 3 Breathing and heart rate estimation using FFT spectral analysis.

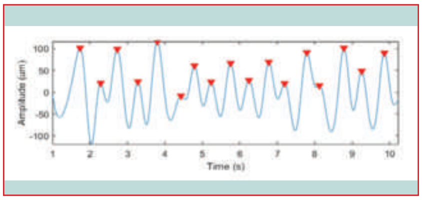

Fig. 4 Heart-rate estimation using peak counting on the filtered time-domain heart signal.

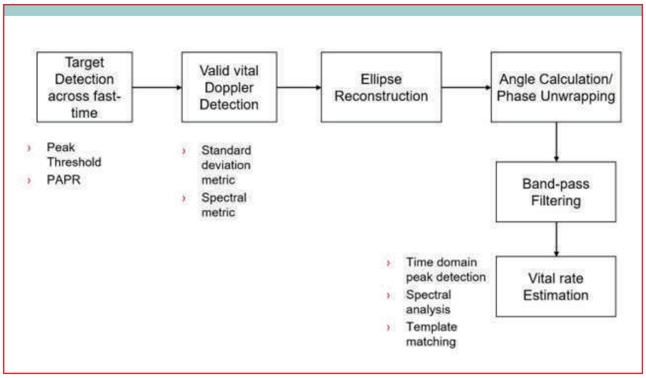

Fig. 5 Processing pipeline for vital signal extraction and estimation using FMCW radar.

1. Spectral estimation techniques use the FFT of the filtered displacement signal. The peaks in the FFT spectrum within the heart rate frequency and breathing rate frequency provide estimates for heart rate and breathing rate respectively. ***Figure 3*** illustrates vital-rate estimation using the spectral analysis approach.
2. Counting the peaks in the filtered time domain displacement signal provides an estimate of breathing and heart rate. ***Figure 4*** shows an estimate of a vital signal frequency through peak counting of filtered time domain data. Red triangles indicate the peaks detected in a window of the heart signal.

Figure 5 summarizes the overall processing pipeline to extract and estimate vital sign signal rate through state-of-the-art signal processing.

Occupancy Monitoring Systems

The concept of occupancy monitoring is relatively new compared to driver monitoring. The information from occupancy monitoring can be used for turning on seat heating, seat belt alarm detection, smart airbag deployment, left behind life warnings and automated air conditioning systems as outlined in ***Table 2***. Occupancy monitoring systems may need to be active for some time after the ignition is turned off and hence overall system power consumption may be an important consideration.

The use of radar for child presence and localization presents challenges. It requires multiple detections per object but radar point cloud data is sparse as compared to time-of-flight or camera data. ***Figure 6*** shows the 3D radar point detection and classification processing pipeline for rear occupant analysis. Range processing is the first step, where fast time data is transformed into range bins with a 1D FFT. A windowing function is applied to the fast time data and then optionally zero-padded:

$$R_i^n = \sum_{l=0}^{N_s} r(l)w(l)\exp\left(-j\frac{2\pi l n}{Z}\right), 0 < n < Z, \qquad (2)$$

where Z is the fast time zero-padding, N_s is the number of analog-to-digital converter samples along fast time, r(l) and w(l) are the sample values and window functions, respectively, and R_i^n denotes the range spectrum value at the i^{th} chirp and n^{th} range bin.

The fast time FFT along all the chirps is followed by slow time filtering to remove static targets and targets with velocity more than 5 Hz

TABLE 2 OCCUPANCY MONITORING			
Use Case	*Sensor*	*Radar Benefits*	*Actuation Examples*
Occupant Detection on Each Seat or Row: Presence with Localization, Distinguishing Life from Lifeless	• Radar • Ultrasound • Weight • Camera • ToF	• Macro and Micro Motion for Robust Detection, with Angle, Range for Localization • Low power Consumption with Ignition Off • Resolves Occupant Occlusion Better due to Material Penetration • Vital Sign Monitoring • Can Detect Life Hiding Between Seats	• Warning • e-call • Smartphone Alert • Airbag Adjustment • Personalization of Seats • Air Conditioning Control
Classification: Distinguish Adults, Children on Each Seat	• 2D Camera • ToF • Radar	If Extremely Minute Details of Body Contour Not Needed, Radar Can Classify from Point Cloud	

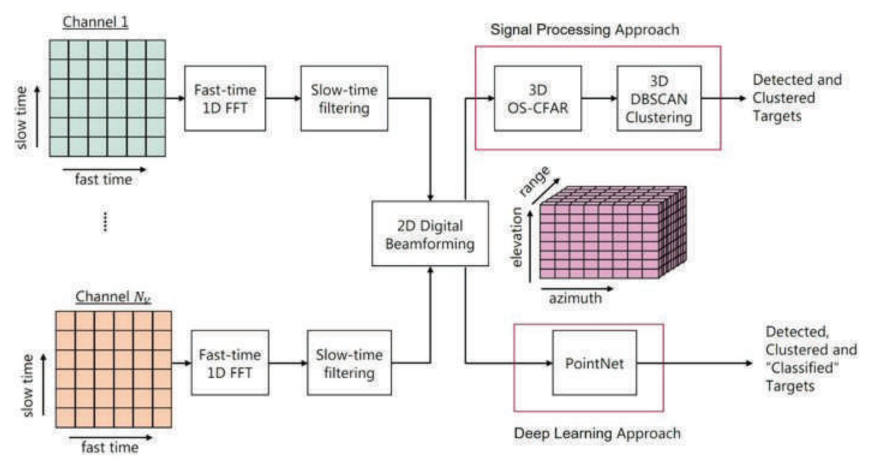

Fig. 6 **Processing for range, elevation and azimuth followed by two signal processing paths for detection, clustering and classification of 3D point cloud data.**

to detect the vital sign signal of the human target. The $N_{tx} \times N_{rx}$ range spectrums are stacked into a matrix along elevation ϕ and azimuth θ as per the position of the virtual antennas. The effective array factor matrix $w(\theta,\phi)$ is calculated as the Kronecker product of the steering vector of the Tx array $a_{Tx}(\theta,\phi)$ and the steering vector of the Rx array $a_{Rx}(\theta,\phi)$ and used to calculate the target angles $\{\theta_t,\phi_t\}^T_{t=1}$ for all range bins. The angle profiles for each range bin along θ and ϕ are generated through either Capon beamformer or maximal likelihood estimation.[11]

After 3D radar point cloud generation, either of two processing approaches might be employed. One involves using 3D ordered statistic constant false rate (3D OS-CFAR) detection followed by 3D density-based spatial clustering (DBSCAN) on a 3D radar data voxel for detection and clustering of the target data points as individual human targets. Alternately, the problem can be addressed by using a deep learning approach using the Doppler velocity and radar cross section values feeding into a PointNet architecture, a neural network that can perform 3D object detection instance segmentation. Compared to the signal processing approach, PointNet[12] enables not only 3D bounding box estimation, but also classification of the detected-clustered

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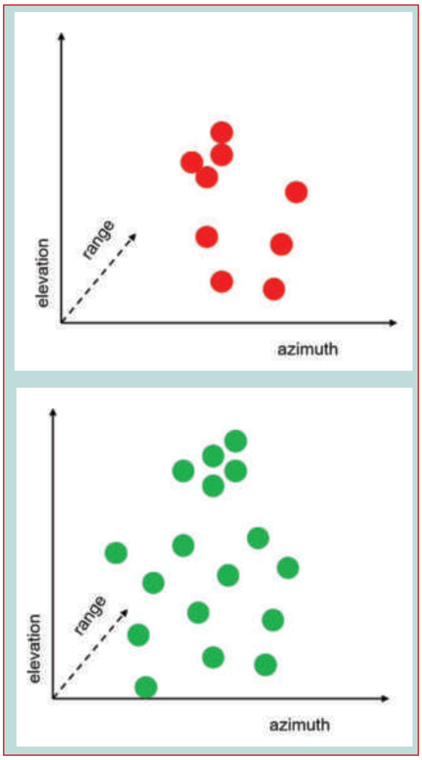

Fig. 7 **Point cloud spread of a sensed child (a) and an adult (b) in a vehicle.**

target as an adult or child. ***Figure 7*** shows the point cloud difference between a child and an adult, which must be determined for child left behind sensing and smart airbag deployment.

Given radar point clouds from the 2D Capon algorithm, the objective of the 3D deep neural network, is to classify and segment objects in 3D space. The radar point cloud is represented as a set of three-dimensional points:

$$p_k = (r_k, \theta_k, \phi_k); = 1, 2, \ldots, K, \qquad (3)$$

where K are the number of detected target points.

For the classification task, the objective is to distinguish between child, adult, luggage or empty. To ensure invariance under geometric transformation, i.e. point clouds rotation should not alter the classification or segmentation results, a transformation T-Net is applied to transform the input feature vectors into transformed feature vectors. This operation is illustrated in ***Figure 8a*** where n points with k dimension are applied through T-Net learning transform parameters, k × k, which can be applied through matrix multiplication on the input

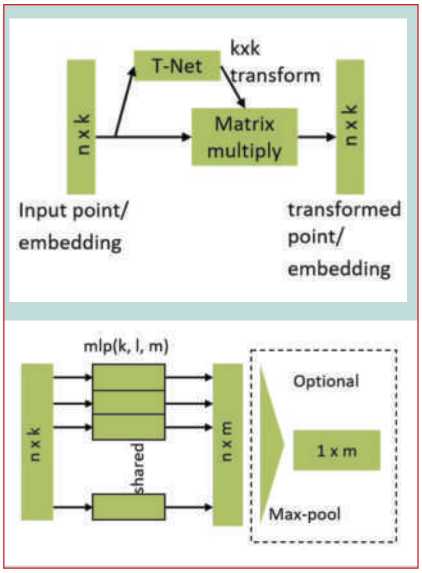

Fig. 8 **T-Net feature transformation in PointNet (a) and vanilla PointNet (b).**

feature vectors, resulting in output/transformed feature vectors, n_k. The vanilla PointNet then tries to approximate the Hausdorff continuous symmetric function by using a multi-layer perception (MLP) and max pooling operation (see ***Figure 8b***). A series combination of T-Net and vanilla PointNets are required to implement the DeepNet that can detect, classify and segment 3D point clouds for child sensing.

The transformation function at the input makes the input data points invariant to geometric transformations, while at the intermediate layers, the input embedding vectors are invariant to geometric transformations. The network architecture contains both the classification network and the segmentation network. The segmentation network marks each pixel with the class it belongs to and it takes input from local and global features followed by the sequence of vanilla PointNets.

FREQUENCY REGULATIONS FOR IN-CABIN RADAR SYSTEMS IN USA AND EUROPE

Because radar in-cabin applications are novel, the automotive community is constantly discussing the best-suited frequency spectrum. ***Table 3*** is an excerpt of ongoing regulatory activities mostly driven by system platform providers. These are subject to change based on day-to-day regulatory committee decisions.

TABLE 3
REGULATORY OVERSIGHT OF RADAR IN-CABIN SENSING
(Green: Allowed; Yellow: Ongoing; Red: Not Allowed)

Body	24 GHz ISM	60 GHz ISM	60 GHz UWB	71–81 GHz
FCC (U.S.)	FCC Part 15.249 Non-Specific SRD; FCC-Part 15.245 FDS	Interactive Motion Sensing Application, FCC 15:255		Equipment Authorization Guidance for 76 to 81 GHz Radar Devices, KDB, FCC, April 12, 2019
ETSI (Europe)	EN 300 440	EN 305 550		Decision by ETSI ERM TG SRR to Stop WI for TR 103 649 Surveillance Radars Inside Ground-Based Vehicles

CONCLUSION

In-cabin sensing is an emerging market, which is expected to see a potential boost due to regulations and legislations world-wide. Radar is seen as one of the promising technologies to address more than passive safety applications like left behind child detection and occupancy sensing. Novel signal processing and deep learning techniques will take these applications to the next level of robustness providing an ideal compromise between computational cost, degree of information needed for specific use cases and system power consumption. In the future, a multi-sensor fusion approach is expected to enable more robust systems by offering sensor redundancy.■

ACKNOWLEDGMENT

Portions of the algorithm sections and figures are taken with permission from "Emerging Deep Learning Applications of Short-Range Radars," published by Artech House. Web: https://us.artechhouse.com/Emerging-Deep-Learning-Applications-of-Short-Range-Radars-P2145.aspx.

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Improving Stability and Accuracy of High Frequency VNA Measurements Over Distance

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Anritsu, Morgan Hill, Calif.

A key aspect of microwave vector network analyzer (VNA) testing is minimizing the measurement effect of the interface to a device under test (DUT). Using high stability, low insertion loss test port cables and applying techniques like reference plane extension and fixture de-embedding, VNA users have been very successful for years in minimizing the effect of the path from the VNA port to the DUT for typical microwave and mmWave S-parameter measurements. These techniques are less successful with longer distances or larger DUTs and at high frequencies, as cable insertion loss and instability grow significantly, making it more difficult to compensate for the path using typical bench VNA techniques.

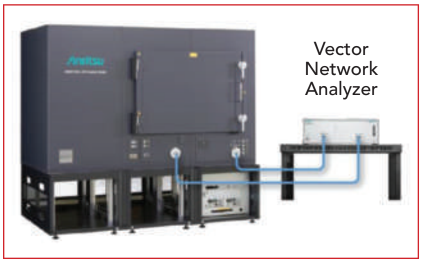

Fig. 1 **Antenna chamber with external VNA.**

HANDLING LONG DISTANCES

Long cable runs between the VNA port and the DUT occur in applications like over-the-air (OTA) testing in indoor chambers and outdoor ranges, as well as measuring the RF/microwave characteristics of large vehicles, like ships and aircraft. A key issue in these applications is the insertion loss of the cable at microwave frequencies reducing the dynamic range of the VNA measurements.

Take, for example, a 5G antenna operating in one of the mmWave bands (i.e., FR2), measured in a typical test chamber (see ***Figure 1***). At 40 GHz, expensive, quality coax cabling has approximately 4 dB/m insertion loss. For a moderately sized antenna test chamber, 2.2 × 1.98 × 1.2 m, several meters of cable are needed to connect the external VNA to both the antenna under test (AUT) and the feed antenna inside the chamber. Assuming a moderate distance of 5 m between each VNA port and the antennas inside the chamber, the cables will add about 40 dB of loss to a transmission measurement, significantly reducing the effective dynamic range of the measurement.

Far-Field Measurements

Many OTA antenna measurements done at far-field distances—where the outgoing wave front from the antenna is essentially planar—significantly increase the size of the


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chamber and the cable length between the VNA and AUT. Antenna measurements are made in the far-field to simulate the transmission conditions at the normal operating distance from the antenna. The Fraunhofer equation is used to calculate where the far-field region begins for a given antenna:

$$d = \frac{2D^2}{\lambda} \quad (1)$$

where D is the largest dimension of the antenna and λ is the wavelength. For a 40 GHz antenna with an approximate diameter of 6 cm, the far-field distance starts at 1 m. Considering an antenna with d = 15 cm, which is about the length of a smartphone, the far-field distance is approximately 6 m at 40 GHz. As the antenna size increases, far-field measurements will require chamber sizes to grow rapidly, increasing the effects of cable insertion loss on OTA testing.

