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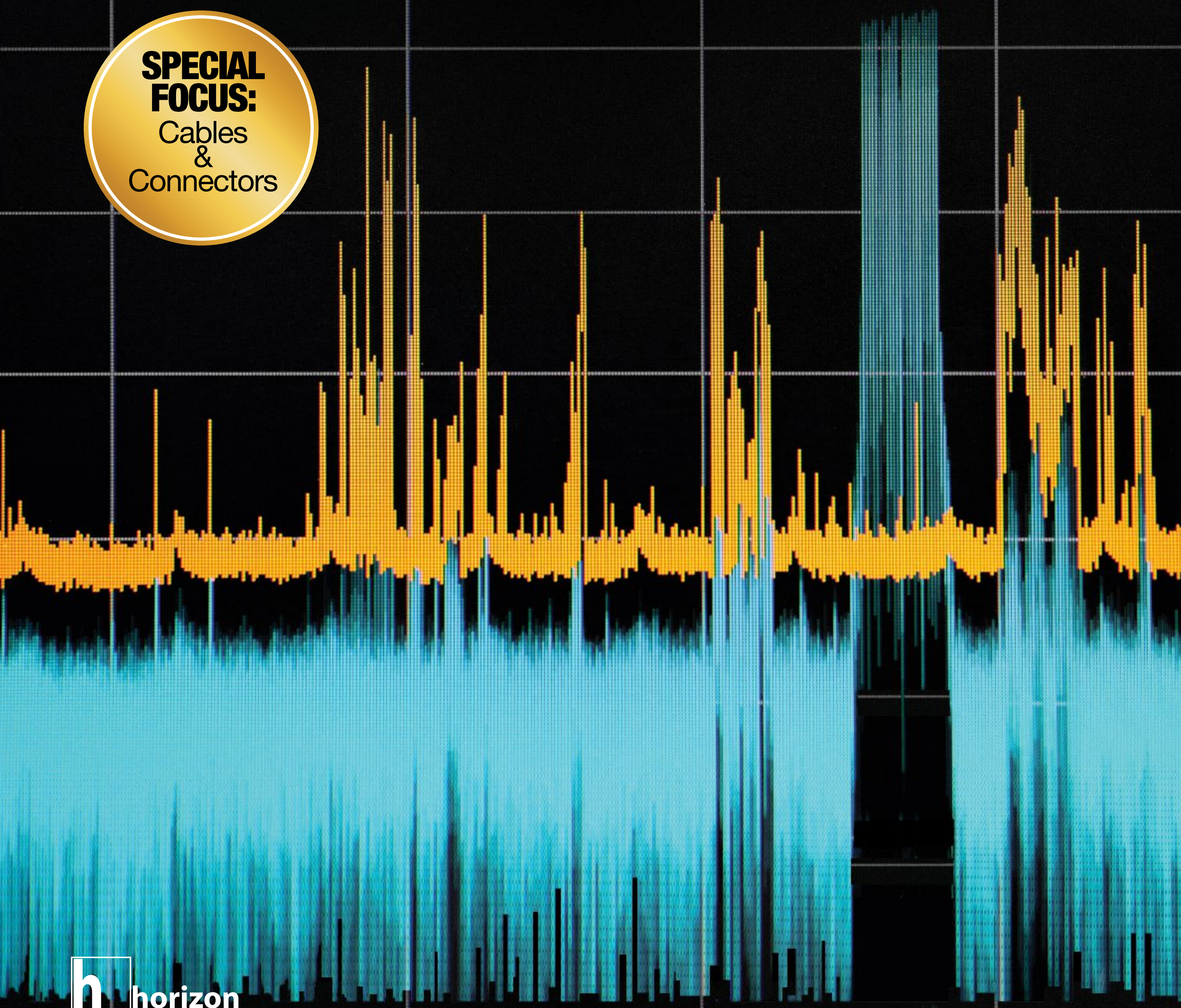

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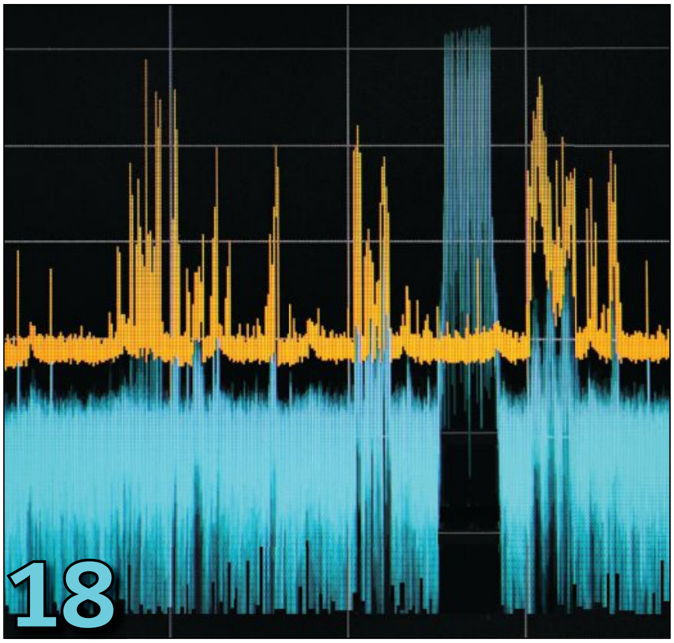

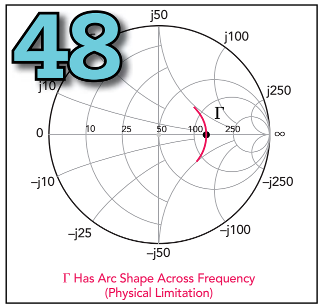

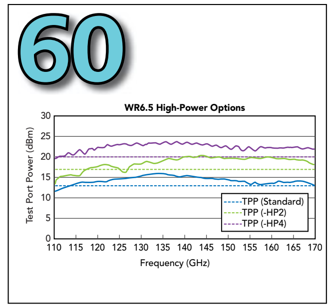

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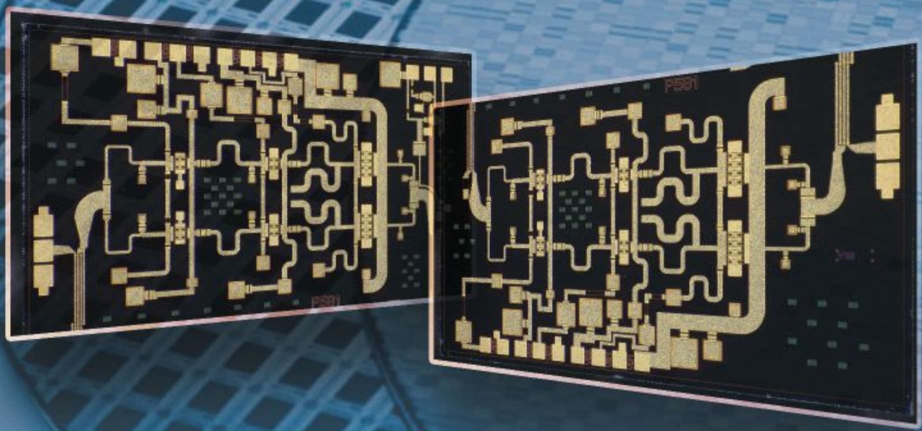


RF Distributed Low Noise Amplifiers

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

Low Noise Amplifiers

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

RF Driver Amplifier

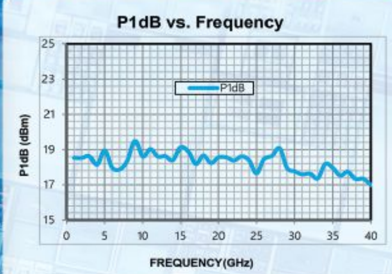
PN	Freq Low (GHz)	Freq High (GHz)	Gain (dB)	NF(dB)	P1dB (dBm)	Voltage (VDC)	Current (mA)	Package
MM3006	2.0	20.0	19.5	2.5	22.0	7.0	130	die
MM3014	6.0	20.0	15.0	-	19.5	5.0	107	die
MM3017T	17.0	43.0	25.0		22.0	5.0	140	die
MM3031T	20.0	43.0	20.0		24.0	5.0	480	die
MM3051	17.0	24.0	25.0	-	25.0	5.0	220	die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

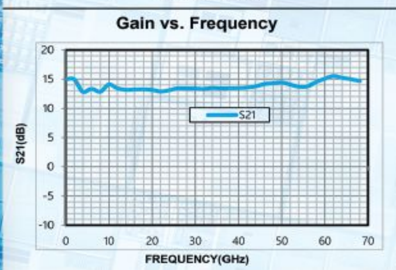
GaAs Medium Power Amplifier

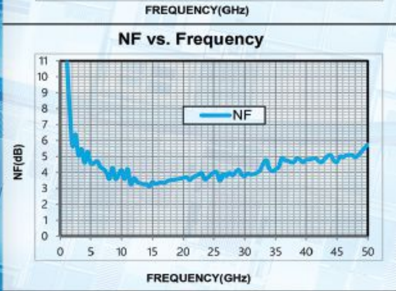
PN	Freq Low (GHz)	Freq High (GHz)	Gain (dB)	P1dB (dBm)	Psat (dBm)	Voltage (VDC)	Current (mA)	Package
MMP107	17.0	21.0	19.0	30.0	30.0	6.0	400	die
MMP108	18.0	28.0	14.0	31.5	31.0	6.0	650	die
MMP111	26.0	34.0	25.5	33.5	33.5	6.0	1300	die
MMP112	2.0	6.0	20.0	31.5	32.0	8.0	365	die
MMP501	20.0	44.0	15.0	27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

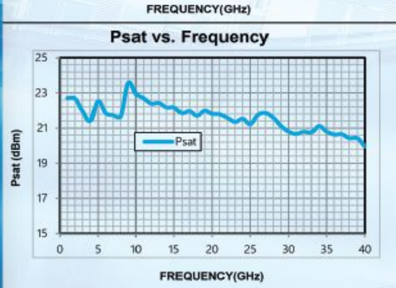
PN: MMW5FP

RF GaAs MMIC DC-67GHz









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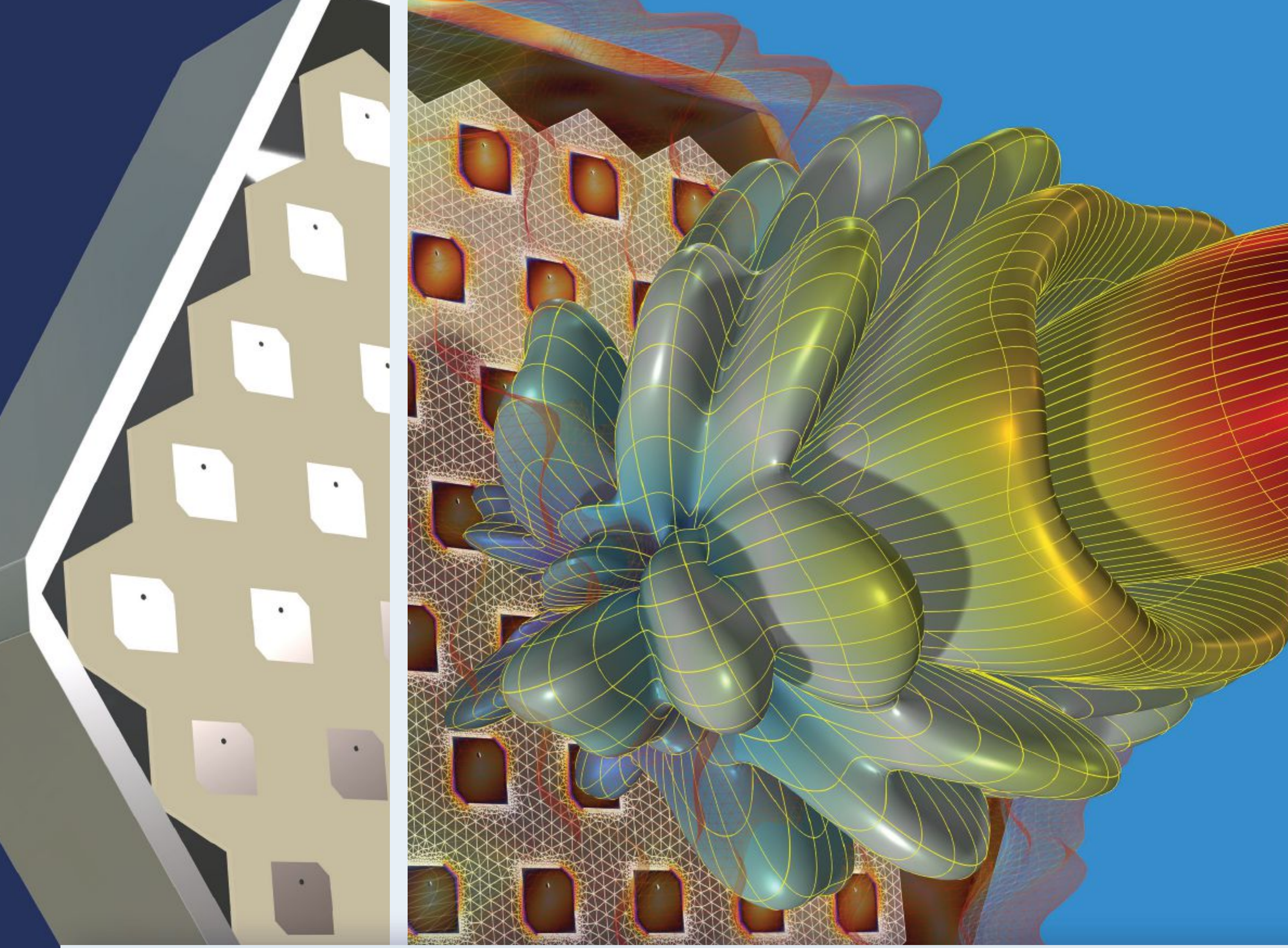

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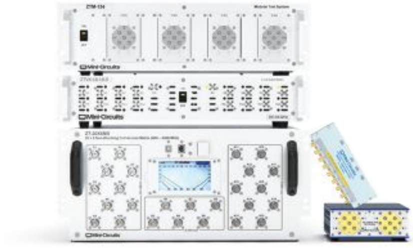

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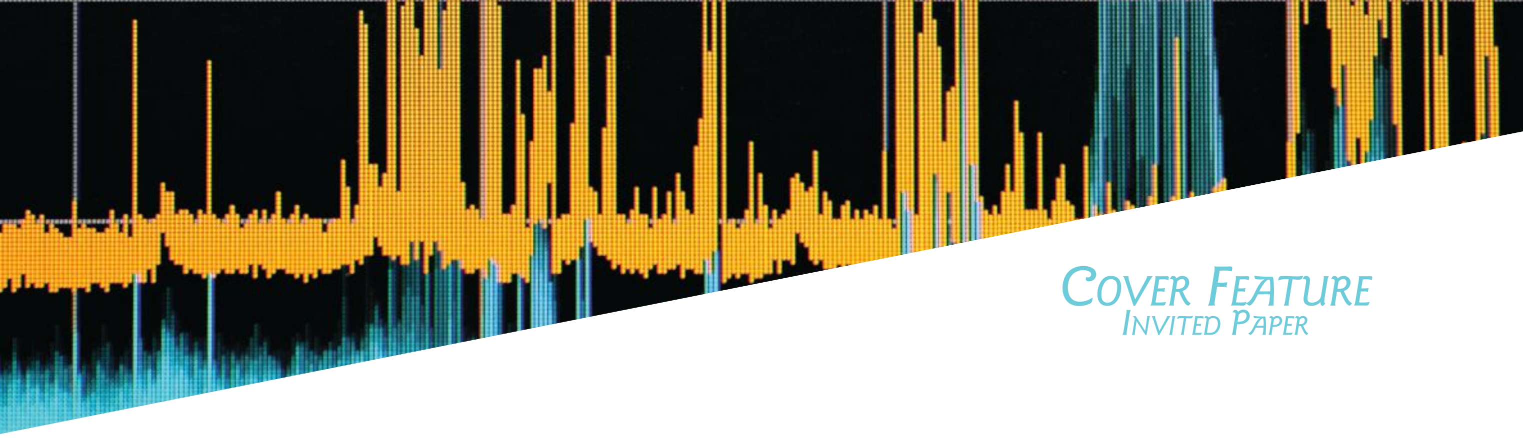

COVER FEATURE
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Noise-Related Technologies Climb Toward THz Territory

Andrew Laundrie
Eravant, formerly Sage Millimeter Inc., Torrance, Calif.

Noise sources and noise analyzers are essential tools for testing and calibrating a wide variety of radar, communication and test systems. They are also vital for characterizing individual components and chip-scale electronic devices. At frequencies from MHz to THz, broadband noise sources are needed to measure the noise performance of amplifiers and receivers. They provide signals for testing digital radios and networks and they frequently support built-in test functions in radars and radiometric receivers. Amplified noise sources are commonly used as jamming signals in electronic countermeasures and emerging applications include gas and material composition detectors and broadband imaging systems.

At mmWave and sub-THz frequencies, electronic noise sources typically use an active device combined with a matching circuit and an attenuator or an isolator to match the output port to a standard impedance or waveguide type. In their most common configuration, electronic noise sources provide two calibrated noise power levels for measuring the performance of receivers and various other types of components and systems. A "hot" noise level is generated when the active device is turned on, while a "cold" noise level is produced when the active device is off.

An ideal noise source generates Gaussian random noise over a flat frequency spectrum with a negligible output mismatch to the reference termination.[1-6] Many coaxial and waveguide noise sources are available for mmWave frequencies with many reaching 110 GHz. A summary of representative noise sources from a variety of manufacturers is shown in ***Table 1***.

At higher frequencies, fewer options exist. Fortunately, waveguide noise sources are now increasingly being offered at frequencies ex-

TABLE 1
MMWAVE NOISE SOURCES

Manufacturer	Model	Frequency (GHz)	ENR (dB)	VSWR	Interface
Elva-1	ISSN-03	220 to 330	26 to 55	N/A	WR-03 waveguide
Eravant	STZ-22427410-03-IT2	220 to 270	7 to 13	1.6:1	WR-03 waveguide
Keysight	Q347B	33 to 50	9 to 17	1.5:1	WR-22 waveguide
NoiseCom	NC 3210M	2 to 110	>15	1.6:1	1.0 mm coaxial
NoiseWave	NW75G110-W	75 to 110	>15	1.6:1	WR-10 waveguide
VDI	WR5.1NS	140 to 220	8.5	N/A	WR-5.1 waveguide


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ceeding 200 GHz. ***Figure 1*** shows a noise source from Eravant that operates to 270 GHz. Electronic noise sources are commonly used with signal analyzers to perform noise figure measurements. Important specifications include excess noise ratio (ENR) flatness and output return loss. Isolators are often included to improve the output match and stabilize the noise output level.

Fig. 1 **Eravant noise source.**

Fig. 2 **Noise calibration system with reference termination immersed in liquid nitrogen. *Source:* Maury Microwave.**

THERMAL NOISE SOURCES

Thermal radiation sources have been used for calibration since Max Planck presented his theory of heat radiation in 1900. At mmWave and THz frequencies, matched terminations are often cooled with liquid nitrogen or heated with boiling water to produce primary noise references. However, "stem corrections" are typically applied to account for noise contributed by transmission lines and anything else in the signal path between the thermal source and the noise receiver.[6] Despite such complications, thermal reference standards are widely used to calibrate noise sources and receivers.

Hot and cold thermal noise standards are available, either individually or integrated into more functional noise calibration systems.[7] Cold reference sources typically include a coaxial or waveguide termination placed inside an insulated Dewar flask. The flask is filled with liquid nitrogen maintained at its boiling point. A regulated heater controls the temperature profile of a coaxial or waveguide transmission line that connects the cold termination to a room temperature user interface. An example of this type of precision noise calibration system is shown in ***Figure 2***.

Thermal noise standards are often characterized by an effective noise temperature that is slightly above or below the temperature of the termination. The noise contribution from an element in the signal path may be estimated as shown in Equation 1:

$$T_E * (1 - G) \qquad (1)$$

Where:

T_E is the temperature of the element

G is the gain factor of the element

To illustrate, a transmission line with a gain factor of 0.99 (0.04 dB attenuation) held at a temperature of 200 K would add 2 degrees to the effective noise temperature of the source. A more rigorous analysis would model the signal path as a cascade of circuit elements with different temperatures.[8]

Cold thermal sources are also constructed from absorbing materials that are cooled with precision temperature controllers.[9] The thermal noise radiated by such structures is typically coupled to a receiver through an antenna with both units operating in a condensation-free environment. ***Figure 3*** shows a thermal noise source with a conical mmWave absorber. The temperature of the absorber is controlled with a circulating fluid.

Fig. 3 **Thermal noise source with conical mmWave absorber.** ***Source:*** **TK Instruments Ltd.**

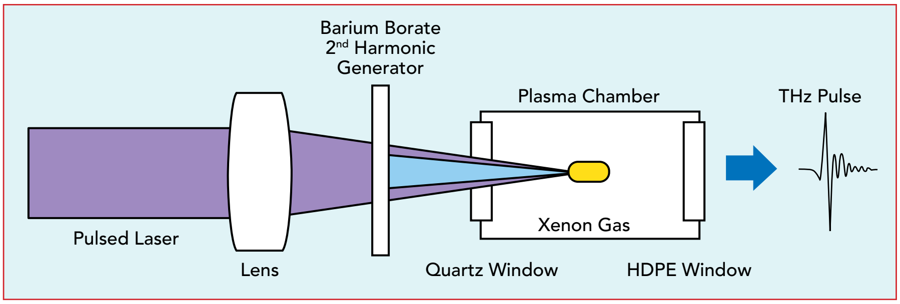


Fig. 4 **Functional diagram for THz pulses created by optical excitation.**

ELECTRONIC NOISE SOURCES

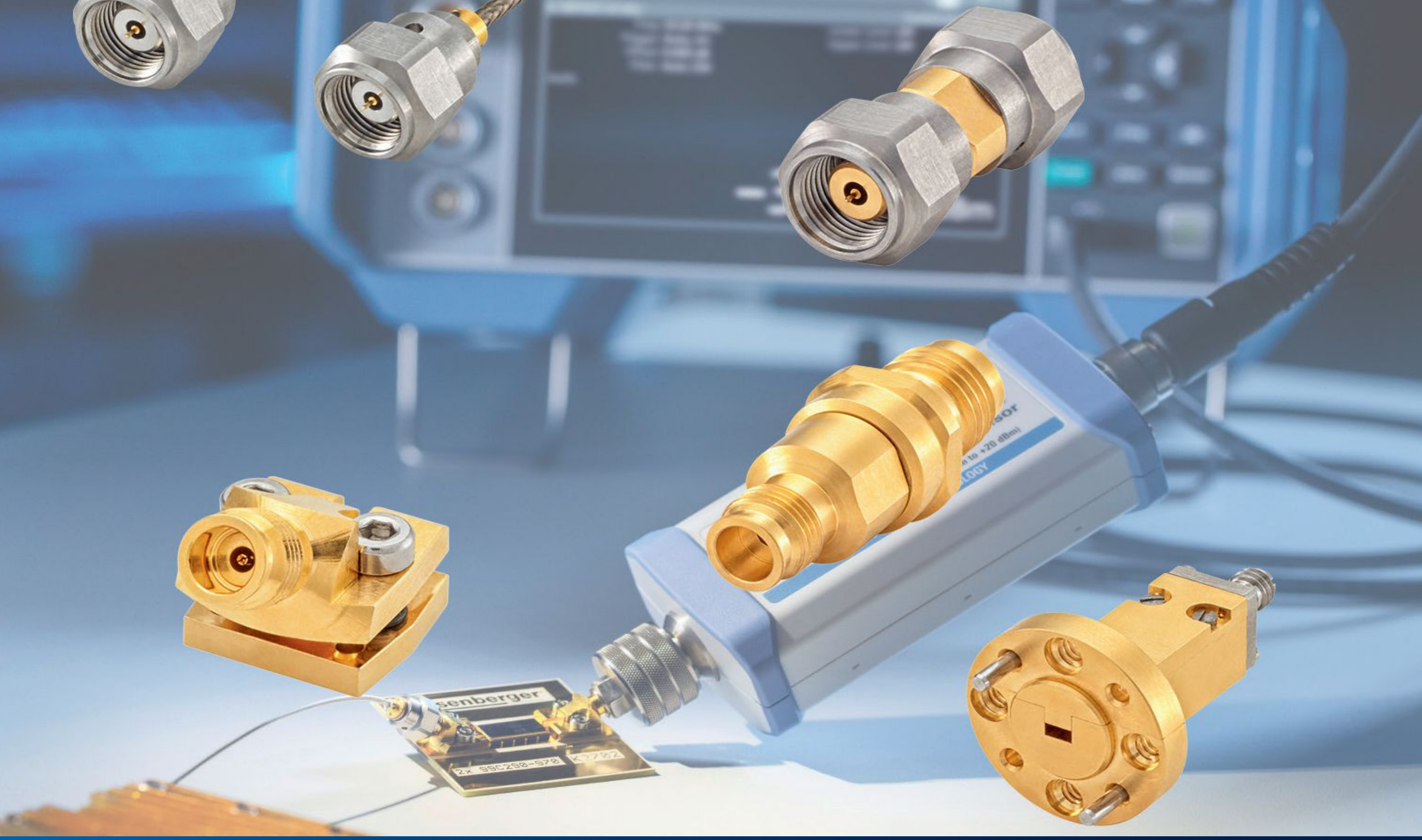
Some of the earliest electronic noise sources were constructed with gas discharge tubes mounted inside waveguides.[10] Gas discharge tubes are still used today, but they are much less common. More recently, laser-induced plasmas in noble gases have produced extremely fast THz signal pulses.[11] Optical mixing in photodiodes also produces THz signals. A functional rendition of this idea is shown in ***Figure 4***, where THz pulses are produced when optical power at different wavelengths excites a plasma in a chamber filled with a noble gas. Another type of THz noise generator applies multiple optical signals at different wavelengths to a high speed photodiode.[12,13] The photodiode mixes the spontaneous emission noise produced by a super-luminescent LED. While such technologies appear to be in early development stages, they offer hope that THz noise sources suitable for laboratory use are on the horizon.