One way to attain the far-field distance while minimizing the size of the chamber is placing a reflector in the chamber, which increases the effective transmission distance within a given volume (see ***Figure 2***). Compact antenna test ranges (CATR) use a reflector to minimize the chamber's dimensions for a given test distance, which reduces cable lengths and insertion loss. While using the reflector does reduce the size of CATRs, it limits the size of the DUT the chamber can test. The region where a reflector can maintain the plane wave, or focus area, bounds the size of the DUT that can be tested (see Figure 2b). As the size of the DUT increases, the reflector must grow significantly to widen the focus area, diminishing any volume reduction gained by using reflectors.

Down-Conversion

Another strategy to reduce cable insertion loss is down-converting the mmWave signal to a lower frequency before transmitting it through the long interface cables (see ***Figure 3***). In this setup, a signal generator is placed physically close to the transmit antenna, to minimize cable length and insertion loss. The AUT and a reference antenna, if needed, receive the test signal, which is down-converted with mixers, along with the local oscillator (LO) and IF distribution hardware. The lower frequency IF signal has less insertion loss from the cable run to the VNA. For long distances, this will significantly reduce the insertion loss: the same cable with 4 dB/m loss at 40 GHz may only have 1 dB/m loss at 4 GHz.

While this approach reduces the loss of the received signal from the VNA, the cable carrying the LO signal to drive the mixer will still have high insertion loss, because the LO frequency is close to the original microwave test frequency. Subharmonic mixing can be used to lower the LO frequency but this will often reduce the dynamic range of the measurement. Also, the down-conversion approach complicates the hardware setup, as the IF and LO signals must be distributed, and the LO must be amplified to compensate for cable loss, which introduces noise and distortion to the measurement. Another drawback is the complex calibration required to compensate for the effects introduced by down-converting the mmWave test signal to IF. This complexity limits the available calibration and de-embedding techniques and the flexibility of the measurement.

Fiber-Optic Links

For applications where the distances are 100 m or greater—characterizing the shielding and propagation performance of large vehicles, like ships and aircraft (see ***Figure 4***)—using coax cables at microwave and mmWave frequencies is often not practical. One solution for this application is using fiber-optic (FO) cables to connect the VNA with the test antennas in the setup (see ***Figure 5***). At microwave frequencies, FO cables have very low insertion loss, on the order of 0.1 dB/30 m at 850 nm. This low loss enables them to be used over long lengths without significantly affecting the measurement signals. A FO transmitter and receiver are used to convert the RF signal to optical in the transmit path and back to RF in the receive path. As with the down-conversion setup, the FO solution relies on active compo-

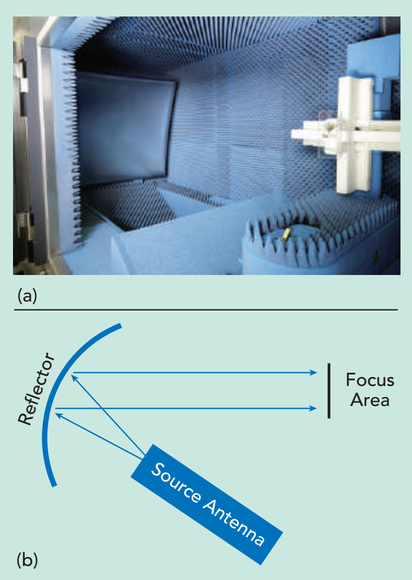

Fig. 2 OTA test chamber using a reflector (a), with the corresponding ray diagram (b).

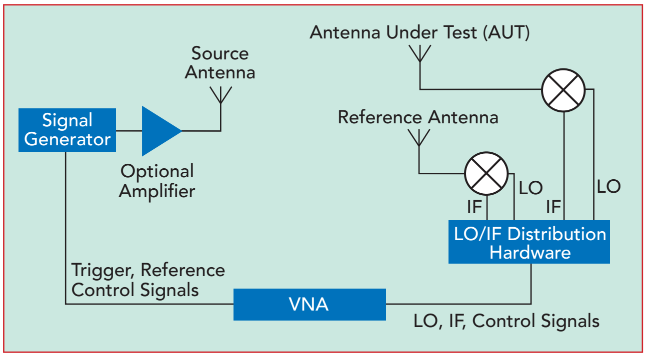

Fig. 3 OTA measurement setup.

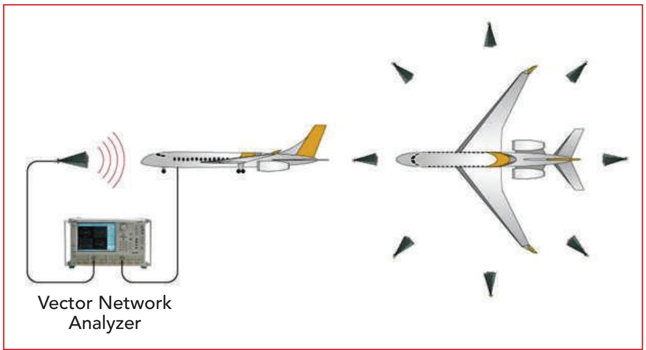

Fig. 4 Large vehicle shielding and propagation testing.

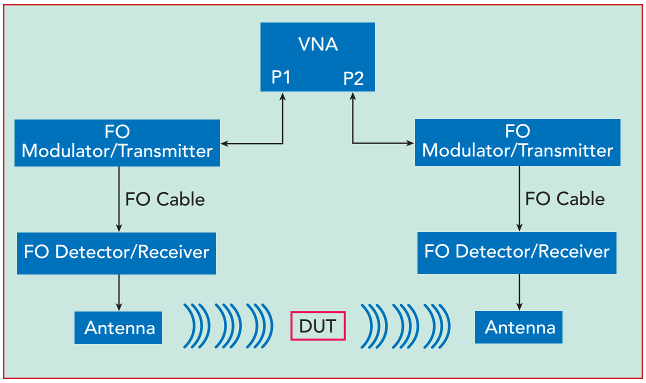

Fig. 5 Test setup using fiber-optic detectors and receivers.

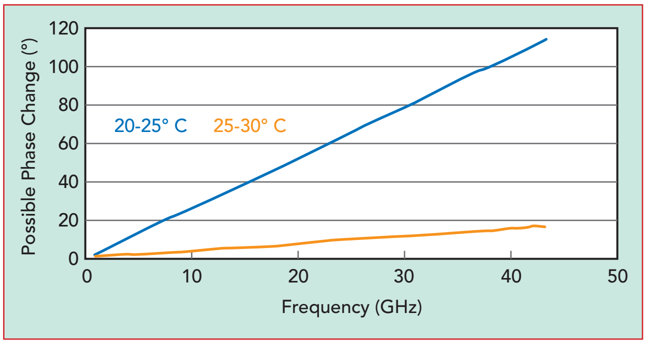

Fig. 6 Phase change of a 4 m cable vs. frequency and temperature.

ponents in the signal path between the DUT and the VNA, which adds complexity and cost. Because electrical-optical (EO) modulation is lossy, the EO to optical-electrical (OE) conversion has poor noise figure, which reduces any dynamic range advantage gained from the lower insertion loss. Also, because the distances are typically very long, the setup can be difficult.

Another issue with VNA measurements over distance is the phase stability of the cable connecting the VNA port and the DUT.

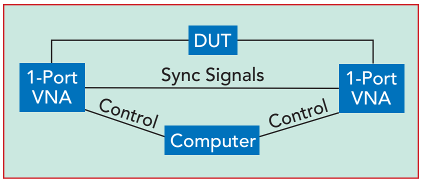

Fig. 7 Modular VNA setup.

Changes in position or ambient temperature can cause small deviations in the electrical length of the cable, enough to produce several degrees of phase shift at microwave frequencies. Limiting movement or temperature change to minimize the phase drift is difficult, especially for long distances outdoors. ***Figure 6*** shows an example of the phase change using a quality, 4 m long cable over two 5°C temperature ranges. Even with these relatively moderate temperature ranges, the phase change is significant. For outdoor applications, where cable lengths are typically longer and the temperature swings larger, the phase change will be even greater.

Restating, the main issue with measuring over long distance is getting the VNA test signal to and from the DUT without significant loss or distortion, which will reduce the accuracy and stability of the measurement.

MODULAR VNA

A novel solution to this is the concept of a modular VNA. Instead of having a single instrument where the ports are co-located in a single chassis, a modular VNA has independent, portable modules placed close to the DUT to minimize the cable lengths to the ports (see ***Figure 7***).

With microwave source and measurement capability in the portable modules, the issue of insertion loss and distortion caused by long coaxial or fiber interconnects is eliminated, improving the stability and accuracy of the measurements. Eliminating active components in the measurement path, such as the EO-OE conversion, improves the noise performance and simplifies calibrating the long distance measurement. The portable ports enable the calibration planes to be essentially at the DUT ports, without intervening hardware and flexible VNA calibration and de-embedding techniques

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DTA-1G18G-60-7-CD-1-HERM https://www.pmi-rf.com/product-details/dta-1g18g-60-7-cd-1-herm	1 - 18	60	20 dB: ±1.0 40 dB: ±1.25 60 dB: ±3.0	On: 1 µs Off: 0.5 µs	5 dB Max, 4.8 dB Typ	7-BIT TTL 2.0" x 2.79" x 0.66" SMA (F)
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DTA-18G40G-50-CD-1 https://www.pmi-rf.com/product-details/dta-18g40g-50-cd-1	18 - 40	50	±1.5	On: 1 µs Off: 0.5 µs	8.5 dB Typ	10-BIT TTL 2.0" x 1.8" x 0.5" 2.92mm (F)
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PVA-500M18G-60-SFF https://www.pmi-rf.com/product-details/pva-500m18g-60-sff-	0.5 - 18	60	0-10 dB: ±1.0 10-20 dB: ±1.5 20-40 dB: ±2.0 40-60 dB: ±2.5	3 µs	4.5 dB Max, 0.5-12 GHz 5.8 dB Max, 12-18 GHz	10 dB / Volt 2.0" x 1.8" x 0.5" SMA (M/F)
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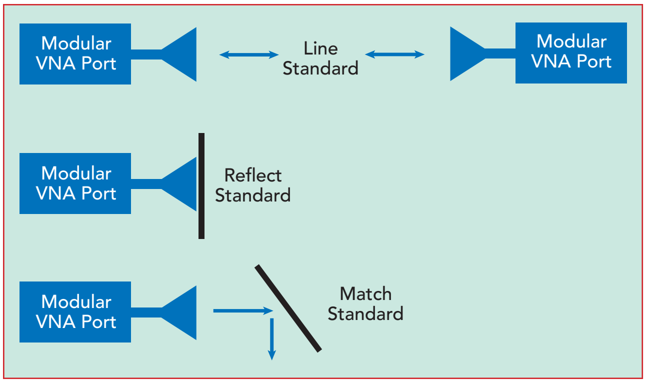

Fig. 8 Calibrating a modular VNA with LRM standards.

can be used, yielding more accurate measurements.

To illustrate the straightforward calibration, consider an OTA setup using horn antennas and calibrating with the line-reflect-match (LRM) technique (see ***Figure 8***). For LRM calibration, the line standard is just the OTA path between the two antennas, and a simple flat sheet of metal will create the reflect and match standards. For the reflect standard, the sheet is placed to completely block the antenna, which reflects the signal power back to the antenna and the VNA. The algorithm does not require precise knowledge of the reflect standard, so the positioning accuracy of the sheet is not as demanding as might be expected. The match standard is formed with the sheet at a 45 degree angle from the boresight of the antenna, so the sheet reflects almost all the signal from the antenna and appears like a perfect match.

While portable, independent VNA ports eliminate the interconnect issues, they do require precise synchronization between the ports to ensure accurate S-parameter measurements (i.e., with magnitude and phase components). Phase synchronization between ports in a VNA where the source/LO synthesizers are separated over long distances is complex. The synchronization must account for source and receiver clocking and triggering in a way that keeps the relative phase stable within a few degrees at the measurement frequencies. This can be difficult to accomplish in a single chassis instrument; to achieve this precision over distances greater than 100 m requires a new design paradigm.

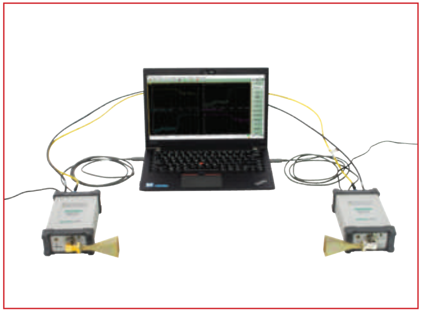

Fig. 9 Distributed 2-port VNA using individual 1-port VNAs.

One example of such a modular VNA architecture is Anritsu's ShockLine™ MS46131A VNA with the PhaseLync™ synchronization option. The MS46131A is a 1-port VNA with an independent source and receiver, frequency coverage to 43.5 GHz and small size to facilitate connecting to antennas and other DUTs. With optional circuitry and cabling, a pair of the PhaseLync VNAs can be synchronized to act as the ports in a distributed 2-port VNA and support measurement setups where the ports are separated by more than 100 m (see ***Figure 9***). The PhaseLync system includes phase compensation to improve measurement stability with mechanical and thermal changes from the environment.

SUMMARY

For VNA applications like far-field antenna and large vehicle shielding and propagation measurements, several methods can address the insertion loss and other negative aspects of long interconnect cables. A modular VNA architecture presents a new alternative for S-parameter measurements by eliminating long cable runs and simplifying the test setup. Bringing the VNA ports to the DUT, the modular architecture enables flexible calibration and de-embedding techniques, which improve measurement stability and accuracy.■

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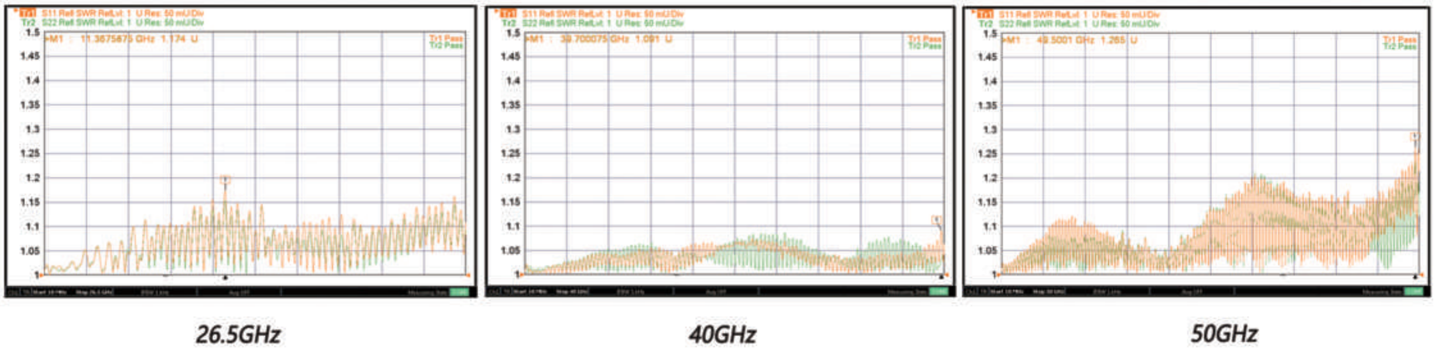

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INVITED PAPER

Understanding and Evaluating the Dynamic Range of Spectrum Analyzers

Holger Schwarz
Narda Safety Test Solutions, Pfullingen, Germany

Thomas Jungmann
Texterei Jungmann, Wangen, Germany

One of the most important aspects in choosing an electronic measurement instrument is dynamic range; however, it is generally not enough to simply compare parameters stated in data sheets. The following discussion explains the relationships among parameters to help understand and evaluate spectrum analyzer dynamic range specifications.