By the late 1970s, solid-state devices started replacing gas discharge tubes.[14,15] The sources exploit the shot noise generated in avalanche diodes and other semiconductor devices. Recent developments with avalanche diodes in silicon carbide show promise for improved high frequency performance as signal sources.[16] Field-effect transistors of various types can also be used to generate controlled levels of broadband noise.[17] At mmWave and sub-THz frequencies, suitable transistors may include GaAs FETs, InP HEMTs and GaN HEMTs. When suitably biased, such devices can produce significant levels of broadband noise.

Noise sources used for noise figure measurements must be turned on and off repeatedly. The source mismatch should be small and more importantly, unchanged between the on and off states. Different noise temperatures are observed depending on whether the source is on (hot) or off (cold). Noise sources are generally characterized by their ENR, as well as a reference termination; either a nominal impedance or a standard waveguide size.

The ENR defines the hot noise level relative to the cold noise level when the source is held at a reference temperature of 290 K.[18] The ENR is generally a frequency-dependent quantity. For noise figure measurements and many other applications, the ENR should be as flat as possible and the source mismatch should be as small as possible.

The ENR is an important consideration when choosing a noise source. As a rule of thumb, a noise



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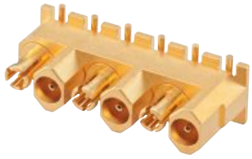

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source is suitable for measurements of noise figures that are up to the ENR value plus about 10 dB.[19] For higher device under test (DUT) noise figures, the difference between measured power levels for the hot and cold noise signals becomes too small to yield accurate results. However, a lower ENR should be used when possible because it tends to avoid overdriving the DUT and the receiver. Available noise sources tend to have ENR values around either 6 or 15 dB.

NOISE SOURCE CALIBRATION

Electronic noise sources are calibrated using a variety of instruments including spectrum analyzers, noise figure meters, signal analyzers and network analyzers. Any suitable instrument must have a sensitive receiver that can measure noise levels over an adequate bandwidth with sufficient linearity and dynamic range. For automated measurements, the instrument should also be capable of controlling a two-level noise source while simultaneously measuring the received power for each noise level.

Many older-model noise figure analyzers, such as the Agilent N8970 series, are essentially spectrum analyzers with additional built-in functions for measuring noise power levels and performing noise figure measurements. Newer signal analyzers, which combine the traditional functions of a spectrum analyzer with a wide range of other measurement capabilities, are rapidly becoming the tools of choice for performing noise measurements. Some of these newer signal analyzers are shown in ***Table 2***.

TABLE 2

SIGNAL ANALYZERS FOR Y-FACTOR NOISE MEASUREMENT

Manufacturer	Model	Frequency
Anritsu	MS2850A	9 kHz to 44.5 GHz
Keysight	N9041B	2 Hz to 110 GHz
Rohde & Schwarz	FSW	9 kHz to 85 GHz

The Y-factor method is a well-established measurement technique for calibrating noise receivers and noise sources. It uses a pair of noise sources or a single source that provides two different noise levels. When the Y-factor is expressed linearly, it is equal to the hot noise power divided by the cold noise power, as measured by the receiver.

When a receiver is calibrated, its noise figure is obtained by performing a Y-factor measurement with a calibrated noise source connected to its input. The measurement is usually repeated each time the receiver is used and certainly whenever the measurement bandwidth changes or when the attenuation or gain settings are changed. The amplitude response of the receiver is separately calibrated using a reference signal generator, a reference power detector and/or a set of reference attenuators. Amplitude calibrations are typically performed infrequently according to a maintenance schedule or when the operating environment changes significantly.

After the noise receiver is calibrated, it can be used

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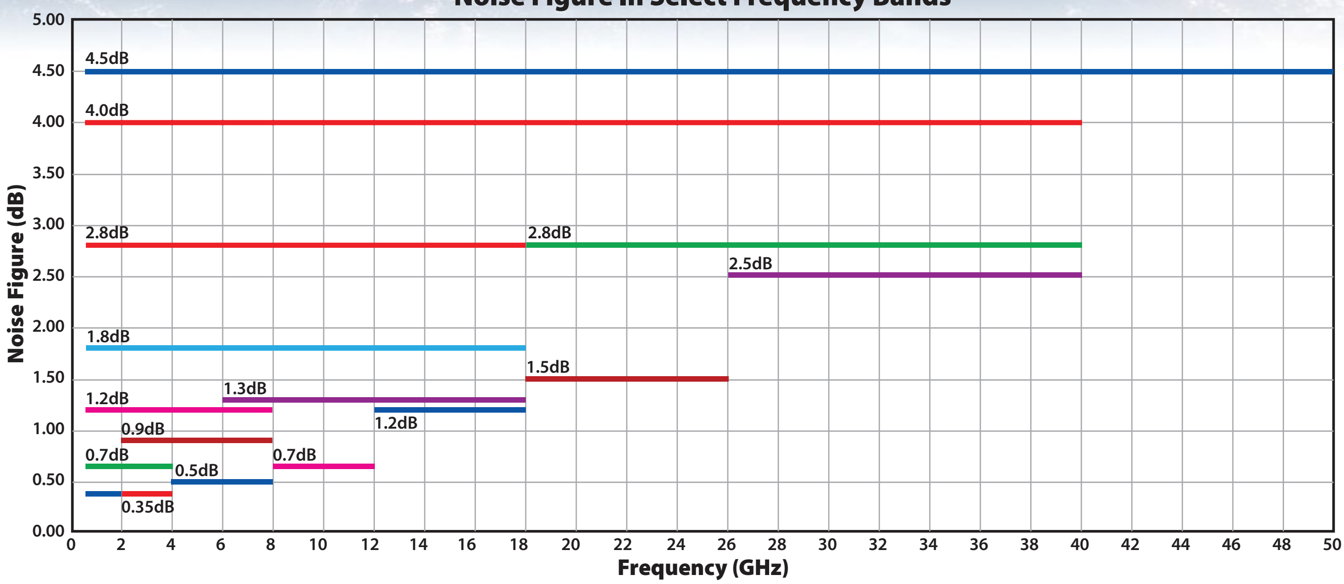

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to perform additional Y-factor measurements and determine the ENR of an uncalibrated noise source. The calibration accuracy of the reference standard is partially transferred to the noise receiver and then partially transferred to the uncalibrated noise source. Analyzing the cumulative effects of measurement uncertainty is one of the more difficult tasks associated with noise source calibration.

Advantages of the Y-factor calibration method include its relative simplicity and its acceptable accuracy, in most cases. Power ratio measurements can be obtained quickly, minimizing the effects of temperature drift in the receiver response. However, basic Y-factor measurements typically do not compensate for mismatch effects and various other sources of measurement uncertainty.

Many studies have focused on analyzing and improving the accuracy of noise source calibrations.[20-22] Suggested enhancements can improve calibration results by applying considerably more effort in both measurements and calculations. By compensating for the measured effects of mismatches, the receiver noise parameters and temperature drift, one study achieved a two-sigma calibration accuracy of 0.046 dB for a noise source with an ENR of 5 dB.

The cold source measurement technique was developed as an alternative to the Y-factor method.[23] Measurements are performed using a single reference noise level provided by a matched termination at room temperature. The cold source method relies on knowing the scattering parameters of the DUT.[24,25] The accuracy of cold source measurements is generally superior to that of Y-factor measurements when the latter includes mismatch compensation.[26] Additionally, the minimum noise figure and the noise parameters of a DUT can be obtained by performing multiple cold source noise figure measurements with different mismatches connected to the DUT input.

Cold source noise figure measurements require absolute noise power measurements, necessitating more accurate receiver calibrations. The measurement bandwidth must be known as well. Whereas the Y-factor method produces both the gain and noise figure of the DUT in one set of measurements, cold source noise figure measurements require independent gain measurements.

Because cold source noise figure measurements involve far more measurements and data manipulation than traditional Y-factor methods, they are usually performed using a fully integrated and automated test system. Some newer vector network analyzer (VNA) models include the ability to perform cold source noise figure measurements. Examples of these VNAs are shown

TABLE 3

EXAMPLES OF VNAS FOR COLD SOURCE NOISE MEASUREMENTS

Manufacturer	Model	Frequency
Anritsu	MS4647B	10 MHz to 70 GHz
Keysight	N5244B	10 MHz to 44 GHz
Rohde & Schwarz	ZNA67	10 MHz to 67 GHz

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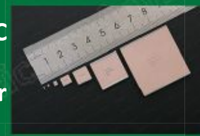

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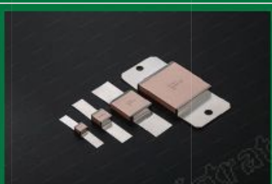

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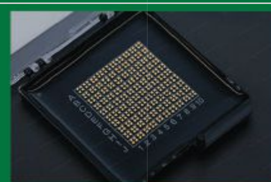

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in ***Table 3***. At frequencies beyond the operating range of VNAs, Y-factor measurements remain the most common method of performing receiver calibrations, noise source calibrations and noise figure measurements.

EXTENDED FREQUENCY COVERAGE

Most receivers that measure RF noise do so by converting input signals to an intermediate frequency (IF) where they are filtered, amplified and fed to a square-law detector or an analog-to-digital converter. To measure noise at frequencies beyond the limit of a given signal analyzer, an external down-converter can be used. Many general-purpose down-converters are suitable for this task.

If the down-converter uses a fixed local oscillator (LO) frequency, the noise receiver/analyzer is operated essentially the same as when measuring lower frequency signals. To preserve measurement accuracy, the noise figure of the down-converter should be comparable to that of the noise receiver. The down-converter should also provide adequate image rejection and good suppression of spurious signals.

Many down-converters built specifically for extending the frequency range of a noise analyzer are designed to accept a swept-frequency LO signal supplied by the analyzer. A frequency multiplier within the down-converter produces a higher-frequency LO signal. The result is a fixed IF for the down-converted signal fed back to the analyzer. This measurement strategy reduces the number of frequency conversions between the noise source and the IF amplitude detector, resulting in less measurement uncertainty.

Down-converters designed to extend the frequency range of noise figure analyzers are typically offered with a matching calibrated noise source. Available models provide full-band coverage up to 270 GHz. Full waveguide band coverage is generally provided with available models covering frequencies up to 170 GHz. An example of this setup is shown in ***Figure 5***.

CONCLUSION

Fundamental aspects of noise generation and measurement remain firmly grounded while noise sources and instrumentation advance toward THz capabilities. At frequencies up to about 110 GHz, noise sources and the instrumentation required to measure noise are available from multiple manufacturers. At higher frequencies, industry support is somewhat harder to find. Fortunately, newer sources produce noise signals beyond 200 GHz and newer technologies may soon pro-

Fig. 5 **Frequency extenders for noise figure analyzers.**

vide high-quality noise sources at THz frequencies. Meanwhile, high performance down-converters are available to extend the frequency coverage of existing noise measurement tools. ■

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Advanced Multilayered Mobile Force Protection Excels at MFIX Demo

Leidos and the U.S. Army Combat Capabilities Development Command (DEVCOM) Aviation and Missile Center's (AvMC) Advanced Multilayered Mobile Force Protection (AM2FP) team demonstrated the successful operation of its counter–small unmanned aerial system (C-sUAS) at the Maneuver and Fires Integration Experiment (MFIX) 2024. The AM2FP correctly tracked and identified 100 percent of the presented threats in the presence of clutter. No false negatives or positives were generated by the system during the MFIX flight tests. The AM2FP was the only C-sUAS system that demonstrated tracking and identification of single threats and swarms while operating on-the-move.

The MFIX 2024 event brought together customers from the U.S. Army and Department of Defense to showcase new advancements and performance improvements in the C-UAS field. The AM2FP team improved its performance from last year's demonstration while also highlighting an additional integration with the Army's Forward Area Air Defense Command-and-Control (FAAD C2) architecture. Significant innovations in radar performance and threat discrimination were also validated using targets and design reference missions provided by the government.

Leidos' AM2FP work began under the Defense Advanced Research Projects Agency (DARPA) Mobile Force Protection program. The program featured a multi-layer defense architecture to defeat unauthorized drone intrusions over fixed-base military installations and on-the-move operations. To meet this need, Leidos developed several capabilities, including the Multifunction X-Band Radar (MXR), an X-Band active electronically scanned array radar and a system deploying two types of reusable interceptors. The AM2FP system is designed to autonomously track and disable enemy sUAS while minimizing the risk of collateral damage, even in challenging and complex scenarios. Leidos also created the Co-axial Unmanned Guided Autonomous Rotorcraft (CUGAR). This highly reusable, low-cost, low regret, low collateral, autonomous interceptor demonstrated the defeat of Group 1 and 2 sUAS threats.

The current contract for upgrades to the MXR sensor, CUGAR interceptor and the C2 system is managed by the U.S. Army DEVCOM AvMC Radar Operations Facility at Redstone Arsenal in Huntsville, Ala. The U.S. Army DEVCOM AvMC provides increased responsiveness to the nation's warfighters through aviation and missile capabilities and life cycle engineering solutions.

MFIX (Source: Leidos)

GA-ASI Demos Autonomy for UCAV Using MQ-20 and Waveform X

General Atomics Aeronautical Systems, Inc. (GA-ASI) demonstrated its hardware-agnostic, open standards-based autonomy ecosystem for unmanned combat air vehicles (UCAVs) on a GA-ASI MQ-20 Avenger® as part of a live flight test on November 13, 2023. The flight included three software-defined radios (SDRs) from L3Harris Technologies to support line-of-sight, command-and-control and data movement capabilities via Waveform X.

One SDR, an L3Harris' Pantera, was integrated into the MQ-20 unmanned aircraft and a second was on the ground working in concert with a third L3Harris SDR, BANSHEE 2, which was on the ground as part of the Mission Control Element, forming an IP-based mesh network. The demonstration showcased Waveform X, a non-proprietary U.S. government-owned communications capability, and the ability to fly, flip, fly flight hardware as part of the Open Mission Systems and skills based unmanned autonomy ecosystem.

MQ-20 (Source: General Atomics)

The flight demonstrated the ability to rapidly plug and play both U.S. Navy and U.S. Air Force (USAF) autonomous unmanned technologies together. It further leveraged autonomy from three separate sources: government-provided human-machine interface hardware, GA-ASI's autonomy core and orchestration of these components using Waveform X.

Autonomy skills were used to meet multiple objectives for collaborative combat missions and close the find, fix, track, target, engage and assess (F2T2EA) engagement chain using a mix of live, virtual and constructive entities. The flight, which took place at GA-ASI's Desert Horizon Flight Operations Facility in El Mirage, Calif., illustrates the company's commitment to maturing future autonomous collaborative platform technologies using the MQ-20 as a flying test bed.

An important goal of GA-ASI's flights is to demonstrate the company's commitment to developing an open government standards-based autonomy ecosystem that enables rapid integration and validation of

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third-party tactical software applications. GA-ASI is focused on supporting the emerging government-managed app store-based model that allows organizations to rapidly develop and deploy software while maintaining safety of flight and ensuring warfighters have up-to-date access to the industry's best capabilities.

RTX Raytheon's GhostEye MR Proves Operational Readiness During USAF Exercise

Raytheon, an RTX business, in partnership with the U.S. Air Force (USAF) Research Laboratory's Strategic Development Planning and Experimentation office and Kongsberg Defence & Aerospace, demonstrated the operational performance and readiness of the GhostEye® MR advanced medium-range sensor for the National Advanced Surface to Air Missile System (NASAMS) during an extended exercise at White Sands Missile Range.

GhostEye MR expands NASAMS' combat-proven capabilities against enemy aircraft, unmanned aircraft systems and cruise missile threats. Raytheon designed and developed the radar primarily through internal research and development investments. During the recent exercise, GhostEye MR was successfully integrated with NASAMS' Air Defense Console and the Battlespace Command-and-Control Center (BC3), a command-and-control element used by the USAF.

In a configuration designed as an air base air defense solution for the USAF, all three system components communicated effectively, sharing information and relevant data during a live threat scenario. GhostEye MR provided a comprehensive air picture for the command-and-control system to determine whether a target was a threat and what response was required. Additionally, the radar supported simulated engagements and, with NASAMS, successfully defeated the targets.

This demonstration also builds on last year's successful air base air defense experiment in Andøya, Norway, that showcased NASAMS' ability to engage and intercept various aerial threats using multiple Raytheon missile types and Kongsberg Defence & Aerospace's Fire Distribution Center.


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"Beyond 5G & 6G Roadmap" for EU-U.S. Collaboration

ATIS' Next G Alliance, the North American voice for 6G, and the 6G Industry Association (6G-IA), the private member of the EU Smart Networks and Services Joint Undertaking (SNS JU), recently announced publication of the "EU-U.S. Beyond 5G/6G Roadmap," a major first step in affirming the two regions' commitment to collaborating in the development of 6G networks. The document results from a request for the two organizations to provide an interim, joint, aligned 6G industry roadmap made during the fourth Ministerial meeting of the EU-U.S. Trade and Technology Council (TTC), which took place in Luleå, Sweden, on May 31, 2023. The collaborative input to the roadmap will be considered for inclusion in a TTC 6G "shared vision" being established by the U.S. and EU governments.

According to the joint statement between the two government administrations, "With this TTC 6G common vision as a basis, we aim to scale up the existing R&D cooperation on 6G between the U.S. and EU funding agencies, namely the SNS JU and the National Science Foundation, create a critical mass among like-minded partners in global regulatory and standardization bodies and cooperate in technology trials and pilots to foster market adoption."

> A foundation for collaboration is important to successfully driving a global vision of success for 6G.

The document "EU-U.S. Beyond 5G/6G Roadmap" contains a set of key strategic observations and recommendations for 6G networks and services, capturing the views and priorities from the Next G Alliance and the SNS JU. It offers a candidate roadmap for future opportunities through EU and U.S. funding. It also aims to provide directions for collaboration opportunities that will go beyond the scope of funding, assisting the academic and business stakeholders between the two sides of the Atlantic to identify mutually beneficial opportunities.

"6G will enable the delivery of transformational services and experiences with the potential for improving the daily lives of people around the world," said David Young, ATIS vice president of technology and solutions and managing director of the Next G Alliance. "The guiding principles and priorities outlined in this document provide a foundation for collaboration which will be important to successfully driving a global vision of success for 6G."

5G Americas Explores 3GPP's Release 18 and Beyond in 5G-Advanced

The transformative potential of 3GPP's current trends and technologies are focused on positively reshaping our daily lives. 5G Americas has released a white paper titled "3GPP Technology Trends," which provides a detailed overview of the 3rd Generation Partnership Project (3GPP) and its journey toward 5G-Advanced that begins with Release 18 (NR Rel-18).

Chris Pearson, president, 5G Americas said, "The enhancements brought forth in 3GPP Release 17, such as improved uplink coverage, precision in positioning and robust power-saving features, signify more than just technological advancements. They represent a leap toward a future where connectivity is both ubiquitous and seamlessly integrated into our daily lives."

> A pivotal moment in mobile communication, initiating the seamless convergence of digital and physical realms

The document underscores pivotal progressions in NR Rel-17, emphasizing their transformative effects on cellular networks and the wider technology arena. It sets the stage for delving into 5G-Advanced distinguished by groundbreaking applications including the metaverse (encompassing extended reality (XR) and digital twins), reduced capacity (RedCap), integrated sensing and communication (ISAC) and ambient IoT. Moreover, it accentuates the critical role of artificial intelligence (AI) and machine learning (ML) in facilitating the transition from 5G-Advanced to the nascent 6G epoch.

Dr. Christina Chaccour, network solutions manager at Ericsson and working group co-leader of the white paper stated, "5G Advanced, heralded by 3GPP Release 18 and beyond, marks a pivotal moment in mobile communication, initiating the seamless convergence of digital and physical realms. This transformative era witnesses the convergence of XR, ISAC and the profound influence of AI and ML on networks, sparking innovation and redefining connectivity."

5G-Advanced and 6G Networks Will Need Additional Spectrum

Developing a comprehensive roadmap for the new commercially available spectrum is necessary to ensure the successful deployment of future mobile networks. 5G Americas has released a white paper titled, "The Evolution of 5G Spectrum" that pro-

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> "Releasing more licensed spectrum for the wireless industry is critical for U.S. leadership in technology, mobile communications and the economy"

vides insights into the future of mobile networks, emphasizing the critical role of licensed spectrum for the successful rollout of 5G-Advanced and future 6G capabilities.

Chris Pearson, president, 5G Americas said, "Releasing more licensed spectrum for the wireless industry is critical for U.S. leadership in technology, mobile communications and the economy. An industry roadmap for more spectrum helps ensure effective deployment of future networks and drive the emergence of groundbreaking technologies."

Balancing both licensed and unlicensed spectrum is vital for the mobile industry. The upper mid-band spectrum, ranging from 7.125 to 15.35 GHz, is key to leveraging existing infrastructure for increased capacity. 5G Americas emphasizes identifying new spectrum integral to a U.S. National Spectrum Strategy pipeline, ensuring rapid commercialization and sustained technological leadership.

"5G Americas supports the 7.125 to 15.35 GHz spectrum range, especially below 10 GHz, for licensed mobile operations for its balance in capacity and coverage. Opening bands in this range involves exploring relocations and sharing strategies. Additionally, mmWave bands are important for deployments in dense locations like urban cores, transportation depots, busy streets and entertainment venues and for fixed wireless access deployments. Sub-THz bands offer very large bandwidths that may be suitable for specialized use cases," said work group co-leader Aleksandar Damnjanovic, principal engineer/manager at Qualcomm Technologies Inc.

The International Telecommunication Union (ITU) for International Mobile Telecommunications (IMT)-2030 has codified various usage scenarios that form the basis for spectrum needs. These scenarios highlight the necessity for high data rates and wide-area coverage for applications like immersive experiences, next-generation healthcare monitoring, human-machine interfaces and joint communications and sensing.

"In response to an expected four-fold cellular network traffic increase by 2028, the ITU World Radiocommunication Conference recently decided to identify spectrum in the 4.4 to 15.5 GHz range for future wireless technology deployments. The wireless industry needs access to more spectrum to support new applications like XR, connected cars and the metaverse," said work group co-leader Brian Olsen, senior manager, technology development and strategy at T-Mobile USA.

Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

IN MEMORIAM

Zvi Galani was born on October 21, 1936, in Warsaw, Poland, and passed away on January 13, 2024, in Bedford, Mass. He received a B.S.E degree from the Milwaukee School of Engineering in 1963 and the M.S. and Ph.D. degrees in electrical engineering from Cornell University in 1969 and 1972, respectively. In 1972 he accepted the position of Senior Design Engineer with Raytheon Missile Systems Division, Bedford Laboratories. From 1976 to 1982, he managed the sources and devices section in the Missile Microwave and antenna department of the Missile Guidance Laboratory. He held numerous patents and has authored many papers on microwave sources, power FET amplifiers and amplifier combiner circuits.

MERGERS & ACQUISITIONS

Qorvo® announced it has reached a definitive agreement to acquire **Anokiwave**. The transaction is expected to close during the March quarter. Anokiwave is based in Boston, Mass., and operates design centers and sales offices in Boston, Mass., and San Diego, Calif. The Anokiwave team will join Qorvo's High Performance Analog segment and will continue to develop beamformers and IF-RF solutions for defense phased array and AESA radar, electronic warfare, satellite communications and 5G applications.

Amphenol Corp., a global provider of high-technology interconnect, antenna and sensor solutions, announced a definitive agreement to acquire the **Carlisle Interconnect Technologies (CIT)** business of Carlisle Companies Incorporated for $2.025 billion in cash, subject to customary post-closing adjustments. CIT is a leading global supplier of harsh environment interconnect solutions primarily to the commercial air, defense and industrial end markets, and is expected to have 2024 sales and an adjusted EBITDA margin of approximately $900 million and 20 percent, respectively. The company's wide range of products, including wire and cable, cable assemblies, contacts, connectors and sensors, are highly complementary to Amphenol's existing interconnect and sensor solutions.

Synopsys and **Ansys** announced that they have entered into a definitive agreement under which Synopsys will acquire Ansys. Under the terms of the agreement, Ansys shareholders will receive $197.00 in cash and 0.3450 shares of Synopsys common stock for each Ansys share, representing an enterprise value of approximately $35 billion based on the closing price of Synopsys common stock on December 21, 2023. Bringing together Synopsys' pioneering semiconductor electronic design automation with Ansys' broad simulation and analysis portfolio will create a leader in silicon to systems design solutions.