When monitoring mobile phone interference in urban areas (see ***Figure 1***), test engineers are frequently faced with the problem that the interference signals are weak, often below the noise floor of the measuring instrument, such as a spectrum analyzer. In such situations, greater sensitivity is typically achieved by reducing the input attenuation, resolution bandwidth (RBW) and reference levels and by using a preamplifier. In this way, the noise floor of the instrument is lowered to a level where the interference signals are visible. The disadvantage of this approach is that the instrument's immunity to stronger signals in the vicinity is reduced. Strong signals may drive devices in the signal chain to operate in nonlinear regions, generating unwanted artifacts such as harmonics, intermodulation products and interference. Artifacts such as second harmonics, which occur at twice the frequency of the input signals, will appear in the spectral display the same as actual signals in the vicinity, and they can be mistaken for interfering transmitters in the radio network (see ***Figure 2***).

Fig. 1 Identifying weak interfering signals in the presence of high signal levels from nearby transmitters.

DYNAMIC RANGE

High dynamic range enables a high performance test instrument such as a spectrum analyzer to suppress such pseudo signals or keep them as small as possible. Dynamic range is the span where the minimum to maximum strength signals can be detected and measured before unwanted artifacts appear above the noise floor. As a rule, the greater this span or the smaller the amplitude of the artifacts, the higher the dynamic range and the more unlikely the artifacts will be mistaken for real signals. A system design goal is to maximize the intermodulation free dynamic range (IMFDR), where all undesirable intermodulation is below the noise floor. The IMFDR of a measuring instrument is defined as the dynamic range just before the second- or third-order intermodulation products emerge from the noise.

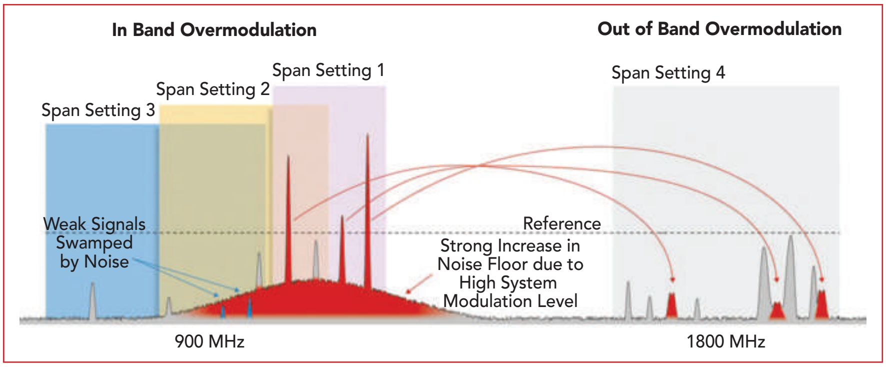

Fig. 2 **Receiver nonlinearity may create spurs that appear as real signals, in this case harmonics around 1,800 MHz.**

The term high dynamic range (HDR) used for spectrum analyzers and radio receivers refers to the ability of the instrument to reliably record small signal levels, such as those from a mobile phone, in the presence of much larger signals. To use an acoustic analogy, this is like a high quality microphone's ability to pick up the fine tones of a flute without significant loss when the flute is played adjacent to an operating jackhammer. This requires a balance between high sensitivity for small level signals and simultaneous immunity to saturation from large signals.

While HDR is important for error-free measurements, spectrum analyzer dynamic range is not a rigid criterion. It can change according to the level of the required signal or signals and the measurement settings of the instrument. For this reason, one must consider at least two types of unwanted artifacts from nonlinearity: harmonics and intermodulation.

Harmonics—Second-order harmonics, for example, occur at twice the frequency of the input signal. Higher-order (i.e., n^{th}-order) harmonics occur at n times the frequency of the input. In contrast with intermodulation, they occur when only a single signal is present, particularly when RF components in the instrument, such as amplifiers and mixers, are driven beyond their linear ranges with increasing power level.

Intermodulation—Intermodulation also occurs when RF components are operated in their nonlinear regions. Unlike harmonics, they are not simple multiples of the individual frequencies, rather the "mixing" of the input frequencies. At least two signals, or tones, are required, which mix together to produce new frequencies. For example, the second-order intermodulation frequencies of the frequencies f_1 and f_2 are $f_1 + f_2$ and $f_2 - f_1$ and the third-order intermodulation frequencies are $2f_1 + f_2$, $2f_2 + f_1$, $2f_1 - f_2$ and $2f_2 - f_1$.

SIGNAL LEVELS

If the level of the input signal changes, the level of the second-order artifacts in dB changes by 2× the magnitude of the input change; the level of the third-order artifacts changes by 3× the magnitude of the input change. If the input signal level changes by 10 dB, for example, the levels of the second-order harmonics and intermodulation products increase by 20 dB, and the third-order artifacts increase by 30 dB.

Considering the dynamic range of an instrument, the input attenuation plays a prominent role determining the so-called intercept points, defined as follows:

- IP2/SOI: the second-order intercept point, based on the intermodulation products.
- IP3/TOI: The third-order intercept point, based on the intermodulation products.
- SHI: The second-order intercept point, based on harmonics.
- THI: The third-order intercept point, based on harmonics.

The values for IP2/SOI, SHI, IP3/TOI and THI automatically change with the input attenuation of the instrument. To accurately and meaningfully compare the data sheet values of various instruments, the

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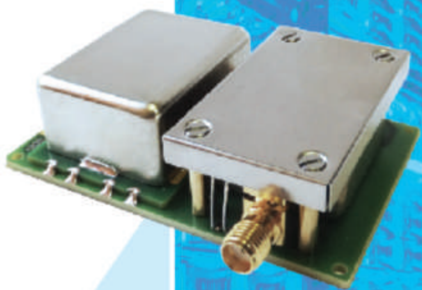
100 Hz	<-160	<-135
1 kHz	<-165	<-160
10 kHz	<-170	<-175
100 kHz	<-170	<-180



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specified dynamic range or the corresponding parameters for immunity and sensitivity should be based on the same system settings. Typically, the intercept points are specified with an input attenuation of 0 dB. In all other cases, the values for IP2/SOI, SHI, IP3/TOI and THI must be reduced by the attenuation for the values to be compared.

INTERCEPT POINTS

The output power at the input signal frequency and its harmonics are linearly related to the input power until the components in the signal chain near saturation. If the linear relationships are extrapolated as the input power increases, the output signal level will intersect the level of the unwanted artifacts. For third-order intermodulation, the level difference and the dynamic range between the third-order products and the target signal is 0 dB. This intersection of the target signal and the third-order intermodulation signal is called the TOI or IP3 value, i.e., the intercept point of the third-order intermodulation products or the third-order intercept point. This value indicates the theoretical level where the signals are equal.

The other intercept points are defined similarly, i.e., IP2/SOI, SHI and THI. SHI is an informative indicator of an instrument's dynamic range when making a high sensitivity measurement of weak signals in the presence of a single strong signal that generates harmonics in the instrument. When the instrument is saturated by a single signal, only the harmonics of the signal are produced. Where the intermodulation is caused by the presence of two or more input signals of comparable amplitudes, the THI is more relevant.

The intercept points depend on the selected system settings, whether second- or third-order harmonics or intermodulation. Again, when comparing instrument performance, the settings should be the same. It is customary to specify intercept points based on the highest system sensitivity, i.e., at the lowest settings for the input attenuation and reference level. Most companies specify the IP2 and IP3 as typical values.

DANL

Intercept points are one of two quantities important to determining an instrument's IMFDR. The other is the displayed average noise level (DANL). The intrinsic noise of an instrument determines the lower limit of measurement, i.e., the sensitivity of the measuring system. The lower the noise floor, the greater the dynamic range. DANL depends on the RBW setting, the system sensitivity or noise figure (NF) and thermal noise. For spectrum analyzers and receivers, -174 dBm, the level of thermal noise, is the physical lower limit of noise power at 300 K, although it can be reduced by cooling the hardware.

When evaluating dynamic range, the DANL or NF should be determined using the same instrument settings used for IP2 and IP3. Any preamplifier connected to the instrument must be inactivated. Although better NFs can be achieved using a preamplifier, the IP2 and IP3 will be degraded. The DANL is generally specified in data sheets as a guaranteed value.

ITU RECOMMENDATIONS

The International Telecommunication Union (ITU) has issued a guideline to better assess dynamic range. The recommendations in the ITU Handbook of Spectrum Monitoring do not refer specifically to spectrum analyzers, rather more generally to monitoring receivers and radio direction finders. In addition to establishing methods to determine dynamic range parameters such as IP3 and NF, the ITU specifies absolute values for different frequency ranges.

As well as the ITU's numerical recommendations, presented as values in a table (see ***Table 1***), a graphical representation of the parameters can show dynamic range in a way that makes the relationships easier to understand and enable quick and easy performance comparisons. ***Figure 3*** shows a triangle constructed from the values of DANL, IP2 and IP3, where the area of the triangle represents the dynamic range. Increasing the area of the triangle corresponds to greater dynamic range. The values shown in the figure correspond to the ITU

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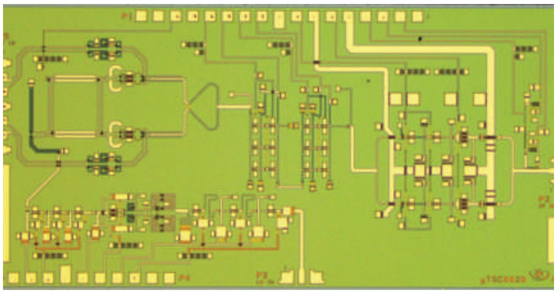

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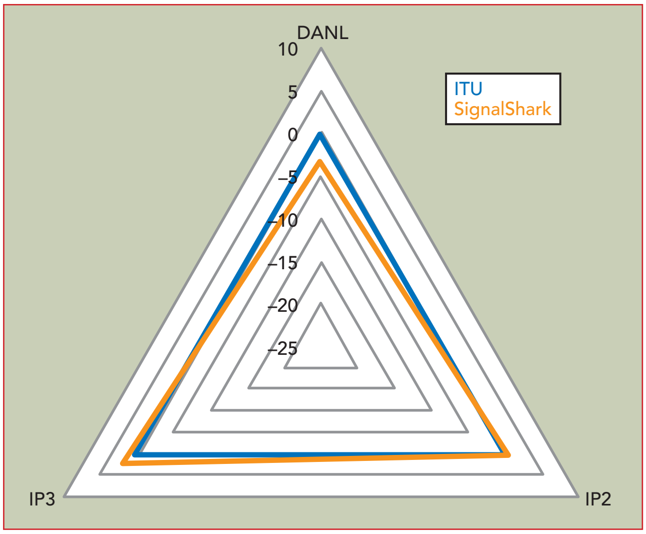
TABLE 1 ITU DYNAMIC RANGE RECOMMENDATIONS		
Parameter	**Frequency Range (MHz)**	**ITU Recommendations**
IP2/SOI	> 3 to < 30	60 dBm
IP2/SOI	≥ 30 to ≤ 630	40 dBm
IP2/SOI	> 630 to ≤ 3000	40 dBm
IP3/TOI	> 3 to < 30	20 dBm
IP3/TOI	≥ 30 to ≤ 3000	10 dBm
Noise Figure	> 2 to < 20	15 dB
Noise Figure	≥ 20 to ≤ 3000	12 dB



▲ Fig. 3 Graphical performance metric plotting DANL, IP2 and IP3, comparing the ITU recommendation for an ideal receiver with the performance of the SignalShark spectrum analyzer. (*Source:* Narda STS).

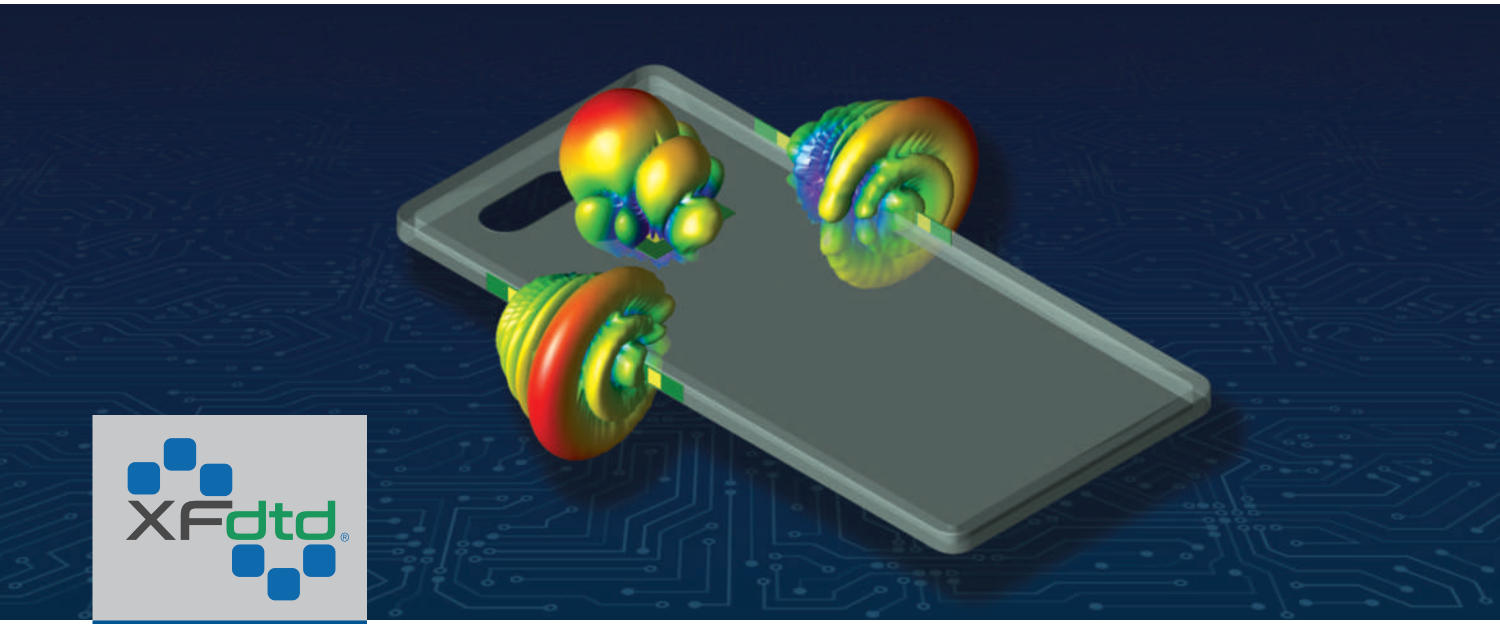
recommendations for the frequency range from 20 MHz to 3 GHz: a NF of 12 dB, an IP2 of 40 dBm and an IP3 of 10 dBm.

The triangle diagram can be used to compare spectrum analyzer dynamic range performance relative to the ITU recommendations. Figure 3 illustrates this by including the performance of the SignalShark spectrum analyzer from Narda Safety Test Solutions. The NF of this device in the corresponding frequency range is 15 dB, 3 dB higher than the ITU recommendation, which is reflected by the smaller DANL value of the triangle. The IP2 above 20 MHz matches the ITU recommendation and the IP3 is better than the ITU recommendation by 2 dB. Overall, the triangle for the SignalShark almost matches the ITU recommendations above 20 MHz, graphically representing the low noise and linear performance of the spectrum analyzer.