COLLABORATIONS

Anritsu and **ASUS** have announced a partnership to validate the latest wireless communications standard, IEEE 802.11be (Wi-Fi 7) 320 MHz performance testing. This series of tests utilizes the Anritsu Wireless Connectivity Test Set (WLAN Tester) MT8862A in Network Mode and the ASUS ROG Phone 8 series smartphones.

OQ Technology and **Round Solutions GmbH** signed a strategic partnership to enable the two parties to sell and promote each other's products and services in global satellite standard 3GPP NTN NB-IoT connectivity for machines and devices in remote and rural areas. The two companies will work together to cross-market their products and services, test OQ modules and devices, integrate them into both companies' solutions and promote them in the DACH region and provide early access to new products and services such as the IO-GATE.

NEW STARTS

Reticulate Micro Inc., a defense technology company dedicated to delivering trusted and resilient communications over any transport and in any environment, has announced the formation of Reticulate Space, its new business segment focused on bringing to market breakthrough multi-orbit satellite communications management technologies for government and commercial users. Reticulate Space will initially focus on defense and selective commercial opportunities, including first responders, broadcasters and in-flight connectivity and mobility providers. Reticulate Space's product platform shares Reticulate Micro's open-source architecture approach and incorporates its VAST™ video compression technology.

ACHIEVEMENTS

In December, **Keysight** and researchers from France's Centre national de la recherche scientifique (CNRS), Lille University and Osaka University announced they had broken the 1 Tbps barrier. In a paper presented at the Asia-Pacific Microwave Conference, professors Guillaume Ducournau and Tadao Nagatsuma detailed this achievement using a system built with a combination of terahertz photodiodes and an electronics-based receiver covering a range of 500 to 724 GHz. In this frequency band, they used channel aggregation with 14 carriers and a range of 16 to 64 quadrature amplitude modulation to achieve a total data throughput of 1.04 Tbps.

The Air Force Research Laboratory and **Raytheon**, an RTX business, have successfully completed a three-week field test of the Counter-Electronic High-Power Microwave Extended-Range Air Base Defense (CHIMERA) high-power microwave (HPM) weapon at White

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VFCTS125-10	125	-156	-165	
VFCTS128-10	128	-155	-160	
FCTS800-10-5	800	-144	-158	
FCTS1000-10-5	1000	-141	-158	
FCTS1000-100-5	1000	-141	-158	
FSA1000-100	1000	-145	-160	
FXLNS-1000	1000	-149	-154	
KFCTS1000-10-5	1000	-141	-158	
KFCTS1000-100-5	1000	-141	-158	
KFSA1000-100	1000	-145	-160	
KFXLNS-1000	1000	-149	-154	
FCTS2000-10-5	2000	-135	-158	
FCTS2000-100-5	2000	-135	-158	
KFCTS2000-100-5	2000	-135	-158	
KSFLOD12800-12-1280	12800	-122	-123	
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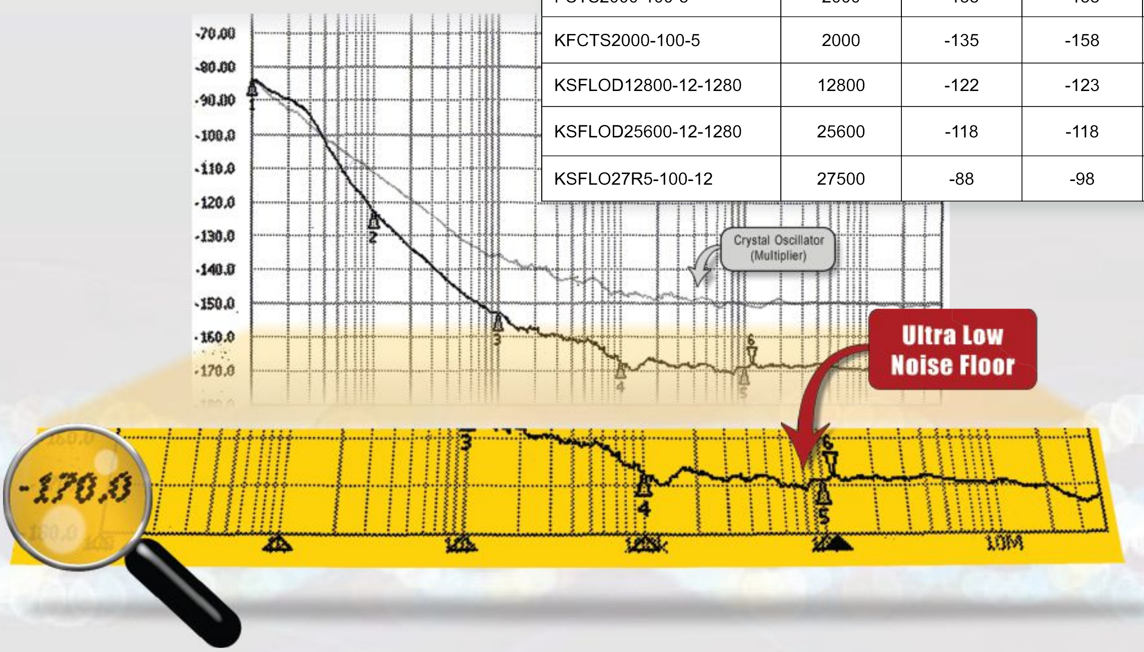

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Around the **Circuit**

Sands Missile Range in New Mexico. During the test, CHIMERA applied directed energy to multiple static target variations and demonstrated end-to-end fire control by acquiring and tracking aerial targets and maintaining tracking for the entire flight path. The CHIMERA system was built to fire highly concentrated radio energy at multiple middle-to-long-range targets. The ground-based demonstration system wields more power than other HPM systems to defeat airborne threats at the speed of light.

CONTRACTS

Momentus Inc., a U.S. commercial space company that offers satellite buses, transportation and other in-space infrastructure services, has been awarded a contract modification valued at $1,196,404 by the **Space Development Agency** to continue development of the Vigoride Orbital Service Vehicle for Department of Defense (DOD) Mission Requirements. Through this Small Business Innovation Research Award, "Orbital Service Vehicle Enhancements to Meet DOD Mission Requirements," with a total value of $1,942,477, Momentus will tailor the capabilities of its Vigoride Orbital Service Vehicle to support a wide range of DOD payloads and mission requirements, setting the stage for a rapid transition to an in-space flight demonstration.

L3Harris Technologies received a contract with a potential value of up to $919 million to design and build 18 infrared space vehicles for the **Space Development Agency's (SDA)** Tranche 2 Tracking Layer program that will provide near-global missile warning and tracking coverage. L3Harris designed the missile defense solutions to support the U.S. military's ongoing effort to build a robust constellation of satellites to protect against a new generation of hypersonic weapons that have increased speed, unpredictable flight trajectories and faint heat signatures. The company's technology will also support preliminary fire control capability for the SDA's Proliferated Warfighter Space Architecture.

Sierra Space, a leading commercial space company building the first end-to-end business and technology platform in space, announced that it has won a significant contract by the **Space Development Agency (SDA)** for 18 missile warning and tracking satellites. The prime contract, valued at $740 million and awarded through an Other Transaction Authority, is for the design, production, delivery, operations and sustainment of 16 missile warning and tracking satellites and two satellites for missile defense and fire control. The contract includes two operational ground segments as well. The satellites are for the portion of SDA's proliferated space warfighting architecture known as Tranche 2 Tracking Layer, part of the Defense Department's low earth orbit constellation.

Comtech announced it received approval from the **U.S. Army Contracting Command** to move forward

on the company's previously announced $544 million Global Field Service Representative (GFSR) contract. Under this contract, Comtech will provide onsite professional engineering services, as well as supply and support the company's market-leading satellite and terrestrial networking communications technologies for the Project Manager Tactical Network (PM TN) for the GFSR support program. The GFSR program provides ongoing communications and IT infrastructure support for the Army, Air Force, Navy, Marine Corps and NATO-enabling U.S. and coalition forces to maintain robust, resilient and secure connectivity for global all-domain operations in all environments.

Sivers Semiconductors AB announced the expansion of its chipset agreement with **Thorium Space**. This $2.9 million (approximately 30 MSEK) second phase will focus on the advanced development and validation of the chipsets designed in the initial phase, further laying the groundwork for future large-scale manufacturing. The company anticipates recognizing revenue of up to USD $2.1 million from this contract in 2024. This new contract represents the continuing and deepening partnership between Sivers Wireless, a business unit of Sivers Semiconductors, and the Polish satellite communication systems pioneer.

PEOPLE

▲ *Ulrich L. Rohde*

In January 2024, **Dr. Ulrich L. Rohde** was appointed "Fellow of Industry Academy" in the high-profile International Artificial Intelligence Industry Alliance based in Hong Kong. The International Artificial Intelligence Industry Alliance has a network of strong partnerships across the world to promote the development of and innovation for applications of artificial intelligence. Their membership of over 3,000 academicians and scientists possesses extensive expertise and a wealth of research achievements. They offer cutting-edge technological insights and drive innovative research forward. The Alliance provides educational programs and events worldwide to drive research and innovation.

▲ *Michelle Rhoades*

Stellant Systems Inc. continues to strengthen its executive leadership team with the selection of **Michelle Rhoades** as vice president and general manager of the Folsom, Calif., facility. Rhoades is responsible for driving operational performance, process improvements, research and development and growth strategy at the Folsom, Calif., site. Rhoades brings over 25 years of program management, operations and production control leadership in the aerospace and defense industry, 17 of which have been with Stellant and its predecessors. Rhoades was with DBS Microwave, a start-

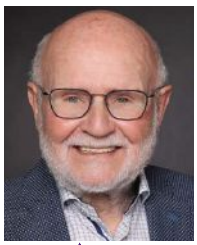
up company that merged with Stellant's Folsom facility (formerly known as Narda Microwave-West), where she was promoted to director of program management.

SweGaN AB, a European semiconductor manufacturer that develops and produces custom-made GaN-on-SiC epitaxial wafers, announced the introduction of CFO **Stefan Axelsson** and R&D Manager **Anders Lundskog**. Axelsson will join the executive management team and Lundskog has come on board in a new R&D role. Both joined SweGaN the first week of January 2024. The company has previously engaged seasoned consultants for guidance in a number of fields. Moving to add permanent key management positions further positions SweGaN for fully embracing its scale-up strategy, new KPIs, investor expectations and achieving ambitious innovation goals.


▲ *Stefan Axelsson*


▲ *Anders Lundskog*

Her Royal Highness, the **Royal Princess Anne**, and IEEE President and CEO **Saifur Rahman** presented the IEEE/RSE James Clerk Maxwell Medal to the recipients of the years 2019, 2022 and 2023 in a ceremony in the Royal Society of Edinburgh (RSE). In 2022, IMST Founder Professor **Ingo Wolff** received recognition for his "development of numerical electromagnetic field analysis techniques to design advanced mobile and satellite communication systems." The RSE Royal Medals were instituted in 2000 by Queen Elizabeth II. They are awarded annually to individuals who have achieved distinction and are of international repute in life, physical, engineering and informatic sciences, arts, humanities and social sciences and business, public service and public engagement.


▲ *Ingo Wolff*

REP APPOINTMENTS

Richardson Electronics, Ltd. announced a global agreement has been reached with **Microwave Components, Inc. (MCI).** MCI, of Dracut, Mass., is a veteran-owned U.S. company that has been a leading manufacturer of custom miniature electronic air coils since 1978. MCI coils are manufactured to meet its customers' specifications. MCI's high Q, miniature air coils are used in a variety of RF and microwave applications, all of which require high performance, reliable and repeatable inductors. This agreement supports **Richardson Electronics'** strategy to partner with technology leaders in passive components that are synergistic with the company's various active technology partners for both component designs and engineered solutions.

INVITED PAPER

Advancing PA Test Methods With VNA-based Wideband Active Load-Pull

Sam Kusano
Keysight Technologies, Santa Rosa, Calif.

As we advance towards the era of 6G and explore the potential of non-terrestrial networks (NTNs), the role of power amplifiers (PAs) in RF communication systems becomes increasingly important. Traditional PA testing methodologies are now being challenged by the complexities of emerging technologies. An emerging approach to PA testing is wideband active load-pull (WALP). This article explores how WALP offers enhanced accuracy and capability while addressing the demands of PA design and optimization in the dynamic landscape of 5G, 6G and NTN communication systems.

ASSESSING PA PERFORMANCE

After the detailed modeling, simulation and design of the transistor, along with designing the primary matching network for fundamental and harmonics frequencies, PA modules are fabricated and prepared for rigorous testing. Ensuring that PAs meet essential performance, efficiency and reliability specifications is a pivotal stage in PA development and manufacturing for communication systems. This testing involves several steps to assess PA performance:

Design verification under 50 Ω conditions: The initial stage involves testing PAs against predefined design targets, measuring various parameters such as frequency response, gain, output power, nonlinearity and efficiency. This testing is measured typically under 50 Ω load conditions, for both CW and modulated stimulus signals.

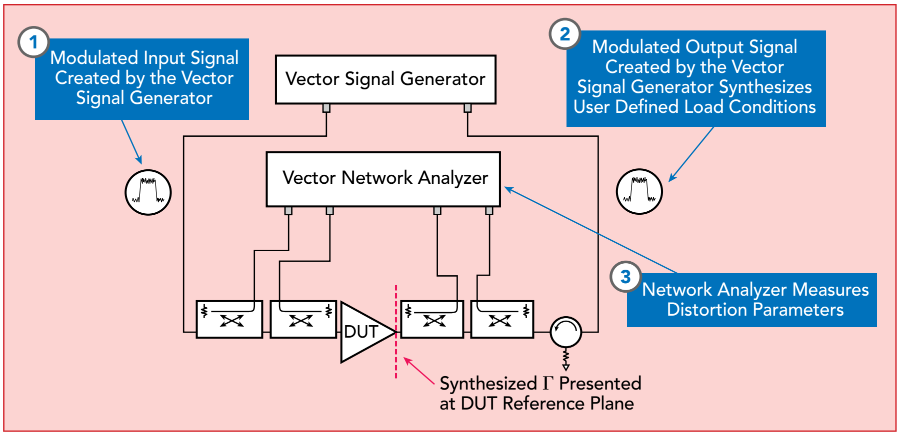
Performance assessment under various load conditions: Traditional methods including passive, active and hybrid load-pull were predominantly used with a CW stimulus. For a modulated stimulus, passive load-pull solutions are often used, but these solutions are faced with the challenge of controlling the load to the specified conditions across the frequency band. This is particularly true for wide frequency, bandwidth-modulated signals. The active load-pull method addresses this challenge by allowing for precise control of load conditions across a wide frequency range.

Ruggedness testing: Focusing on the PA's durability and reliability, robustness testing subjects the PA to extreme conditions, such as high power levels and mismatched loads. This is done to evaluate the ability of the PA to operate without failure or degradation over time. This step is crucial in ensuring the longevity and robustness of the PA in actual applications.

Comprehensive PA testing is essential to ensuring that PAs meet the stringent demands of modern RF communication systems. This is particularly true since PAs are deployed in a variety of field conditions. As communication technologies evolve to include phased array or MIMO technologies, the importance of accurate and thorough PA testing under various load conditions becomes increasingly important.

VNA-BASED WALP OVERVIEW

In response to these evolving PA test challenges, vector network analyzer (VNA)-based WALP solutions have been developed. These approaches are designed to address the limitations of traditional PA testing methods, particularly in the context of wideband modulated signal conditions. The VNA-based WALP solution stands out for its ability to provide accurate and comprehensive insights into PA performance across a wide range of load conditions. This is especially crucial in the 5G era and beyond, where PAs must operate linearly and efficiently over broader frequency ranges and



▲ Fig. 1 Hardware block diagram of VNA-based WALP system.

under various driving conditions.

Hardware configuration: The hardware block diagram of the VNA-based WALP system is shown in ***Figure 1***. The device under test (DUT) is stimulated by a dual-channel RF vector signal generator. Phase coherence between the two channels is required so that the stimulus at the input of the DUT is synchronized to the stimulus at the DUT output. Vector and power calibration at the DUT connectorized reference plane is used so the four traveling voltage waves can be accurately captured by the VNA.

Software tools: To specify target load conditions over the measurement bandwidth and comprehensively analyze nonlinear distortion characteristics, software tools are required for the VNA-based WALP. Additionally, the advanced calibration techniques and algorithms of the VNA are essential to capture calibrated signals at the reference plane.

WIDEBAND LOAD-PULL METHODOLOGIES: PASSIVE VS. ACTIVE

Unlike CW signals with a single tone in the frequency domain, modulated signals are represented by a multi-tone spectrum with a given bandwidth in the frequency domain. At the output of the DUT, a variable, controlled load condition is desired since the PA can experience changes to the load condition depending on the operating conditions. For example, PAs that are used in phased array antennas will experience a change in the load condition as the beam angle changes. Passive and active load-pull techniques have different approaches to present a desired gamma (Γ) at the DUT output.

Passive Load-Pull

Passive tuners control the impedance over a given frequency range using a low-loss transmission line with an insertable electronically-controlled reflective probe. The probe interferes with the electrical field and generates a reflection coefficient with a magnitude and a phase angle. These tuners can be geared toward the fundamental or harmonic signals and they are limited to generating gammas that are less than one. Although passive tuners can handle high power and help simplify the test setup, there are drawbacks to using passive tuners in wideband measurements. Any loss in the transmission line and test set will further constrain the maximum achievable gamma when using a passive tuner. This will limit the magnitude of the gamma values that can be presented to the DUT. Additionally, tuners used for wideband or high frequency load-pull measurements can introduce significant errors due to trajectory deviations of the gamma over the frequency band.

Figure 2 shows a typical passive tuner setup for load-pull measurements. The measurement results from this typical setup are shown in

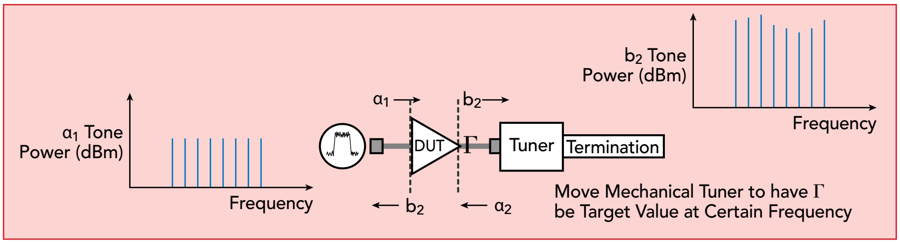


Fig. 2 **Passive load-pull setup.**

Figure 3. The modulated input signal results in a gamma that has an arc shape as shown in Figure 3. This is due to the phase of the reflection changing with frequency and this presents a physical limitation. The frequency-dependent phase variation of the reflection coefficient is due to the electrical delay of the cables and tuner and could be different from the user-specified gamma. The targeted gamma is 0.4, zero degrees for the specified center frequency and is represented as the dot on the Smith Chart.

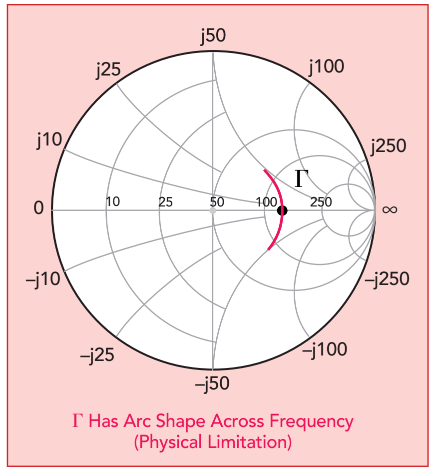


Fig. 3 **Gamma trajectory of passive load-pull for a modulated signal.**

Active Load-Pull

Active load-pull techniques inject an incident wave into the output of the DUT to synthesize a gamma condition. There are two conceptually different methods in active load-pull; closed-loop and open-loop. Closed-loop techniques couple the DUT-generated b_2 signal from the signal path where the amplitude and phase can be adjusted and injected into the output of the DUT as the α_2 signal. Open-loop techniques do not reuse DUT-generated waves but instead use a second signal source to inject power on the output side of the DUT to synthesize the gamma condition at the frequencies of interest. ***Figure 4*** shows a simplified block diagram of an open-loop configuration.

One method of open-loop active load-pull uses an algorithm that minimizes the complex error between the measured and targeted reflection coefficient for a given modulated input signal. The first step is to upload IQ samples to SigGen1, shown in Figure 4, to generate the input wave α_1. The output wave, b_2, is measured and the required IQ samples for α_2 are computed to achieve the desired gamma. The IQ samples are uploaded to SigGen2, shown in Figure 4, and the actual α_2 is evaluated. This process is iteratively repeated until the desired gamma is achieved at the DUT output reference plane.

This method of active load-pull enables gamma values that can be

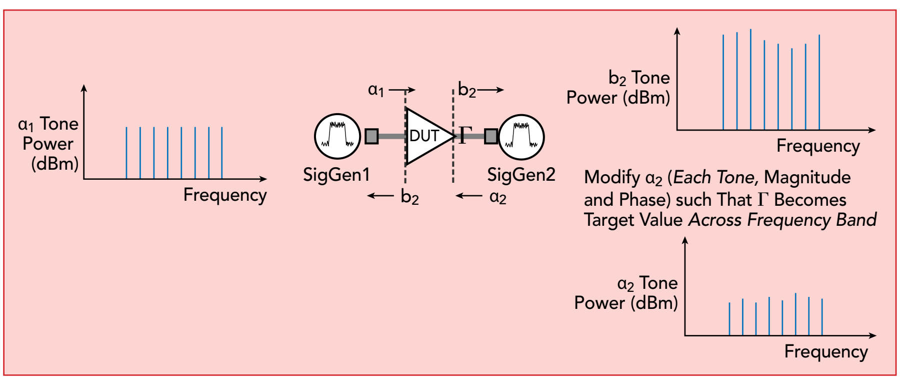


Fig. 4 **Open-loop active load-pull block diagram.**

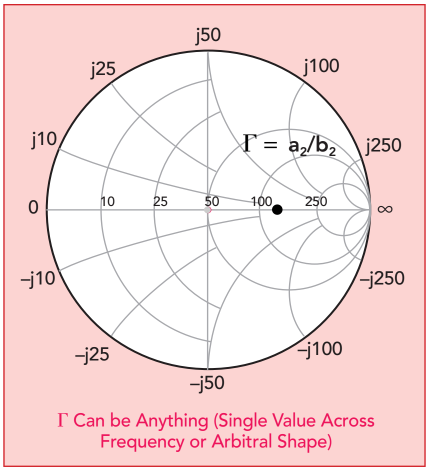


Fig. 5 **Example gamma controlled by WALP across the frequency range.**

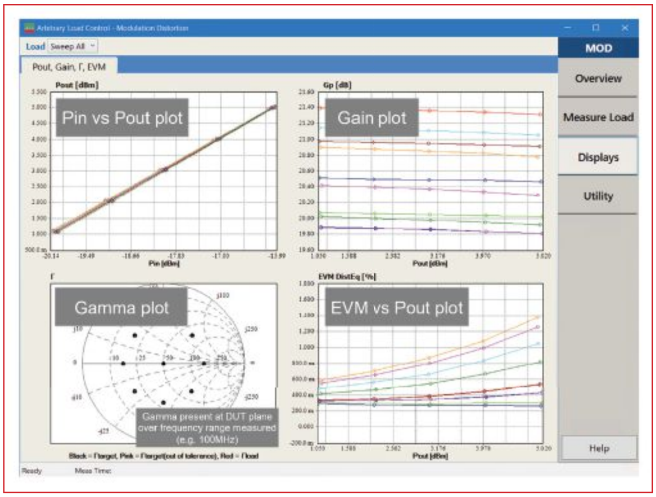


Fig. 6 **Representative measurement results display.**

arbitrarily defined for the modulated signal bandwidth. In ***Figure 5***, gamma is targeted to have a single-phase value across the frequency range. However, gamma, defined as α_2/b_2, can be a single value across a frequency range or any arbitrary shape.

In addition to differing gamma characteristics across the frequency range, there are a few more distinctions between passive and active load-pull:

Impedance range: Active load-pull can generate a broader range of impedances on the Smith Chart compared to passive load-pull, provided that the signal generator for α_2 has sufficient power.

Power budget: Active load-pull requires sufficient power for α_2 to support the targeted gamma at a specific frequency. In a typical hardware configuration, supporting a wide impedance range requires 10x more power than the DUT output power.

One of the critical aspects of wideband load-pull testing is understanding and characterizing nonlinear distortion. Regardless of the method (passive or active), the test system is required to comprehensively characterize the nonlinearity of PAs under modulated signals. This is crucial for designing amplifiers that maintain signal quality, particularly for modern communication systems.

VNA-BASED WALP METHOD IMPLEMENTATION

The VNA-based WALP method has unique technical aspects that enable accurate gamma control and nonlinearity characterization in the modulated signals.

Vector correction: Utilizes the VNA's calibration capabilities for accurate measurements of signals at the reference plane.