The performance of a spectrum analyzer, monitoring receiver or radio direction finder reflects no single component in the signal processing path, rather the combination of all the components in the signal chain, including the analog-to-digital converter and the signal processing architecture of the RF front-end. To improve dynamic range, receivers often include preselectors or filter banks to suppress frequency ranges that may overload the front-end and degrade performance. Using low noise preamplifiers and minimizing the noise of the first mixer stage help set a low intrinsic noise floor of the receiver.

SUMMARY

The dynamic range of an instrument such as a spectrum analyzer is not a fixed quantity easily compared by reviewing the data sheets of commercial instruments. Dynamic range depends on interrelated factors reflecting the input signal level and the instrument's settings. Comparing instruments requires understanding of all the parameters determining the dynamic range and how they depend on the instrument's settings. The ITU guidelines and triangle diagram are helpful for assessing instrument performance and comparing products from different manufacturers.■



Cable Dielectric Minimizes Phase Change Over Temperature

Carlisle Interconnect Technologies
St. Augustine, Fla.

Microwave cable assemblies have an electrical length that varies with temperature. Often it is required that this length vary minimally or linearly with temperature. The electrical length of a cable assembly depends primarily on the dielectric material, and the dielectric of choice for many microwave applications is a form of polytetrafluoroethylene (PTFE). While PTFE generally exhibits excellent electrical and mechanical properties, at around 19°C it has a structural phase change, resulting in dramatic dimensional changes that affect the electrical length of the cable assembly (see ***Figure 1***). This type of abrupt phase length with temperature change can be challenging for systems requiring linear or minimal phase change over temperature.

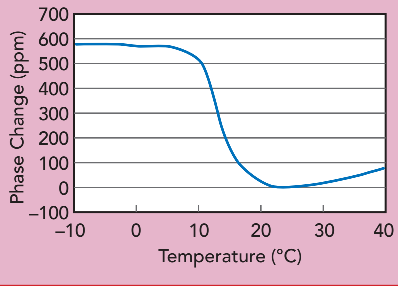


Fig. 1 **Typical phase change vs. temperature for cables with an ultra-low density PTFE dielectric.**

UTiPHASE CABLES

The UTiPHASE™ series of flexible cables developed by Carlisle Interconnect uses a proprietary microporous dielectric technology. The UTiPHASE cable consists of a center conductor (1), the dielectric (2), outer conductor (3), outer shield (4) and outer jacket (5), as shown in ***Figure 2***. The center conductors are either silver-plated copper (SPC) or silver-plated copper-weld steel (SPCW) and meet the requirements of MIL-DTL-17. As noted, the dielectric is microporous to improve phase linearity and

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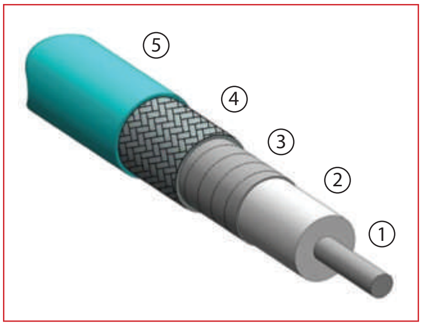

Fig. 2 UTiPHASE cable construction: center conductor (1), dielectric (2), outer conductor (3), outer shield (4) and outer jacket (5).

stability with temperature change. The outer conductor is SPC, per ASTM B-298, and the outer shields are either SPC, per ASTM B-298, or ARACON® (silver-plated polypara-phenylene terephthalamide), which offers up to a 15 percent reduction in weight. The outer jacket may be extruded fluorinated ethylene propylene (FEP) or ethylene tetrafluoroethylene (ETFE), in accordance with ASTM D-3159. Eight part numbers in the UTiPHASE series offer combinations of these options. The

TABLE 1
UTiPHASE SERIES

UTiPHASE Part Number	Center Conductor Material	Outer Shield	Outer Jacket	Outer Diameter (in)	Nominal Weight (g/ft)
MCX088D	SPCW	ARACON	ETFE	0.088	3.3
UFP088D	SPCW	SPC	FEP	0.088	4.0
MCX142A	SPC	ARACON	ETFE	0.142	8.4
UFP142A	SPC	SPC	FEP	0.142	9.5
MCX205A	SPC	ARACON	ETFE	0.250	15.9
UFP205A	SPC	SPC	FEP	0.250	18.7
MCX311A	SPC	ARACON	ETFE	0.311	35.6
UFP311A	SPC	SPC	FEP	0.311	45.7

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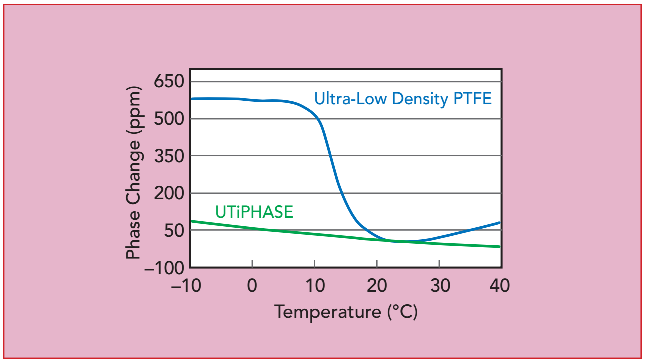
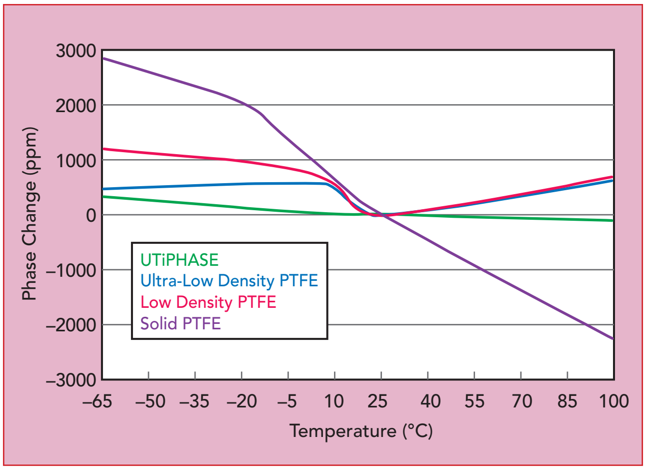


▲ Fig. 3 **Phase change of the UTiPHASE vs. ultra-low density PTFE cables.**

cable sizes were chosen to be consistent with Carlisle's UTiFLEX™ flexible cable product line, so they use the same connectors (see ***Table 1***).

PERFORMANCE

Multiple lots of UTiPHASE cable assemblies have been tested, measuring the electrical length from -65°C to 100°C to demonstrate the microporous dielectric eliminates the abrupt phase change caused by the PTFE dielectric. ***Figure 3*** compares the typical phase change for a UTiPHASE cable with a flexible cable fabricated with the ultra-low density PTFE dielectric. ***Figure 4*** extends the comparison to add two additional cables fabricated with PTFE dielectrics: low density and solid



▲ Fig. 4 **Phase change of the UTiPHASE cable vs. cables fabricated with three PTFE dielectrics.**

PTFE. The UTiPHASE cable assembly has the most stable electrical length with temperature variation.

The UTiPHASE series of cables can be used wherever flexible cables are needed with minimal or linear phase change versus temperature. Using a proprietary microporous dielectric flattens the phase change versus temperature response curve.

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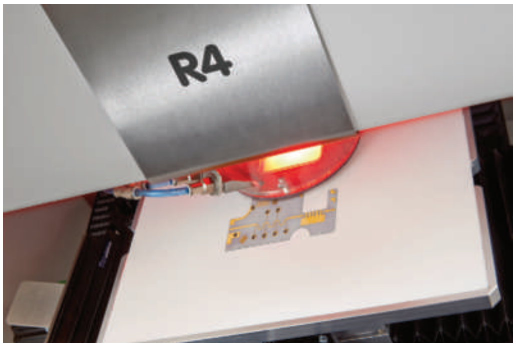


Single-Step Processing of Plated GaN Substrates

LPKF Laser & Electronics AG
Garbsen, Germany

Metal plated GaN-based ceramic materials with a thin metallic conductor layer on a thick, brittle ceramic base, pose an intriguing challenge for material processing. The LPKF ProtoLaser R4 system can quickly and cleanly process both material layers, regardless of the specifications and stark contrast in their material properties. The ProtoLaser R4 offers accuracy, adaptability and tunability.

Novel materials and advances in material processing technologies have pushed innovation since ancient times. Current trends include using GaN-based chips and interconnects, rather than silicon, for power electronics and RF/microwave components for radar, electronic warfare, 5G and satellite communications.

Fig. 1 LPKF ProtoLaser R4.

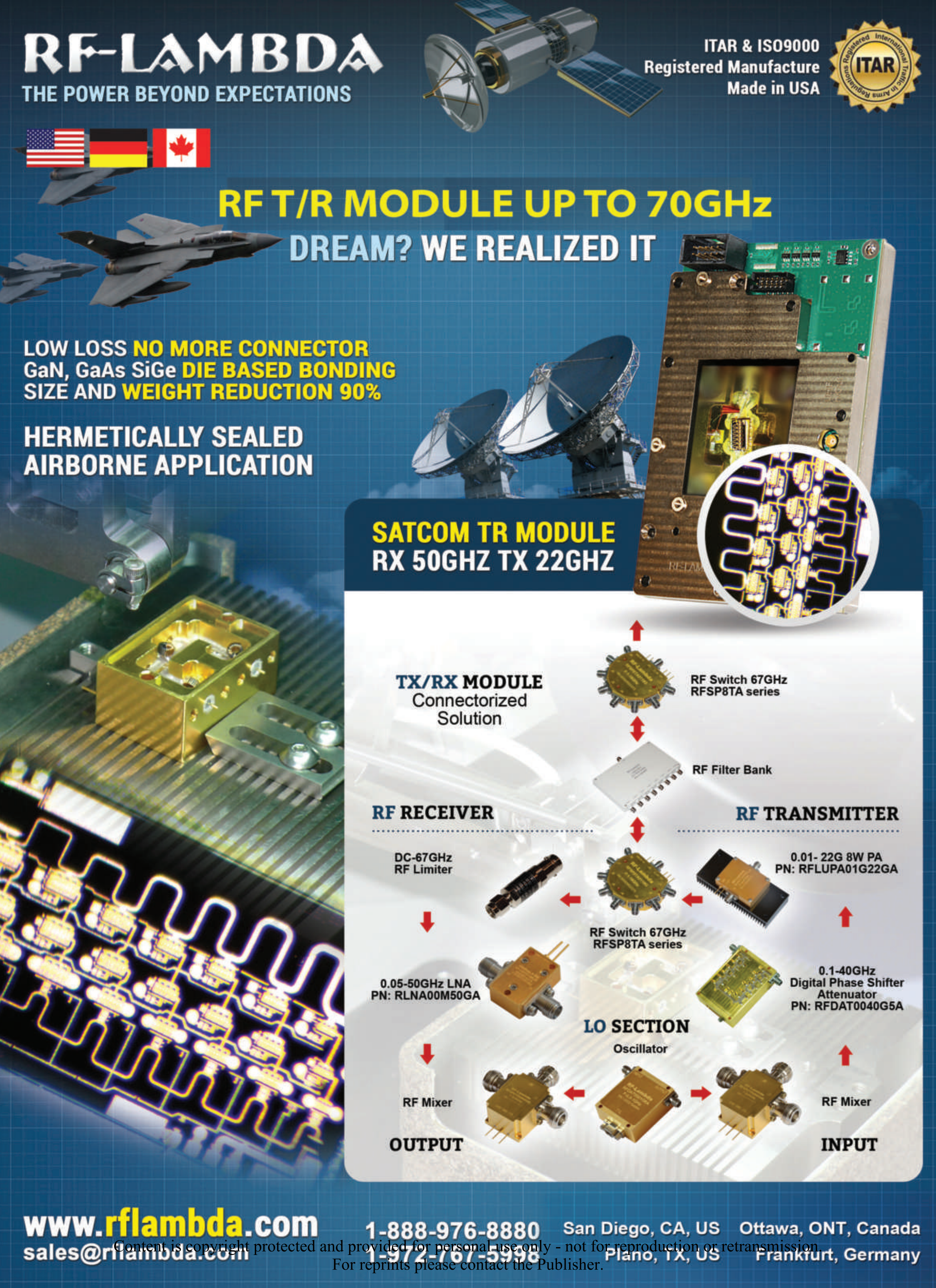
Commonly, GaN ceramic is the substrate material and covered with thin metal layers, typically micrometer-thick gold. Material processing includes dicing the ceramic substrate and etching the metal layer, traditionally two separate steps. The goal of laser-based processing using the LPKF ProtoLaser R4 system (see ***Figure 1***) is integrating the two manufacturing steps into a single contactless and chemical-free step. While contactless and chemical-free processing are properties of all laser machining procedures, the ProtoLaser R4 system implements an ultra-short pulsed laser source capable of achieving or surpassing the tolerances of the traditional manufacturing steps. The ultra-short pulses and machine design eliminate the need for final cleaning of the material, yielding fast processing times for small batch production or individual samples.

PROCESSING STEPS

The first step of the laser processing procedure is cutting the outline of the desired sample in the ceramic. The top gold layer acts as a shield against accumulated heat and the ejected plasma, protecting against cracks and chips forming in the ceramic substrate. As traditional dicing techniques offer a trusted level of edge quality, the laser process strives to achieve—even improve—this performance.

An important aspect of laser cutting is maximizing efficiency: the amount of laser energy delivered into the material per surface area and per unit time must be carefully optimized and constantly controlled. Optimizing processing efficiency provides both the highest speed processing and the lowest thermal impact to the surrounding material and works in the so-called cold ablation regime. This is only achievable with the optimized application of ultra-short laser pulses, which the ProtoLaser R4 provides.

Figure 2 compares the edge quality of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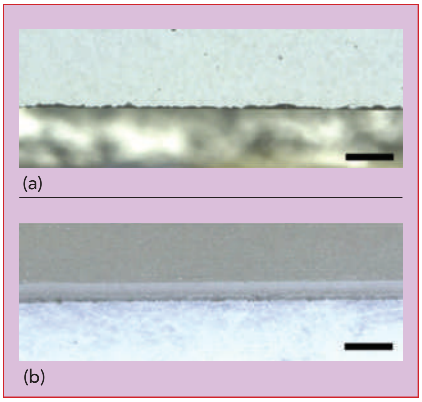
the ceramic using dicing and the laser process. With the laser, cracks and chips are virtually nonexistent. Where dicing produces a taper-free cut, laser cutting solid materials intrinsically creates a V-shaped, tapered channel, with a small difference between the top and bottom dimensions. This tapered edge does not affect the functional properties in any way. Optimizing the laser cut for cosmetic appearance and to minimize the taper results in approximately 0.1 mm taper for a 0.25 mm thick ceramic. For example, if the top side length is 10.0 mm, the bottom side length will be 10.1 mm.

After cutting, the sample is held firmly in place by the ProtoLaser R4 vacuum table, and no user intervention is required to proceed to the second step. The laser output power is reduced, tuned to the thin top layer of metal. In contrast to the



▲ Fig. 2 GaN edge after dicing (a) and laser cut (b).

high power, high pulse energy used to cut the ceramic, the laser now emits low power, low energy pulses for etching the top gold. At low energy, the size of metal structures and the spacing between them can be comparable to the size of the laser beam, which has a spatial Gaussian profile. The ProtoLaser R4 provides a beam spot size as low as 15 µm, enabling laser etched metal layers to have features as small as 15 µm with equally small spaces between them (see ***Figure 3***). The smallest features are largely determined by the thickness of the metal layer, which is thin compared to the lateral dimension of the structure, and the uniformity of the layer.

Whether using chemical etching techniques or laser processing, the ability to achieve finely spaced structures is a function of the material properties, device design and the processing parameters. Important processing considerations include the design features, both curves and straight lines; minimizing damage to the substrate; and clean removal of debris. Using the laser, debris-free processing is achieved with the ProtoLaser R4's air flow chamber; ultra-short pulsed ablation, which ejects very small particles; and the energy input per surface area.

Figure 4 shows the finished experimental sample. The small size of the sample is a handling challenge for traditional cutting techniques, but the laser has no trouble—even adding rounded corners to the design to demonstrate the ability to create shapes with irregular outlines.

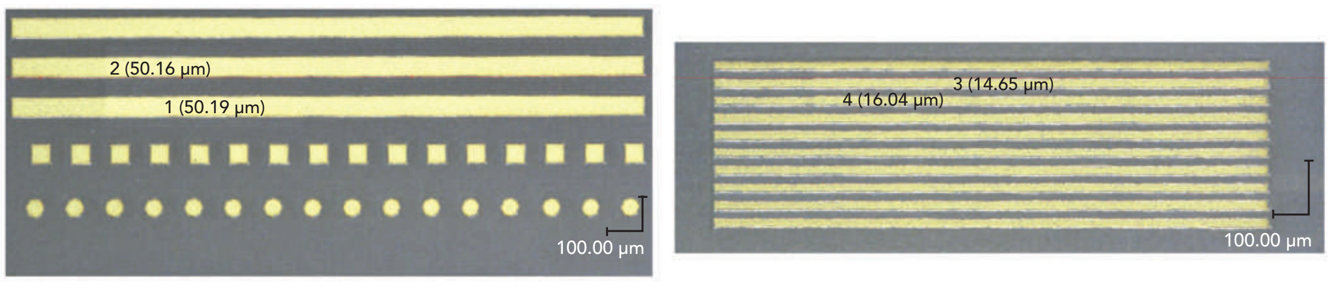


Fig. 3 Uniformity of gold metallization etched with the laser.

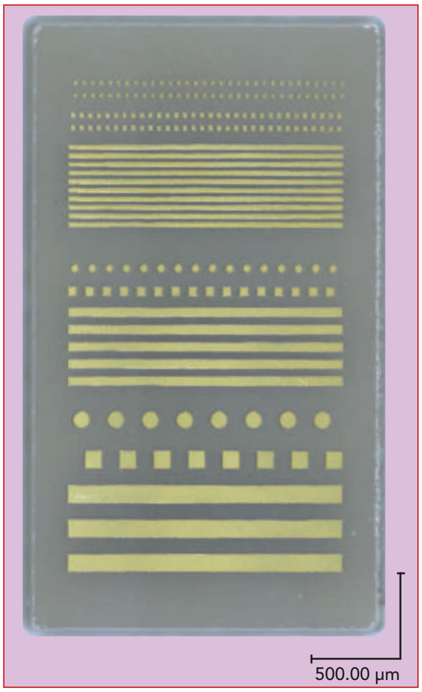


Fig. 4 GaN sample, including rounded edges, processed with the LPKF ProtoLaser R4.

SUMMARY

As demonstrated, the LPKF ProtoLaser R4 provides a single-step manufacturing procedure for cutting and etching plated GaN ceramic structures. The optimized ultra-short pulsed laser processing enables fast, clean, precise, chemical-free processing with a user-friendly approach, supporting applications demanding tight tolerance, reliable output and fast turnaround to accommodate frequent design changes. This application is just one of the ProtoLaser R4's rather unique applications, which include cutting, drilling and structuring typical RF/microwave materials, PTFE, double-sided flexible PCB laminates and thin metal layers on glass.

LPKF Laser & Electronics AG
Garbsen, Germany
www.lpkf.com

1200 W LDMOS Power Transistor Targets Particle Accelerators

Ampleon's new 1200 W power transistor, the BLF978P, was developed for the solid-state power amplifiers (SSPA) used in particle accelerator systems. Fabricated using Ampleon's latest Gen9, 50 V technology, the cost-effective LDMOS process enables the BLF978P to deliver high output power, excellent efficiency and outstanding reliability. For example, at 352 MHz, the device can deliver 1150 W CW output power at 1 dB gain compression with a typical drain efficiency of 76.7 percent.

Particle accelerators have historically used expensive high-voltage tube amplifiers such as klystrons and tetrodes. While offering high power, tubes are well known to create a single point of failure for a system. By combining multiple 1 kW SSPAs to generate the required 10 to 400 kW output power provides system redundancy, preventing accelerator "beam drop" if some SSPA modules fail.

Practical experience from accelerators in Europe and the U.S. has shown that LDMOS devices have much longer operating lifetimes—meaning zero failures—than tube amplifiers. This enables the particle accelerators to run with greater reliability, without the need to periodically shut down normal operation to replace a klystron or tetrode. As Ampleon's advanced LDMOS technology enables a much lower $/W lifetime cost, many particle accelerators are replacing their klystron and tetrode amplifiers with LDMOS SSPAs.

BLF978P evaluation boards are available at several frequencies used by synchrotron and linear particle accelerators (linac). Devices and demo boards are available from RFMW, which offers technical support for applications from HF to 704 MHz.

VENDORVIEW

Ampleon
Nijmegen, Netherlands
www.ampleon.com

RFMW
San Jose, Calif.
www.rfmw.com

Versatile, Rugged GaN PAs from Germany

Kuhne electronic has introduced a 10 W S-Band power amplifier (PA) module based on an innovative GaN HEMT circuit design. At 10 W output, the KUPA200270-10A/B module achieves efficiency greater than 40 percent over its entire 2.0 to 2.7 GHz bandwidth, with noise figure of less than 1.5 dB, gain of 47 dB and typical ripple of ±0.75 dB across the full band.

The high efficiency combined with an extended operating temperature range from –30°C to +80°C enables the PA to be used even with suboptimal cooling. The KUPA200270-10A/B includes low impedance monitoring outputs for measuring and monitoring forward and reverse power, as well as operating temperature. An over-temperature shutdown at +80°C with automatic restart protects the module from overheating. Designed to be rugged and "user friendly," the PA will tolerate arbitrary mismatch at the output port without instability or damage, and it can withstand input power levels to 1 W.

The A version is biased with a fixed 28 V DC supply; a B version is available with a wider supply voltage range, from 10 to 50 V DC, making the PA module compatible with nearly any DC supply available. The DC supply, control and monitoring signals are connected with an I/O interface protected against reverse polarity, overvoltage, ESD and EMI.

With its high bandwidth, ruggedness and unique features, the KUPA200270-10A/B supports a variety of applications: communications, jammers, radar, plasma generation, microwave heating, medical and scientific applications and measurement setups including EMC testing. It is available for immediate shipment. Additional GaN PA modules with the same features covering other frequency ranges are planned to be released later this year.

Kuhne electronic GmbH
Berg, Germany
www.kuhne-electronic.com/funk/en/

IMS2021 ATLANTA, GA | 6-11 JUNE 2021

International Microwave Symposium

CALL FOR PAPERS

IEEE

MTT-S IEEE MICROWAVE THEORY & TECHNIQUES SOCIETY

IMS

The IEEE Microwave Theory and Techniques Society's 2021 International Microwave Symposium (IMS2021) will be held June 6–11, 2021 at the Georgia World Congress Center in Atlanta, Georgia. You are cordially invited to join us in Atlanta at the intersection of communications, aerospace, automotive, IoT and other emerging technologies to learn the latest developments in MHz-to-THz theories, techniques, devices, systems and applications. IMS2021 is the centerpiece of Microwave Week 2021 which is comprised of three conferences including the RFIC Symposium (www.rfic-ieee.org) and the ARFTG Conference (www.arftg.org)

New this year: IMS will be a hybrid conference – both face-to-face and virtual. More details will be reported soon.

Microwave Week, with more than 8000 participants and 600 industrial exhibits of state-of-the-art microwave products, is the world's largest gathering of radio-frequency (RF) and microwave professionals encompassing MHz to THz ranges and is the most important forum for the latest research advances and practices in the field. IMS2021 offers something for everyone, including the following:

- Technical Program – Oral/Poster Sessions, Workshops, Technical Lectures, and Panel/Rump Sessions
- Connected Future Summit (formerly 5G Summit) showcasing the next-generation wireless technologies for mobility, V2X and IoT
- RF Bootcamp intended for students, engineers, and managers from non-microwave engineering disciplines
- Job Fair for students offering employment opportunities within our exhibitor community
- Exhibitor workshops and application seminars featuring presentations by the preeminent technologists from our exhibitors, explaining the technology behind their products
- Special small business/entrepreneurs' area on the exhibitor floor
- Discounted pricing for students with a SUPERPASS offering access to all conference events
- Competitions for Best Industry Paper, Advanced Practices Paper, Student Paper Award, Three-Minute Thesis (3MT), Student Design Competitions and Student Demonstrations; a Student Demonstration event to showcase the prototypes developed by students and presented in the technical papers
- Project Connect for underrepresented minority engineering students, and the Ph.D. Student Initiative for new students
- Networking events for Amateur Radio (HAM) enthusiasts, Women in Engineering (WIE)/Women in Microwaves (WIM), and Young Professionals (YP)
- STEM Program featuring hands-on activities and exhibitions designed to help students in middle and high school expand their understanding of what it is to be an engineer
- Guest hospitality suite and tour programs for attendees and their guests
- New technical areas on RF to mm-wave physical layer security, quantum electronics and AI/ML for RF and microwave

Paper Submission: Authors are invited to submit technical papers describing original work on RF, millimeter-wave, and terahertz theory and techniques.The deadline for submission is 16 December 2020. A blind review process will be used to ensure anonymity for both authors and reviewers. Detailed instructions on submitting a blind-review compliant paper can be found at www.ims-ieee.org. Papers will be evaluated on the basis of originality, content, clarity, and relevance to IMS.

PAPER SUBMISSION INSTRUCTIONS:

1. All submissions must be in English.
2. Authors must adhere to the format provided in the template, which can be downloaded from www.ims-ieee.org.
3. For regular submissions, authors must submit their paper at www.ims-ieee.org by 11:59 PM Hawaii Standard Time on 9 December 2020. Late submissions will not be considered. The initial submission should be between three and four pages, must be in PDF format, must be double-blind compliant, and cannot exceed 2MB in size. Hardcopy and email submissions are not accepted.

Page Limit: For the initial submission deadline, the paper length should be three pages. Papers longer than three pages will not be considered. The final page length for the papers accepted for publication in the proceeding is three pages.

Paper Selection Criteria: Papers are reviewed by IMS2021 Technical Program subcommittees. The selection criteria will be:

- **Originality:** Is the contribution unique and significant? Does it advance the state of the art of the technology and/or practices? Are proper references to previous work by the authors and others provided?
- **Quantitative content:** Does the paper give a comprehensive description of the work with adequate supporting data?
- **Clarity:** Is the paper contribution and technical content presented with clarity? Are the writing and accompanying figures clear and understandable?
- **Interest to MTT-S membership:** Why should this work be reported at this conference?

Technical Areas: During the paper submission process, authors will choose a primary and two alternative technical areas (see the Technical Areas). The paper abstract should contain information that clearly reflects the choice of the area(s). Author-selected technical areas will be used to determine an appropriate committee for reviewing the paper. The technical areas are divided into five different categories that are used to organize the paper presentation schedule. It is permissible to choose primary and alternative technical areas that are in different categories.

Presentation Format: IMS offers three types of presentation formats. The authors' preference will be honored where possible, but the IMS2021 Technical Program Committee (TPC) reserves the right to place papers in the most appropriate technical area and presentation format.

1. Full-length (20-minute) papers report significant contributions, advancements, or applications in a formal presentation format with questions and answers (Q&A) at the end.
2. Short (10-minute) papers typically report specific refinements or improvements in the state of the art in a formal presentation format with Q&A at the end.
3. Interactive forum papers provide an opportunity for authors to present their theoretical and/or experimental developments and results in greater detail and in a more informal and conversational setting. Papers will be presented in a standard poster format. An IMS2021 poster template will be provided. In addition, authors have the opportunity to display hardware, perform demonstrations, and conduct discussions with interested IMS attendees.
4. Authors of accepted IMS2021 papers must submit a pre-recorded video of their paper presentation. Details of the video presentation will be communicated with the first author of the selected papers.

Notification: Authors will be notified of the decision by 10 February 2021 via the email address(es) provided with the initial paper submission. For accepted papers, an electronic version of the final manuscript (three to four pages, to be published in the Symposium proceedings) along with a copyright assignment to the IEEE must be submitted by 4 March 2021. Authors will be required to submit their presentation slides using the approved template by 20 May 2021, and these will be made available to all attendees at the conference. The submission instructions will also be provided through emails and can be accessed through the Symposium website. The Symposium proceedings will be recorded on electronic media and archived in IEEE Xplore.

Clearances: It is the authors' responsibility to obtain all required company and government clearances prior to submitting a paper. Authors are strongly urged not to wait until the last day to start the paper submission process. Those unfamiliar with the process may encounter paper formatting or clearance issues that may take time to resolve. A statement certified by the submitting author that such clearances have been obtained and a completed IEEE copyright form must accompany the manuscript of each accepted paper. Details regarding clearances will be available during the paper submission process.

Student Superpass: IMS2021 enthusiastically invites participation from students at all levels to attend IMS2021. All students will be offered the opportunity to purchase a SUPERPASS allowing access to the IMS, RFIC, and ARFTG conferences, all workshops, short courses and panel sessions, Connected Future Summit (formerly 5G Summit), and most other events over the course of the week. Student SUPERPASS prices are significantly discounted to encourage student participation.

Student Paper Competition: Eligible students are encouraged to submit papers for the Student Paper Competition. These papers will be reviewed in the same manner as all other contributed papers. First, second, and third prizes will be awarded based on content and presentation. To be considered for an award, the student must be a full-time student during the time the work was performed, be the lead author, and personally present the paper at IMS. During the submission process, the student is required to provide the email address of the faculty advisor, who will be asked upon the selection of the paper to certify that the work is primarily that of the student. Please refer to www.ims-ieee.org for full eligibility details.

Industry and Advanced Practice Paper Competitions: Eligible authors from industry are encouraged to submit papers for the Industry Paper Competition. Additionally, any author who submits a paper on advanced practices may be entered into the Advanced Practice Paper Competition. A paper on advanced practices describes an innovative RF/microwave design integration technique, process enhancement, and/or combination thereof that results in significant improvements in performance and/or in time to production for RF/microwave components, subsystems, or systems. The papers will be evaluated using the same standards as all contributed papers. Please refer to www.ims-ieee.org for details.