Multi-tone measurement: Accurately evaluates the multi-tone spectrum (amplitude and phase) of the scattered wave from the DUT (b_2) and the synthesized signal from the signal generator (α_2) across the frequency band.[1]

Optimization algorithm: An optimization algorithm estimates the α_2 required to achieve the desired impedance across the frequency range, improving measurement time.[2]

Nonlinearity estimation: Facilitates accurate estimation of nonlinear distortion under wideband modulated signals, supported by a modulation distortion algorithm.[3]

User Interface (UI) and Testing Capabilities

The VNA-based WALP method requires the integration of advanced hardware with a comprehensive software interface. This streamlines the complexity of load-pull testing. The UI benefits from the intuitive and easy adjustment of crucial test parameters, including frequency range, power levels and load impedance conditions.

Test parameter: Users configure critical test parameters, such as power levels and load impedance conditions (load grid), along with gamma search conditions.

Data displays: The data visualization capabilities of the software allow for a quick review of results. This feature provides immediate, intuitive insights into power sweep results for various load conditions to provide a sanity check of the measurement.

A representative display of parameters is shown in ***Figure 6***.

With modern VNAs and software tools, the user can define a custom gamma at the reference plane. This facilitates power sweep measurements. This is essential for acquiring detailed insights into nonlinear distortion using the specified gamma trajectory across the frequency range. This will enhance the accuracy of the PA performance evaluation. ***Figure 7*** shows representative results from this process. In this case, the S-parameters for a bandpass filter are given, along with the gamma trajectory and the bandpass PA/filter response for that desired gamma response is shown.

COMPREHENSIVE TESTING FUNCTIONS

The combination of an intuitive UI and advanced visualization features makes the VNA-based WALP method a powerful tool for PA testing. It not only streamlines the testing process but also provides deeper insights into PA performance, aiding designers to efficiently optimize their designs. Several aspects of the software features enhance testing capabilities:

Automated test sequences: Test sequences that can be automated through SCPI commands save time and reduce the potential for human error. The automation interface is especially useful for repetitive or standardized testing procedures.

Compatibility and integration: Compatibility with a wide range of testing equipment and the ability

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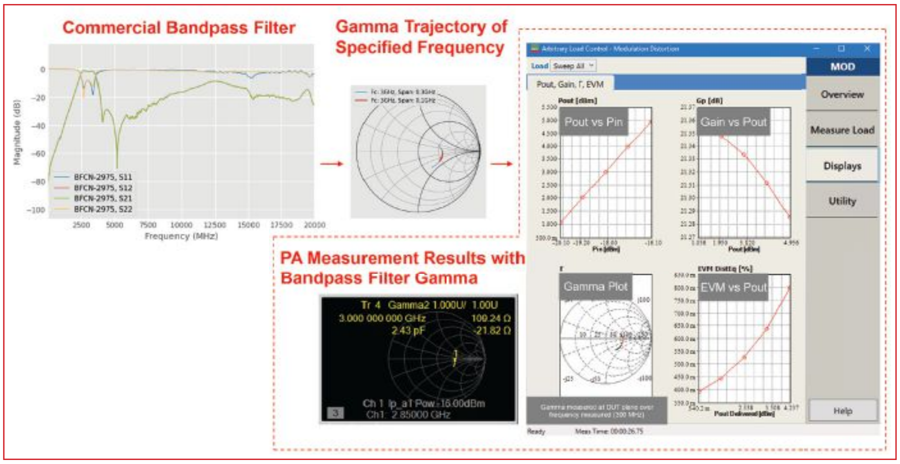


Fig. 7 Representative results from a custom gamma creation and power sweep.

to integrate seamlessly into existing testing environments ensures that the solution can be adopted without extensive modifications to current setups.

Result export and visualization: The ability to export allows detailed measured test data to be collected and analyzed. External software, like Keysight's ADS,[4] can be used for further analysis and to create contour plots for distortion parameters like EVM and ACPR. Contour plots are created by taking a set of parameters like output power and gain for each load condition and plotting a constant value for one of the parameters. The power contour indicates the load impedances that, when presented to the output of an amplifier for a given source impedance and power combination, cause that power to be delivered to the load. This helps determine trade-offs between output power, gain or EVM for different load conditions. ***Figure 8*** shows a representative set of plots from ADS for a PA contour plot.

CASE STUDIES AND PRACTICAL APPLICATIONS

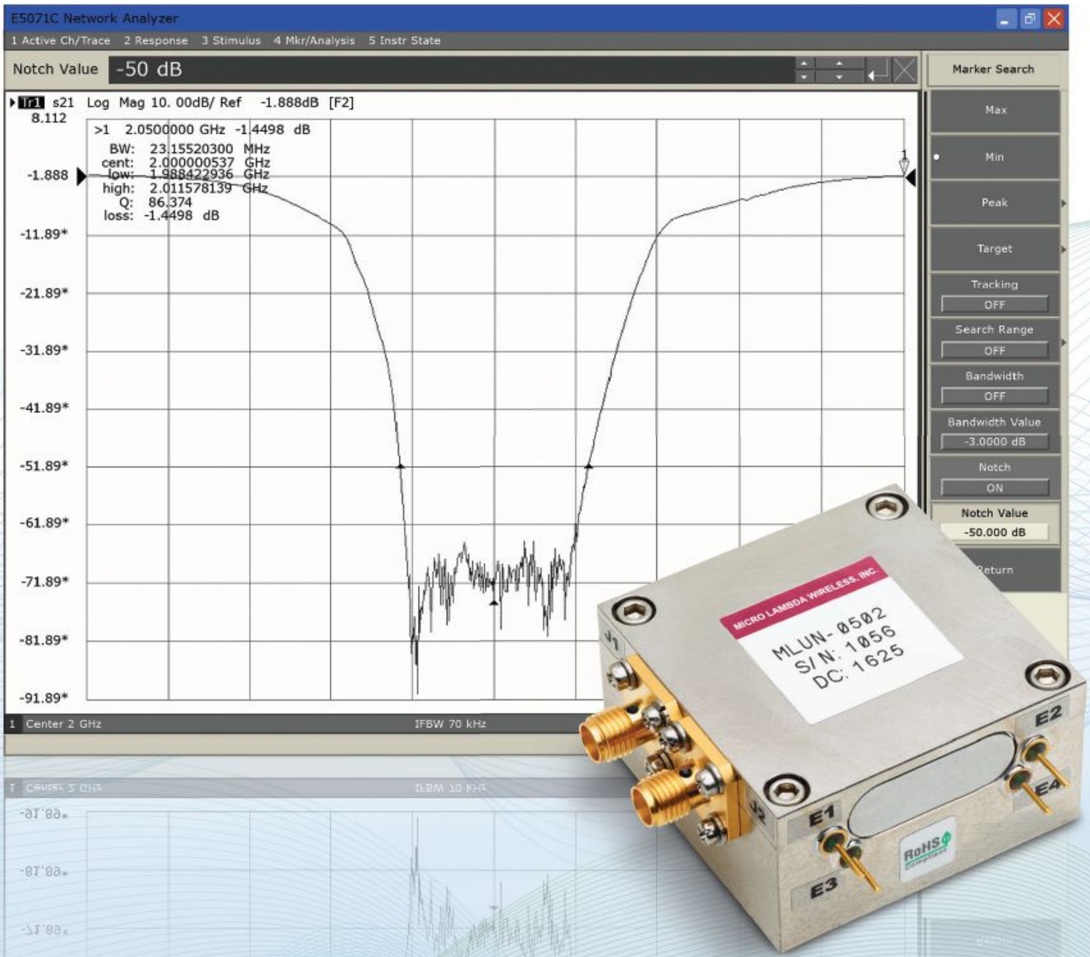
The true value of the VNA-based WALP solution is best understood through its use in actual applications. The full details are beyond the scope of this article, but the following case studies indicate actual uses where the method has been used to address specific challenges in PA testing.

Enhancing PA performance in front-end modules: This study details the use of the VNA-based WALP solution by a leading component company to optimize the distortion performance of PAs. Similar to the results described in Figure 7, the PA was combined with an output chain filter with a specific gamma across the frequency band. The ability of the solution to evaluate nonlinearities and predict system-level performance for various gamma trajectories improved the efficiency of the design flow for the matching circuit and this helped to optimize linearity.

Improving satcom PA systems: The VNA-based WALP solution was employed to test and improve PAs used in phased array systems in satellite communication. In these applications, reliability and performance stability over a broad range of conditions are critical. The testing capabilities of the solution helped to enhance reliability in demanding conditions.

Robustness testing: The VNA-based WALP method assessed PA robustness under extreme load conditions. The insights ensured consistent performance by evaluating PA performance before and after extreme loading conditions.

Each case study shows how the solution provided insights into the sensitivity of PA performance to load impedance variations. These insights are crucial and help designers understand the trade-offs between output power, efficiency and linearity. For all the case studies, a key benefit of using the VNA-based WALP method is the measurement and calibration capabilities of the VNA. This extends the abilities of the measurement setup from WALP measurements to small-signal S-parameters, gain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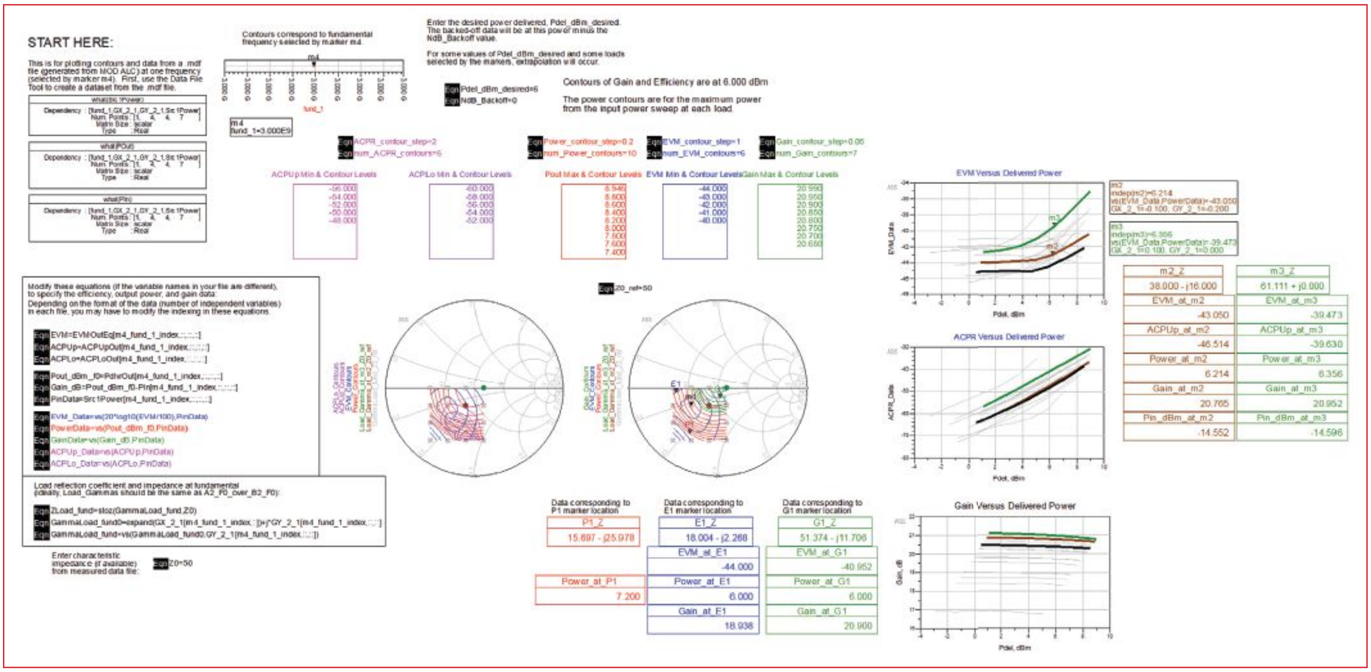

Fig. 8 **Example of an ADS contour plot result.**

compression, noise figure and others, providing measurement flexibility. The VNA-based WALP system allows users to make those measurements seamlessly, without the need to reconfigure the test setup.