Workshops, Technical Lectures, Focus and Special Sessions, Panel and Rump Sessions: Topics being considered for these areas include, but are not limited to, next-generation wireless systems (5G and beyond), emerging RF/microwave applications, latest technologies for RF/microwave measurements, and advances in RFIC technology. Please consult www.ims-ieee.org for a more detailed list of desired topics and instructions on how to prepare a proposal. Proposals must be received by 23 September 2020.

MicroApps and Exhibitor Workshops: Microwave Application Seminars (MicroApps) continue as a forum on the exhibition floor for IMS exhibitors to present the technology and special capabilities behind their commercial products. In addition, the Exhibitor workshops provide IMS exhibitors a unique opportunity to provide more in-depth presentations of technical topics to the attendees. Both events are open to all conference and exhibit attendees. Exhibitor workshops require a nominal fee while MicroApps are free of charge.

Student Design Competition: All eligible students or student teams are invited to consider taking part in the Student Design Competitions (SDCs) during the IMS2021. Please refer to www.ims-ieee.org for full eligibility details, a list of IMS2021 SDCs, and the rules for each SDC.

Student Demonstrations: All students who have submitted papers for oral or interactive forum are invited to participate in the Student Demonstrations during the IMS2021. This will be a unique opportunity for students to showcase prototype hardware that was presented during technical sessions. Please refer to www.ims-ieee.org for full eligibility details.

Three-Minute Thesis (3MT®) Workshop: For eligible students and young professionals, participants with accepted papers are invited to attend a full-day workshop on Sunday on presenting technical work for broader audiences. Following the workshop, students will be invited to enter the 3MT® competition. The 3MT® contestants will make a presentation of three minutes or less, supported only by one static slide, in a language appropriate to a non-specialist audience.

IEEE T-MTT Special Issue: Authors of all papers presented at IMS2021 can submit an expanded version of their IMS papers to the Special Issue of the IEEE Transactions on Microwave Theory and Techniques (IEEE T-MTT) devoted to the IMS2021. Please refer to www.ims-ieee.org for details.

TECHNICAL AREAS:

Electromagnetic Field, Device and Circuit Techniques

1. **Field analysis and guided waves** — Novel guiding and radiating structures, new physical phenomena in transmission lines and waveguides, and new analytical methods for solving guided-wave and radiation problems.
2. **Numerical techniques & CAD algorithms** — Finite-difference, finite-element, integral equation, and hybrid methods for RF, microwave, and THz applications. Simulation, modeling, uncertainty quantification, and design optimization; circuit-, EM-, multi-physics-, and statistics-based, including surrogate modeling, space mapping, and model order reduction techniques.
3. **Instrumentation and measurement techniques** — Theoretically supported and experimentally demonstrated linear and nonlinear measurement techniques for devices and materials, error correction, de-embedding, calibration, and novel instrumentation.
4. **MHz-to-THz device modeling** — Active and passive, linear and nonlinear device and structure modeling (physical, empirical, and behavioral) including characterization, parameter extraction, and validation.
5. **Nonlinear circuit and system analysis, simulation, and design** — Distortion, stability and qualitative dynamics analysis; circuits and systems (C&S) simulation techniques and applications; behavioral modeling of nonlinear C&S (excluding PAs); and nonlinear C&S design and implementations.

Passive Components and Packaging

6 Transmission-line structures – Novel transmission-line structures and devices, transmission-line equivalent circuits, artificial transmission lines and metamaterial structures, transmission-line applications for devices and systems.

7 Passive circuit elements – Couplers, dividers/combiners, hybrids, resonators, and lumped-element approaches.

8 Planar passive filters and multiplexers – Planar passive filters and multiplexers including lumped elements, theoretical filter and multiplexer synthesis methods.

9 Non-planar passive filters and multiplexers – Resonators, filters and multiplexers based on dielectric, waveguide, coaxial, or other non-planar structures.

10 Active, tunable, and integrated filters – Integrated (on Si, LTCC, LCP, MCM-D, GaAs, etc.), active, and tunable filters.

11 Microwave acoustic, ferrite, ferroelectric, phase-change, and MEMS components – Surface and bulk acoustic wave devices including FBAR devices, bulk and thin-film ferrite components, ferroelectric-based devices, and phase-change devices and components. RF microelectromechanical and micromachined components and subsystems.

12 Packaging, MCMs, and 3D manufacturing techniques – Component and subsystem packaging, assembly methods, inkjet printing, multi-chip modules, wafer stacking, 3D interconnect, and integrated cooling. Novel processes related to 3D printing or additive manufacturing techniques.

Active Devices

13 Semiconductor devices and process characterization – RF, microwave, mm-wave, and THz devices on III-V, silicon and other emerging technologies. MMIC and Si RFIC manufacturing, reliability, failure analysis, yield, and cost.

14 Low-noise amplifiers, variable-gain amplifiers and receivers – LNAs, VGAs, detectors, receivers, integrated radiometers, cryogenic amplifiers and models, and characterization methods for low-noise integrated circuits and components.

15 Signal generation, modulators, frequency conversion, and signal shaping ICs – CW and pulsed oscillators in silicon and III-V processes including VCOs, DROs, YTOs, PLOs, and frequency synthesizers, signal modulators, and frequency conversion ICs in silicon and III-V processes, such as IQ modulators, mixers, frequency multipliers/dividers, switches, and phase shifters.

16 Mixed-signal and wireline ICs – High-speed mixed-signal components and subsystems for transmission; equalization and clock-data recovery techniques for electrical backplanes and electro-optical interfaces. High-speed mixed-signal components and subsystems, including ADC, DAC and DDS technologies.

17 High-power MHz, RF and microwave amplifiers – Advances in discrete and IC power amplifier devices and design techniques based on III-V and LD-MOS devices, demonstrating improved power, efficiency, and linearity for HF, UHF, VHF, RF and microwave bands (< 26 GHz). Power-combining techniques for SSPA and vacuum electronics.

18 Compound semiconductor power amplifiers – Advances in IC power amplifier devices, design techniques and power combining based on III-V and other compound semiconductor devices demonstrating improved power, efficiency, and linearity for millimeter-wave bands; vacuum electronics for millimeter-wave.

19 Silicon power amplifiers – Advances in RFIC and digital power amplifier design and power combining techniques based on silicon CMOS and SiGe processes, demonstrating improved power, efficiency, and linearity for RF, millimeter-wave, and sub-THz bands.

20 Linearization and transmitter techniques for power amplifiers – Power amplifier design, characterization, and behavioral modeling; linearization and pre-distortion techniques; envelope-tracking, outphasing and Doherty transmitters for III-V and silicon technologies

21 Integrated transceivers, beamformers, imaging and phased-array chips and modules – Design and characterization of complex III-V ICs, silicon ICs, heterogenous systems, and related packaging in the RF to mm-wave including narrowband and wideband designs. Innovative circuits and sub-systems for communications, radar, imaging, and sensing applications. Integrated on-chip antennas and on-package antennas.

22 Millimeter-wave and terahertz integrated circuits and systems – Design and characterization of active components including LNAs, PAs, and frequency conversion ICs in silicon and III-V processes and/or packaging in the upper mm-wave and THz regimes; innovative THz circuits systems for communications, radar, imaging, and sensing applications. Demonstrations of on-chip antennas. Novel multi-feed antennas and antenna-electronics co-designs and co-integrations.

23 Microwave photonics and nanotechnology – Integrated devices and 1D-2D material-based technology. Multidisciplinary field studying the interaction between microwaves, THz waves, and optical waves for the generation, processing, control, and distribution of microwave, mm-wave, and THz signals. Emerging RF applications of nanophotonics, nanoplasmonics, and nano-optomechanics; nanoscale metrology and imaging.

Systems and Applications

24 Phased Arrays, MIMO and Beamformers – Technology advances combining theory and hardware implementation in the areas of phased-array antennas, integrated beamformers, spatial power combining, retro-directive systems, built-in self-test techniques, broadband arrays, digital beamforming, and multi-beam systems. New beamforming, beam-tracking, and spatial notching algorithms, signal processing, and demonstrations.

25 Radar and Imaging Systems – RF, millimeter-wave, and sub-THz radar and imaging systems, automotive radars, sensors for intelligent vehicular highway systems, UWB and broadband radar, remote sensing, radiometers, passive and active imaging systems, radar detection techniques, and related signal processing.

26 Wireless, 5G & Beyond, and New Satellite Communication Systems – RF, millimeter-wave, and sub-THz communication systems with hardware implementation for terrestrial, vehicular, satellite, and indoor applications, point-to-point links, backhaul and fronthaul applications, radio-over-fiber links, cognitive and software-defined radios, MIMO and full-duplex technologies, and simultaneous transmit and receive (STAR) systems.

27 Wireless System Characterization and Architectures – Wireless and 5G & Beyond enabling technologies including but not limited to beamforming techniques, MIMO, massive MIMO, multiple radio access technologies, centralized radio access networks, shared and novel spectrum use, waveform design, modulation schemes, and channel modeling.

28 Sensing and RFID Systems – Short range wireless and RFID sensors, gas and fluidic sensors, passive and active tags from HF to millimeter-wave frequency, RFID systems including wearables and ultra-low-power.

29 Wireless Power Transmission – Energy harvesting systems and applications, rectifiers, circuits, self-biased systems, combined data and power transfer systems

30 MHz-to-THz instrumentation for biological measurements and healthcare applications – Devices, components, circuits and systems for biological measurements and characterizations; biomedical therapeutic and diagnostic applications; systems and instrumentation for biomedical applications; wireless sensors and systems, and implantable and wearable devices for health monitoring and telemedicine.

31 MHz-To-THz interaction of materials and tissues – Electromagnetic field interaction at molecular, cellular, and tissue levels; electromagnetic characterization of biological materials and living systems; MRI and microwave imaging. Industrial and scientific, medical applications utilizing microwave power technology; microwave-enhanced chemistry; non-destructive evaluation /testing and material property measurements at nanometer to millimeter. Multi-modal and multi-physical imaging techniques, such as microwave-induced acoustic imaging.

Emerging Technologies

32 Innovative systems and applications – Emerging technologies and novel system concepts for RF/microwave applications such as 6G, Internet of Things (IoT), Internet of Space (IoS), wearable computing/communication systems, machine-to-machine (M2M) communication, intelligent transportation, smart cities, smart environment, heterogeneous integration and 3D ICs, silicon photonics and plasmonics.

33 MHz-to-THz physical layer security – Devices, circuits, and systems for secured communication and sensing from MHz to THz, addressing general security vulnerability due to electromagnetic emissions, hardware and software co-design for physical layer security, advanced devices and materials to enhance RF, mm-Wave, and THz physical layer security, trusted design, fabrication, packaging, and validation for RF, mm-Wave, and THz electronics;

34 AI/ML for RF and Mm-Wave – AI/ML algorithms, implementations, and demonstrations for spectrum sensing, mobile edge networking, and MIMO and array beam operations and management; AL/ML algorithms for design and optimization of RF/mm-Wave components, circuits, and systems; AL/ML algorithms for in-situ sensing, diagnostics, control, reconfiguration, and optimization of MHz to THz communication and sensing circuits and systems.

35 Quantum devices, systems, and applications – Cryogenic RF devices, circuits, and systems for general quantum device interfacing and quantum computing applications.

CONNECTING FOR A SMARTER, SAFER WORLD

Atlanta 2021

Important Dates

16 September 2020 (Wednesday)

PROPOSAL SUBMISSION DEADLINE
For workshops, short courses, focus and special sessions, panel and rump sessions

9 December 2020 (Wednesday)

PAPER SUBMISSION DEADLINE
All submissions must be made electronically.

3 February 2021 (Wednesday)

PAPER DISSEMINATION
Authors will be notified by email.

3 March 2021 (Wednesday)

FINAL MANUSCRIPT SUBMISSION DEADLINE
Manuscript and copyright of accepted papers

5 May 2021 (Wednesday)

WORKSHOP NOTES SUBMISSION DEADLINE
Electronic upload of workshop notes to the Workshop Organizers.

5 May 2021 (Wednesday)

VIRTUAL PRESENTATIONS SUBMISSION DEADLINE

19 May 2021 (Wednesday)

FINAL PRESENTATIONS SUBMISSION DEADLINE
Electronic upload of presentations in both PDF and PPT format

6–11 June 2021

MICROWAVE WEEK
IMS2021, RFIC 2021, ARFTG, and Exhibition

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Flexible 0.047 Low Loss Cable Assembly Performs to 67 GHz

For applications with limited space that need a flexible cable, Samtec has developed a low loss cable assembly with performance to 67 GHz. The RF047-A uses 1.85 mm male and female connectors and has a maximum VSWR of 1.4:1 to 67 GHz. Other connector options are male and female 2.92 mm and SMPM series. The connectors are solder clamp designs with fully captivated center contacts, and the body components are passivated stainless steel with gold plated brass solder ferrules and beryllium copper contacts.

Samtec has expanded its portfolio of precision microwave and mmWave cable assemblies to support the latest in 5G and other high frequency, low latency communications systems, offering a full line of off-the-shelf products with upper frequency performance from 18 to 110 GHz. Complete, end-to-end cable assemblies are available with a wide range of low loss and flexible cables, including 0.047, 0.085, 0.086 and versions optimized by Samtec. Cable connectors, board-level interconnects and cable assemblies are available with interface types of 1.00 mm, 1.85 mm, SMPM, SMP, 2.40 mm, 2.92 mm, 3.50 mm, SSMA, SMA, Type N and TNCA.

As one example, Samtec's Bulls Eye® high performance cable assembly for test and measurement applications has upper frequency options of 20, 40, 50 or 70 GHz. The high density array enables smaller evaluation boards and shorter trace lengths, while the compression interface ensures easy installation and removal, while eliminating solder costs.

Samtec manufactures its microwave and mmWave products to precise mechanical tolerances to achieve superior performance and repeatability. It will customize products to meet a customer's unique requirements, whether quick-turn modifications or new designs, and provide technical support to optimize launch designs, from simulation to testing.

Samtec Inc.
New Albany, Ind.
www.samtec.com

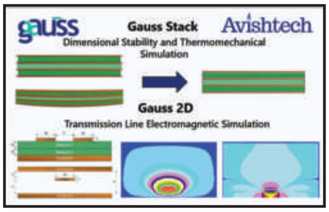
AR RF/Microwave Instrumentation EMC Test Software

VENDORVIEW

AR's new EMC test software, emcware® 5.0, makes testing more intuitive and cost effective. From accelerated start-up to one-click reporting, emcware 5.0 provides a complete EMC software solution with an easy-to-use interface. It includes 500+ built-in testing profiles, test profile customization, pre-built reporting templates, steamlined validation and new reverb immunity chamber testing methodologies. This EMC software will transform your capabilities.

AR RF/Microwave Instrumentation
https://www.arworld.us

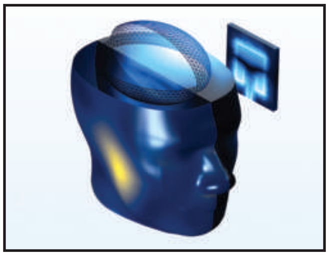
Gauss Stack and Gauss 2D



Gauss Stack allows you to rapidly build PCB stackups, implement key reliability checks and run thermomechanical simulations, including dimensional stability, as well as electromagnetic simulations via its native Gauss 2D engine, to guide you through development of boards with high performance and high reliability. Gauss 2D provides impedance, RLGC, effective dielectric properties, insertion loss and more, for virtually any PCB transmission line, also allowing you to flip the problem and solve the geometry for a target impedance.

Avishtech Inc.
https://www.avishtech.com

COMSOL Multiphysics® Software



The RF Module, an add-on to the COMSOL Multiphysics® software, analyzes RF, microwave, mmWave and THz designs in various multiphysics scenarios. The RF Module optimizes impedance matching and far-field gain pattern of antennas, and insertion loss and coupling effects of passive circuits in the application area of 5G and IoT. The EM simulation can be extended to perform multiscale modeling with ray tracing. It is possible to include other physics phenomena, such as temperature increase with absorbed radiation, and structural deformation induced by heat expansion.

COMSOL
www.comsol.com/rf-module

New Software Makes the Shift to Standalone 5G Easier

Communications service providers can now tap into the full potential of 5G new radio (NR) technology with the commercial availability of Ericsson Standalone 5G NR software for 5G mid- and low bands. With this software, communications service providers can now operate 5G NR without the need for signaling support from an underlying LTE network. This will allow service providers to add 5G NR to existing 4G sites with a simpler architecture or deploy 5G independently in new areas such as factories, to support enterprise applications and services.

Ericsson
https://www.ericsson.com/

HUBER+SUHNER RF Assembly Calculator Allows An Easy Cable Comparison With Direct Access To Technical Specifications

VENDORVIEW

The RF Assembly Calculator allows an easy comparison of up to three out of more than 320 HUBER+SUHNER radio frequency cables in different configurations and environments. The app includes a straight access to technical specifications such as insertion loss and power rating as well as extended calculations of individual cable constructions—to name just a few of its many advantages. All results become visual by means of graphics and can be easily exported to PDF and sent by e-mail.

HUBER+SUHNER AG
www.hubersuhner.com

K&L Filter Wizard

K&L Microwave's Filter Wizard® synthesis and selection tool streamlines identification of RF and microwave filters meeting customer requirements across a large portion of K&L's standard product offerings. Filter Wizard® accelerates user progress from specification to RFQ over an ever-increasing range of response types, bandwidths and unloaded Q values. Provide the application with desired specifications and the software returns a list of products that match, placing response graphs, outline drawings and downloadable S-parameters at your fingertips. Visit www.klfilterwizard.com via computer or mobile device to get started.

K&L Microwave
www.klfilterwizard.com

µWave Wizard Version 2020

The new 2020 version of Mician's µWave Wizard hybrid full-wave EDA-software tool is now available. The latest release offers new library elements, performance enhancements and flexible licensing options. Additionally, several novel features are separately available for µWave Wizard licenses: 3D Mesh Morphing for faster convergence and reduced "mesh jitter" due to coarse discretization and Filter Workbench, a novel Filter Synthesis tool aiding in the design and optimization of narrowband microwave filter of various topologies.

Mician GmbH
www.mician.com

MCL Microwave Calculator App

Mini-Circuits is excited to announce the newest version of its Microwave Calculator app for iOS and Android devices. Designed specifically for RF and microwave engineers, the newly renovated app now includes 31 calculations and an improved user interface to make calculations more accessible for engineers in the lab, in the field or on the fly. Mini-Circuits is pleased to offer this tool for FREE as part of its commitment to support industry peers with innovative resources to make your job easier.

Mini-Circuits
www.minicircuits.com/applications/microwave_calculator.html

Modelithics COMPLETE Library™ v20

Modelithics releases version 20 of the COMPLETE Library™, showcasing nearly 40 new models. COMPLETE includes over 750 models from nearly 70 vendors, representing over 18,000 components. An indispensable collection of simulation models for all types of passive and active RF and microwave devices. Go from concept to product faster and easier! Version 20 is now available for Keysight ADS, Cadence®, AWR Design Environment® and Ansys® HFSS™. Additional releases coming soon! Request a FREE trial of the Modelithics COMPLETE Library.

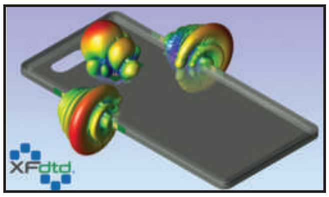
Modelithics, Inc.
https://www.modelithics.com/model

Capacitor Application Program

Passive Plus Inc.'s (PPI) brand new online Capacitor Application Program (C.A.P.) helps engineers and designers select capacitors according to parameters such as cap value and frequency. C.A.P. allows engineers to insert capacitors requirements (cap value, frequency), producing scattering matrices (S2P) charts while providing options (case size, terminations, mounting) and parameters (ESR, Q, impedance) along with datasheets. Once engineers have determined their capacitor requirements, C.A.P. also includes online requests for quotes and/or sample requests.

Passive Plus Inc.
www.passiveplus.com

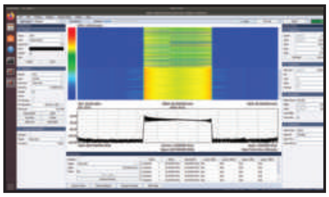
XFdtd's Superposition Simulation Enables Highly Sophisticated Array Analysis



Designing high frequency MIMO and 5G devices requires intensive, yet efficient, analysis. Beamforming applications increase complexity due to hundreds or even thousands of beam states that must be analyzed. XFdtd® leverages the EM principle of superposition to quickly analyze port phase combinations with a single simulation and identifies the ones that maximize far zone coverage in each direction. As a result, the design workflow for MIMO beamforming array analysis is greatly simplified and streamlined.

Remcom Inc.
https://www.remcom.com

Spike Spectrum Analyzer Software for Linux Now Available



Signal Hound's Spike™ spectrum analyzer software is now compatible with the Linux OS, specifically 64-bit Ubuntu 18.04. The Linux version of Spike contains the full feature set of the Windows variant, providing a 1:1 experience for those familiar with using Spike on Windows. Spike for 64-bit Linux offers the same powerful features as the Windows version, including real-time analysis, digital demodulation analysis, EMC precompliance testing features, interference hunting capabilities, phase noise measurements, 802.11 WLAN modulation analysis and spectrum emission masks, among others.

Signal Hound
https://signalhound.com/

NEW PRODUCTS

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COMPONENTS

Solid State Absorptive Switch Matrix

MIcable has developed a 1×64 solid state absorptive switch matrix covering 0.5 to 6 GHz. Compared with the traditional solid state switch matrix, it has lower 4.5 dB typ. insertion loss, higher 70 dB minimum isolation and 250 nS switching speed. The matrix uses phase and amplitude matched design, typical phase and amplitude consistency among each of the ports are at ±5° and ±0.3 dB. The user can control the switch matrix via USB/Ethernet or manual control.

Fuzhou MIcable Electronic Technology Co. Ltd.
www.micable.cn

SP4T SMA Coaxial Switch

Logus Microwave introduced the premium SPMT SEM Series, engineered to be your direct coax switch legacy replacements. Featuring NRSEM143: SP4T, SMA, normally open, performs DC to 18 GHz at 28 VDC. Series options include latching, failsafe, indicators, TTL, weather sealed and more. Established in 1961, Logus Microwave has been providing globally trusted unmanned aerial vehicle products with customization like you have never seen.

Logus Microwave
www.logus.com

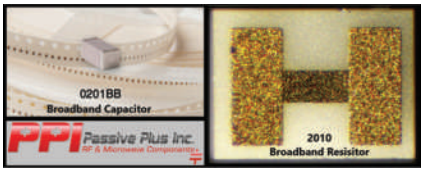
26 to 34 GHz mmWave Four-Way Power Divider

VENDORVIEW

MECA expanded offering of 5G millimeter-wave products. Featuring four-way power dividers covering 26 to 34 GHz with 2.92 mm interfaces. Typical specifications of 1.2:1 VSWR, 19 dB isolation, 2 dB insertion loss and 1 dB amplitude balance. Also available are attenuators, terminations, bias tee's, DC blocks and adapters. Additionally, octave and multi-octave models covering up to 50 GHz built by J-Standard certified assemblers and technicians. Made in U.S. and 36-month warranty.

MECA Electronics Inc.
www.e-MECA.com

Broadband Components



Passive Plus Inc. (PPI) has expanded its broadband components to include the 0201BB104KW160 broadband capacitor, complimented by the R35-2010BB50R-00FR1QE broadband resistor for case size and footprint requirements as well as to meet your high frequency needs.

Passive Plus Inc. (PPI)
www.passiveplus.com

Positive Slope Equalizers

VENDORVIEW

Pasternack, an Infinite Electronics brand and a provider of RF, microwave and mmWave products, has just introduced a new line of positive slope equalizers that are ideal in compensating for gain variation and optimizing performance in systems where excessive losses may occur at the low end of the frequency band. The broadband performance makes them ideal for a variety of applications involved in aerospace and defense, MILCOM and SATCOM, test and measurement and wireless infrastructure.

Pasternack
www.pasternack.com

Four-Way Power Divider

VENDORVIEW

PMI Model No. APD-4-2G26G-292FF-1W is a 2 to 26 GHz, four-way power divider. This model offers a maximum insertion loss of 2.25 dB with a maximum VSWR of 1.7:1 and a minimum isolation of 15 dB; insertion loss 2.25 dB max; VSWR (In/Out) 1.7:1 max; amplitude balance ±0.5 dB; phase balance ±6° max measured +1.71° max, -1.33° min and power handling >1 W CW. Unit contains 2.92 mm (F) connectors and size is 3.00" × 2.00" × 0.375."

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

Integrated Microwave Filters (IMF)

Pole/Zero's new IMF series of digitally tunable bandpass and notch filters features accelerated tuning speeds packed in very small, lightweight QFN packages. IMF frequency hopping filters are available in multiple frequency bands across the 4 to 24 GHz frequency range, with tune times <100 ns via GPIO tuning control (0 V OFF, +5 V ON) of 16 discrete tunable steps. The reduced size, weight, power consumption and cost (SWaP-C) of Pole/Zero's IMFs make them suitable for applications on radar, electronic warfare, SATCOM-On-The-Move (SOTM), RF front end and commercial platforms.

Pole/Zero
www.polezero.com

High-Power Low Pass Filters

RLC Electronics' high-power low pass filters are designed for high-power systems in the frequency range of 100 to 8,000 MHz. These filters are designed to handle 2,500 W average under extreme temperature and altitude conditions, while offering low loss (0.15 dB typical) and 1.5:1 VSWR (max). RLC filters offer you the flexibility of choosing your cutoff frequency, number of sections and connector type (N, SC, HN, 7/16) for a truly custom high-power low pass product.

RLC Electronics
www.rlcelectronics.com

Switches for 5G Automotive Telematics

Skyworks introduced the SKY5A1007, a new switch in their portfolio of Sky5® product solutions, designed to support the ever-growing demand for cellular vehicle-to-everything (C-V2X) connectivity. The SKY5A1007 is a state-of-the-art CMOS, silicon-on-insulator double-pole, double-throw switch with high linearity performance, low insertion loss and high isolation. The device enables high speed switching between antennas for high data throughput and minimizes the need for additional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IEEE

filtering. The SKY5A1007 meets the necessary requirements for 5G automotive telematics including operation within cellular, 5GNR and 5.9 GHz C-V2X bands.

Skyworks
www.skyworksinc.com

Surface Mount Resistors

VENDORVIEW

Smiths Interconnect, a provider of technically differentiated electronic components, subsystems, microwave and radio frequency products, announced the release of its extended CXH series of surface mount chip resistors and terminations. The CXH Series uses a patented layout to provide improved power handling over conventional flip chart resistors, without compromising broadband performance. This makes the CXH Series well suited for a wide array of RF applications, particularly in the space and defense markets.

Smiths Interconnect
www.smithsinterconnect.com

CABLES & CONNECTORS

Waveguide to Coax Adapters

VENDORVIEW

HASCO's newly stocked Waveguide to Coax Adapters, ranging in size from WR-10 to WR-430, allows for a seamless transition between a waveguide and a coax connector, guiding electromagnetic waves of a specific frequency range with the least loss of energy possible. The right angle and end-launch Waveguide to Coax Adapters, in stock at HASCO, are offered in a variety of waveguide bands and flange sizes.

HASCO
www.hasco-inc.com

Precision Right Angle Adapters

Withwave's precision test adapters with right angle types are designed based on precision microwave interconnection technologies. These 1.85 mm and 2.92 mm/2.92 mm to 2.92 mm types are manufactured to precise microwave specifications and constructed with male and female gender on both sides. The precision microwave connector interfaces ensure an excellent microwave performance up to 40 GHz.

withwave co. ltd
www.with-wave.com

AMPLIFIERS

Solid State Amplifier

VENDORVIEW

AR's Model 2500A225B solid state amplifier delivers up to 2,500 W of power across the entire band of 10 kHz to 225 MHz. It is ideal for a wide range of automotive, military and aviation uses, as well as various applications where instantaneous bandwidth, high gain and linearity are required. In addition to unsurpassed mismatch capabilities and excellent flatness, this AR amplifier is built to last.

AR RF/Microwave Instrumentation
www.arworld.us

X-Band Radar Solid State Power Amplifier

COMTECH PST introduced a new GaN amplifier for ground or surface X-Band radar applications. The AB linear design operates from 9.2 to 9.7 GHz frequency range over an instantaneous bandwidth of 500 MHz. Development of this product is for a TWT replacement. The amplifier design features self-protection for load VSWR, duty factor, pulse width, temperature, as well as a graceful degradation in case of a RF power module failure. An MTBF increase of 10 times that of a TWT is achieved for greatly improved reliability and lower maintenance costs. Comtech supports custom configurations and features are available as well as specific power levels up to 16 kW.

COMTECH PST
www.comtechpst.com

Broadband Amplifier

SBB-0117031815-VFVF-E3 is a broadband amplifier with a typical small signal gain of 18 dB, a nominal P1dB of +15 dBm and a typical noise figure of 6 dB across the

frequency range of 0.01 to 70 GHz. The DC power requirement for the amplifier is +12 VDC/200 mA. The use of a heat sink is advised to assist in cooling the device. The RF connectors are female 1.85 mm connectors. Other port configurations are available under different model numbers.

Eravant
www.eravant.com

5G Outdoor Amplifiers

VENDORVIEW

Exodus Advanced Communications' outdoor Ka-Band series is designed for 5G mobile and fixed SATCOM terminals. This series features high linear power and long-term reliability in a light weight and small outdoor form factor. Other frequency ranges and power levels are available. The new AMP4069-ODT covers 26.5 to 40 GHz, produces 5 W, 3 W P1dB, with 37 dB min. gain. The unit has excellent band flatness. The nominal weight is 22 lbs and dimensions of 8.43"W × 13.15"L × 5.7"H.

Exodus Advanced Communications
www.exoduscomm.com

Class AB High-Power Amplifiers

VENDORVIEW

Fairview Microwave Inc., an Infinite Electronics brand and a provider of on-demand RF, microwave and mmWave components, has released a new series of class AB broadband high-power amplifier modules that incorporate GaN, LDMOS or VDMOS semiconductor technology. Fairview's comprehensive new line of class AB broadband high-power amplifiers consists of 18 new models spanning frequency bands from 20 MHz to 18 GHz. These designs are unconditionally stable and operate in a 50 Ohm environment.

Fairview Microwave Inc.
www.fairviewmicrowave.com

SGA/SGN Series SSPA's

KRATOS General Microwave's SGA/SGN Series SSPA's offer GaAs/GaN technology reliability that can be customized to meet specific pulse or CW output powers. The product line supports both X-Band and Ku-Band applications with bandwidths up to 10 percent and offers peak power outputs up to 400 W. Designed for demanding defense, aerospace and satellite communication applications. General Microwave SSPA's have excellent power efficiency with demonstrated field proven performance and reliability. General Microwave's vertical integration process affords flexible layouts and architectures to meet individual specifications for electrical, mechanical and environmental parameters.

KRATOS General Microwave
www.kratosmed.com

NewProducts

GaN IMFET for L-Band Radar

VENDORVIEW

RFMW announced design and sales support for a fully matched GaN IMFET from Qorvo. The QPD1006 provides 450 W of pulsed RF power from 1.2 to 1.4 GHz along with greater than 300 W power output for CW applications. Linear gain is 17.5 dB from this internally matched, discrete GaN on SiC HEMT device. Supporting 50 V for pulsed applications and 45 V for CW, the device is housed in a low thermal resistance package ideal for both military and commercial radar.

RFMW
www.rfmw.com

Solid State High-Power Amplifier

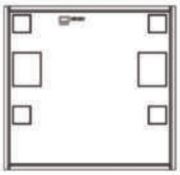
Richardson RFPD Inc., an Arrow Electronics company, announced the availability of a new solid state high-power amplifier from Empower RF Systems Inc. The 1219 is a 500 to 6,000 MHz amplifier guaranteed to deliver 25 W minimum output power and related RF performance under all specified temperature and environmental conditions. It is designed for RF product testing, broadband mobile jamming and band-specific high-power applications in the UHF, L, S and C frequency bands.

Richardson RFPD Inc.
www.richardsonrfpd.com

SEMICONDUCTORS

GaAs MMIC Die

VENDORVIEW



Mini-Circuits' model EQY-3-453-D+ is an absorptive gain equalizer die with negative insertion loss slope from DC to 45 GHz. Supplied in chip form on nonstatic material, the 50 Ω, RoHS-compliant gain equalizer exhibits insertion loss of 4.6 dB at 10 MHz, 4.3 dB at 10 GHz, 3.6 dB at 20 GHz and 1.1 dB at 45 GHz. VSWR is typically only 1.14:1 through 10 GHz, 1.22:1 or less from 10 to 30 GHz and 1.23:1 from 30 to 45 GHz.

Mini-Circuits
www.minicircuits.com

SYSTEMS

1U SlimBox OpenVPX Chassis

Pixus Technologies, a provider of embedded computing and enclosure solutions, has announced a new horizontal-mount OpenVPX chassis platform for 3U, 6U or hybrid versions. The first in the 1U SlimBox OpenVPX series is a three-slot version for 3U boards. A modular fixed power supply provides up to 600 W of power and one rear transition module is supported. A hybrid configuration option is available with 1× 6U slot and 1× 3U slot.

Pixus Technologies
www.pixustechnologies.com

SOURCES

MLBS-Synthesizer Test Box

Two to 20 GHz standard models cover the 2 to 8 GHz, 8 to 20 GHz and 2 to 20 GHz frequency bands. Tuning consists of a control knob, keypad, USB and Ethernet connections. Units provide +10 dBm to +13 dBm output power levels and either 30 dB or 60 dB of power leveling is available. Units are specified over the lab environment of +15°C to +55°C, are CE certified and LabVIEW compatible.

Micro Lambda Wireless
www.microlambdawireless.com

4.55 GHz CRO VCO

VENDORVIEW

The new CRO4550X2-LF utilizes a doubled CRO oscillator design to cover the operating frequency of 4,550 MHz within a tuning window of 0.5 to 4.5 VDC. This new ceramic resonator VCO features incredible phase noise of -110 dBc/Hz at 10 kHz offset and is available in Z-COMM's standard MINI-16-SM package measuring 0.5 × 0.5 × 0.22 in. The CRO4550X2-LF is well suited for satellite communication systems requiring optimal spectral purity.

Z-Communications
www.zcomm.com

TEST & MEASUREMENT

Direction Finding and Interference Analyzers

Advanced Test Equipment Corp. (ATEC) will now offer SignalShark RF Direction Finding and Interference Analyzers by Narda Safety Test Solutions. ATEC, the official U.S. and Mexico distributor, and the only authorized U.S. service center for calibration and repair of Narda STS equipment, will be renting, selling, calibrating and servicing SignalShark Analyzers. The Narda STS SignalShark is an analyzer for the detection, analysis, classification and localization of RF signals between 8 kHz and 8 GHz.

Advanced Test Equipment Corp.
www.atecorp.com

Bench Top mmWave Antenna Test System

VENDORVIEW

Millibox's portfolio takes a whole new dimension: MBX33; with 8 ft in length, 22" × 22" interior cavity section and ~2 m far field distance. MilliBox is a family of mmWave antenna test systems which are modular, compact and affordable. MilliBox is designed for applications between 18 and 95 GHz. MBX33 is made of 3 × 30" cube sections. This new dimension is desired for larger DUT measurements or mmWave radar performance verification.

Milliwave Silicon Solutions
www.millibox.org

Thermal Power Sensors

VENDORVIEW

By adding the R&S NRP90T and R&S NRP90TN models to its portfolio of thermal power sensors, Rohde & Schwarz releases the very first test and measurement instruments in the market to support the novel, robust 1.35 mm precision coaxial connector. The connector covers frequencies up to 90 GHz and shall be included in the next releases of both IEEE and IEC relevant standards. Rohde & Schwarz has been a partner in the 1.35 mm E connector development project since its beginning in 2017.

Rohde & Schwarz
www.rohde-schwarz.com

Test Bench

VENDORVIEW

Löhnert Elektronik was looking for a reliable automotive radome tester for its new test bench and chose the R&S QAR quality automotive radome tester from T&M manufacturer Rohde & Schwarz. The R&S QAR is presently the only tester on the market that can test these radomes quickly and over their full surface area. Automotive radomes are protective covers for vehicle radar sensors. They must have good and uniform transmission characteristics over their entire surface for radar signals in the 77 GHz and 79 GHz bands (E-Band).

Rohde & Schwarz
www.rohde-schwarz.com/us

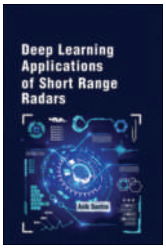
Digital Matrix Attenuator Handover Test System

VENDORVIEW

Vaunix Technology Corp., a provider of portable and programmable RF/microwave test devices, announced its latest product, the Vaunix 64 × 8 digital matrix attenuator handover test system, the VMA-Q64X8SE. This digital matrix attenuator system is ideally suited for research labs conducting automated handover, MIMO performance analysis and product verification testing. It is available for a fraction of the size and cost of competitive rack mount matrix attenuators and handover test systems.

Vaunix Technology Corp.
www.vaunix.com

MICRO-ADS



Deep Learning Applications of Short Range Radars

Avik Santra and Souvik Hazra

This exciting new resource presents emerging applications of artificial intelligence and deep learning on short-range radar. The book covers applications ranging from industrial, consumer space to emerging automotive applications. The book presents several human-machine interface applications, such as gesture recognition and sensing, human activity classification, air-writing, material classification, vital sensing, people sensing, people counting, people localization and in-cabin automotive occupancy and smart trunk opening.

The underpinnings of deep learning are explored, outlining the history of neural networks and the optimization algorithms to train them. Modern deep convolutional neural network (DCNN) architectures for computer vision and their features are also introduced. The book presents other deep learning architectures, such as long-short term memory, auto-encoders, variational auto-encoders and generative adversarial networks. The application of human activity recognition as well as the application of air-writing using a network of short-range radars are outlined. This book demonstrates and highlights how deep learning is enabling several advanced industrial, consumer and in-cabin applications of short-range radars, which were not otherwise possible. It illustrates various advanced applications, their respective challenges and how they are being addressed using different deep learning architectures and algorithms.

To order this book, contact:

Artech House
www.artechhouse.com
Email: artech@artechhouse.com
US 800-225-9977
UK +44 (0)20 70596 8750

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£155

https://us.artechhouse.com/Deep-Learning-Applications-of-Short-Range-Radars-P2145.aspx

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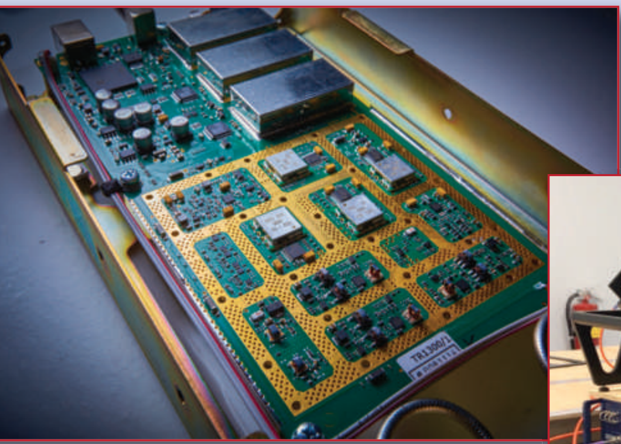
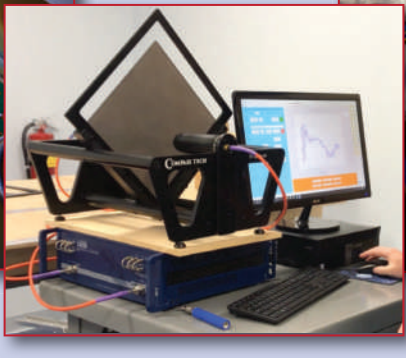
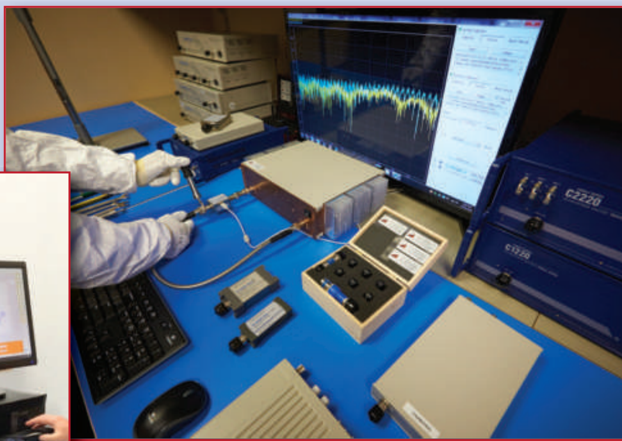
FABS and LABS

Copper Mountain Technologies — Affordable, Metrology-Grade VNAs







Frustration and insight led to the birth of Copper Mountain Technologies (CMT). Three of the founders were "heavy" VNA users, frustrated that VNAs were expensive, so expensive they had to be shared among projects, if not by an entire company. With so many users, no one could be sure the equipment was being carefully protected and maintained, essential for accurate data. At some point these frustrated engineers asked, "Can't we just build our own VNA?"

While pursuing this DIY project, they realized there must be an untapped market of frustrated engineers who needed an affordable instrument to make accurate S-parameter measurements. Their next insight was recognizing the life of microwave hardware is far longer than the currency of a computer. All commercial VNAs at the time had embedded computers and no way to upgrade without buying a new expensive VNA. So, the VNA would come with software but no computer, to avoid being locked into an obsolete processor. That same choice to separate the computer from the measurement hardware would enable the VNA to be small, even portable, and eliminating possible PC and peripheral failures would yield a lower lifetime cost.

The third insight the founders had was recognizing that a small upstart entering an industry dominated by large, established players needs instant credibility. In test and measurement, that means metrology: the new company's equipment and measurements must be traceable to national standards, so users have no doubt about the quality of the measurements.

From the founders' initial frustrations and subsequent insights, Copper Mountain Technologies was officially born in 2011, introducing the first low cost, metrology-grade, USB VNA. The company now offers more than 30 models with frequency coverage to 110 GHz — above 300 GHz using third-party extenders.

CMT is devoted to accurate measurements and the engineering precision required to achieve them. With a VNA, this is determined by the directional coupler, mixer, frequency source and step attenuator. Digital interfaces and basic measurement software complement the RF/microwave hardware, simplifying the measurement complexity for the user. Users can develop custom test routines in many languages, controlling the VNA with SCPI commands.

Building on a strong design foundation, CMT has a staff of five metrologists to assure the measurement quality of its VNAs. The company is accredited to the ISO/IEC 17025 standard for testing and calibration laboratories and has been certified by the National Institute of Standards and Technology (NIST) and the International Laboratory Accreditation Cooperation (ILAC).

You might think a low cost VNA offering high measurement quality would be sufficient. For CMT, that's just a start, seeing itself as an extension of the customer, its lab an extension of the customer's lab. CMT provides a measurement solution, not a product, and the team is not satisfied until the customer's measurement needs are met — even modifying equipment to support unique requirements when required. Thousands of VNAs have been shipped to global customers, quite a few to customers CMT assisted in developing a whole test solution.

During the almost 10 years since introducing that first USB VNA, CMT has grown to some 65 on staff — and growing — with headquarters in Indianapolis and a large development team based in the Ural Mountains of Russia, near The Copper Mountain, the oldest mine in the Urals. Customer feedback clearly shows the company is succeeding: meeting a market need for affordable, accurate vector measurements across the RF to mmWave spectrum.

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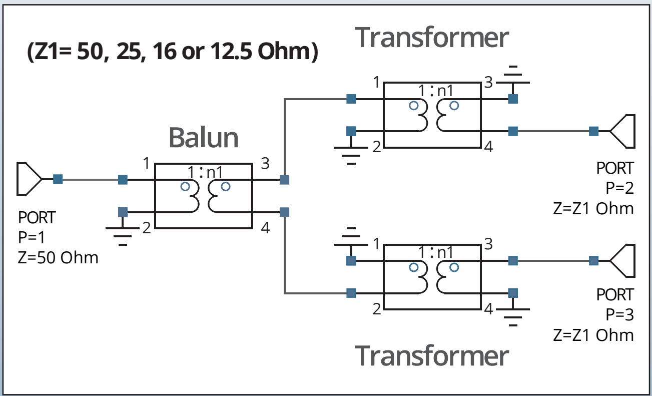
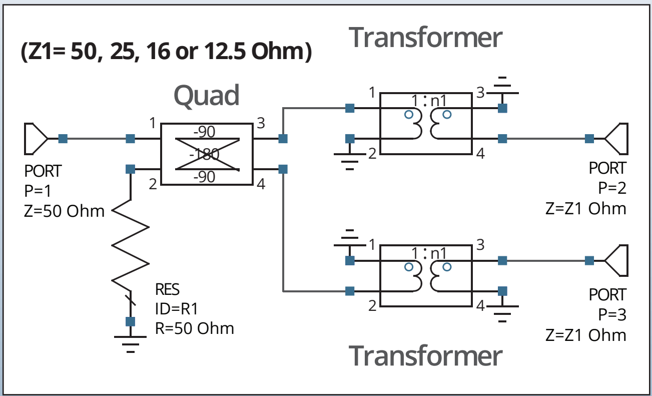
Reduced complexity and power dissipation facilitate the construction of compact high-power components. 100 Watts saved at the output, with a Werlatone device, can save 400 Watts of DC input power at the system level. The substitution of lower loss Werlatone components, at the output, can lower cooling cost and improve reliability.

Balun - Transformer Assembly



Quad - Transformer Assembly



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