CONCLUSION

As this article has demonstrated, the VNA-based WALP method represents a significant advancement in the field of PA testing. The method enables users to replicate actual load conditions that a PA may see in an application. The ability to test PAs across a wide range of frequencies makes this method an important tool in the modern RF communication system design process. The landscape of RF communication is continuously evolving, with new challenges emerging as technologies advance. The VNA-based WALP method not only addresses current testing challenges but also positions itself as a tool capable of adapting to future advancements. ■

References

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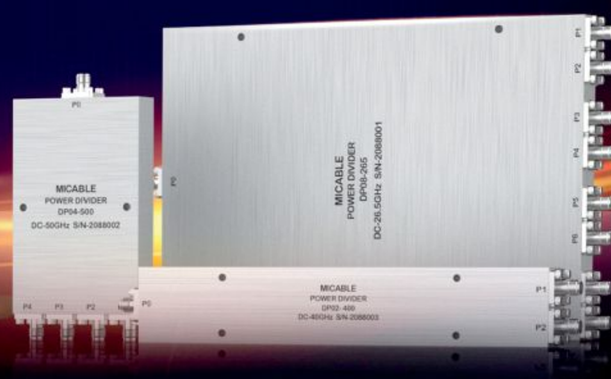

Way	Freq. Range (GHz)	P/N	Sum VSWR (:1) Typ./Max.	Distri. VSWR (:1) Typ./Max.	Insertion Loss* (dB) Typ./Max.	Amplitude Unbalance (dB) Typ./Max.	Phase Unbalance (dB) Typ./Max.	Isolation (dB) Typ./Min.
2	DC~0.5	DP02-265	1.7/-	1.7/-	0.6/1.2	±0.1/±0.3	±1/±3	8/-
	0.5~18		1.2/1.5	1.2/1.5	1.2/1.7	±0.2/±0.3	±2/±3	22/17
	18~26.5		1.2/1.5	1.2/1.5	1.6/2.4	±0.3/±0.4	±3/±4	22/18
	DC~0.5	DP02-400	1.7/-	1.7/-	0.6/1.2	±0.1/±0.3	±1/±3	8/-
	0.5~26.5		1.3/1.6	1.3/1.6	2/2.6	±0.2/±0.3	±3/±4	22/16
	26.5~40		1.3/1.6	1.3/1.6	2.8/3.5	±0.3/±0.4	±3/±5	22/18
	DC~1	DP02-500	1.7/-	1.7/-	0.8/1.6	±0.1/±0.3	±1/±3	8/-
	1~26.5		1.3/1.6	1.3/1.6	1.2/1.9	±0.2/±0.3	±3/±4	22/16
	26.5~50		1.3/1.6	1.3/1.6	2.2/3	±0.3/±0.5	±4/±6	22/18
4	DC~0.5	DP04-265	2.8/-	2.8/-	2/3	±0.2/±0.3	±2/±3	8/-
	0.5~18		1.2/1.5	1.2/1.5	3.2/4	±0.2/±0.3	±3/±5	22/16
	18~26.5		1.3/1.6	1.3/1.6	4.4/5.2	±0.3/±0.4	±4/±6	22/18
	DC~0.5	DP04-400	2.8/-	2.8/-	2/3	±0.2/±0.3	±2/±3	8/-
	0.5~26.5		1.3/1.6	1.3/1.6	4.2/5.4	±0.3/±0.4	±4/±6	22/15
	26.5~40		1.3/1.6	1.3/1.6	6/7.5	±0.3/±0.5	±5/±7	22/18
	DC~2	DP04-500	2.8/-	2.8/-	2/3	±0.2/±0.3	±2/±3	8/-
	2~26.5		1.3/1.6	1.3/1.6	2/2.9	±0.3/±0.4	±4/±6	22/16
	26.5~50		1.4/1.7	1.4/1.7	3.5/4.4	±0.4/±0.6	±6/±8	22/18
8	DC~0.5	DP08-265	5.8/-	4.8/-	4/5.5	±0.3/±0.6	±3/±6	8/-
	0.5~18		1.3/1.6	1.3/1.6	4.8/6	±0.3/±0.4	±4/±6	22/15
	18~26.5		1.3/1.6	1.3/1.6	6.8/8	±0.3/±0.5	±5/±7	22/18
	DC~0.5	DP08-400	5.8/-	4.8/-	4/5.5	±0.3/±0.6	±3/±6	8/-
	0.5~26.5		1.4/1.7	1.3/1.6	6.8/8.2	±0.3/±0.5	±4/±6	22/15
	26.5~40		1.4/1.7	1.4/1.7	9.6/11	±0.4/±0.6	±6/±8	22/18
	DC~1	DP08-500	5.8/-	4.8/-	4.4/5.7	±0.4/±0.7	±4/±7	8/-
	1~26.5		1.4/1.7	1.4/1.7	6/7.1	±0.5/±0.7	±6/±8	22/15
	26.5~50		1.5/1.8	1.5/1.8	9.9/11.1	±0.6/±0.9	±9/±12	22/18

*Above Theoretical I.L.

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INVITED PAPER

Millimeter Wave and Sub-THz Power Sweep and Active Load-Pull Measurements

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Vertigo Technologies, Delft, The Netherlands
Cliff Rowland
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The advancement of semiconductor technologies is driving the emergence of new and expanded applications within the mmWave and sub-THz frequency spectrums. These applications include 5G, 6G and upcoming evolutions of wireless communications, radar in automotive and security markets, imaging and sensing, radio astronomy, satellite communications, military applications like electronic warfare and scientific research. Whether a particular semiconductor technology is ultimately successful in one or more of these applications is determined, in part, by its performance in certain critical areas, including output power, gain and efficiency. Designers can determine and optimize these performance parameters through device characterization and, more specifically, by performing power sweep and load-pull measurements.

AN INTRODUCTION TO LOAD-PULL MEASUREMENTS

Load-pull refers to the technique of altering the load impedance presented to a device under test (DUT), typically a transistor. This is done to assess the performance characteristics of the device across different large signal conditions. Systematic adjustments are made to impedances while concurrently measuring or calculating parameters like output power, gain and efficiency. Contours are generated to reflect fixed performance values, such as an output power of X dBm or efficiency of Y percent. These contours aid in visualizing the optimum performance point, understanding how performance changes and evaluating the trade-offs between different parameters.

To understand the load-pull technique, consider a DUT as a two-port network, as shown in ***Figure 1***. The magnitude of reflection, Γ_L, is calculated as shown in Equation 1:

$$\Gamma_L = \frac{a_2}{b_2} \tag{1}$$

Load-pull changes the magnitude of reflection presented to the load of the DUT by manipulating the reflected signal, a_2, and this manipulation has a similar effect on the phase of the reflection signal. Any load impedance can be expressed as the relationship shown in Equation 2.

$$Z = Z_0\left(\frac{1+\Gamma_L}{1-\Gamma_L}\right) \tag{2}$$

This relationship can be applied to the DUT as long as achieving the desired a_2 signal is feasible.

There are two common methodologies to vary the impedance presented

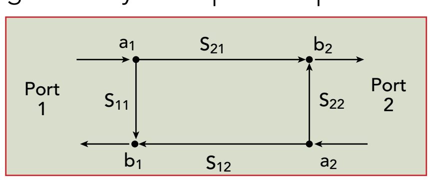


Fig. 1 **Two-port network representation of DUT.**

to a DUT: passive load-pull and active load-pull. Passive load-pull employs mechanical impedance tuners to modify both the magnitude and phase of a_2, which alters the impedance encountered by the DUT. Instead of using a mechanical tuner, active load-pull artificially creates, controls and injects the a_2 wave into the output port of the DUT to synthesize the desired Γ_L condition. In the specific case of open loop active load-pull, an external signal source that is phase-coherent with the a_1 wave and equipped with magnitude and phase control is used to generate a_2.

OPEN LOOP ACTIVE LOAD-PULL AT MMWAVE AND SUB-THZ FREQUENCIES

Armed with these basic concepts, the block diagram of a typical mmWave and sub-THz active load-pull system is shown in ***Figure 2***. The system works by generating an RF signal using the first signal source embedded in the vector network analyzer (VNA). The RF signal is routed into the vector modulator unit (VMU) where it is split into an RF1 and an RF2 signal that can be independently manipulated in magnitude and phase using embedded IQ modulators. The RF1 signal is routed into the VNA frequency extender module at the input of the DUT and the RF2 signal is routed into the VNA extender on the output side of the DUT. The VNA extender modules provide frequency up-conversion for the RF signals with an extender-specific frequency multiplication factor that takes the signals to the mmWave or sub-THz frequency of interest. The up-converted RF1 signal, which is equivalent to the a_1 wave shown in Figure 1, is injected into the input of the DUT to drive it at a specific power level. The up-converted RF2 signal, which is equivalent to the a_2 wave shown in Figure 1, is injected into the output of the DUT. By using the VNA extender modules to measure the b_2 wave, it is possible to iteratively adjust the injected a_1 wave to obtain the desired load condition. The drive power for the DUT is dependent on the power output of the VNA extender module, minus any losses between the module and DUT. An example of these losses would be losses caused by the wafer probe. It is important to note that the RF1 and RF2 signals, and therefore the a_1 and a_2 waves, are phase-coherent since they have been generated from the same signal source within the VNA. Additionally, the b_2 wave will be phase-coherent with the a_1 wave and with the a_2 wave. This allows the a_2 wave to be properly adjusted with respect to the b_2 wave to obtain the desired Γ_L response.

The formula that governs the relationship between the transistor, the system impedance, the injection power and the tuning range is presented in Equation 3:

$$Z_L = \frac{Z_{Sys} + K Z_{DUT} - \sqrt{\left(Z_{Sys} + KZ_{DUT}\right)^2 - (1-K)\left(Z_{Sys}{}^2 - KZ_{DUT}{}^2\right)}}{1-K} \quad (3)$$

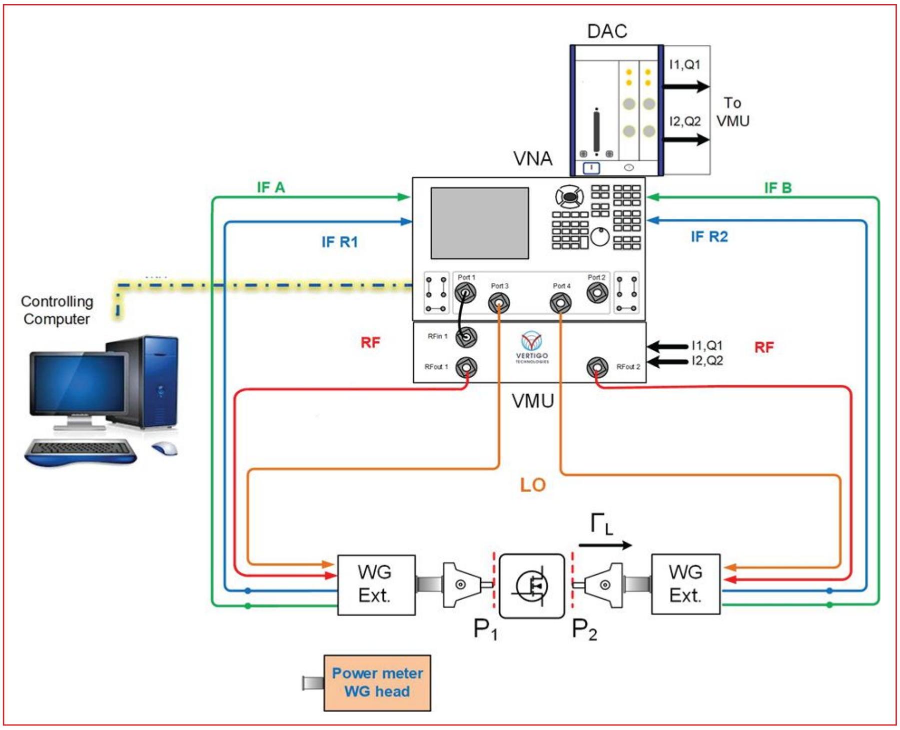


Fig. 2 mmWave and sub-THz active load-pull system block diagram.

Where:
Z_L is the impedance presented to the DUT
Z_{Sys} is the system impedance
Z_{DUT} is the DUT's output impedance
The factor K is defined in Equation 4:

$$K = \frac{P_{a2}}{P_{b2}} \cdot \frac{1-\left|\Gamma_{Sys}\right|^2}{1-\left|\Gamma_{DUT}\right|^2} \frac{\left|Z_{Sys} + Z_0\right|^2}{\left|Z_{DUT} + Z_0\right|^2} \quad (4)$$

Where:
P_{a2} is the active tuning power injected into the output of the DUT at the DUT reference plane
P_{b2} is the DUT's output power
Z_0 = 50 Ω

The net magnitude of reflection achievable at the DUT reference plane can be calculated using the equation shown in Equation 5:

$$\Gamma_L = \frac{Z-50}{Z+50} \quad (5)$$

From Equation 5, a higher available output power, P_{a2}, allows for a higher achievable Γ_L or Smith chart coverage. In a mmWave and sub-THz active load-pull system, the available power is determined by the VNA extender module used to up-convert the signal to mmWave or sub-THz frequencies.

VNA EXTENDER MODULES

VNA extender modules are used to extend the VNA measurement capabilities to higher frequency bands. These modules typically contain components that use rectangular waveguide connectors for signal transmission. This means that each system operates only across

a particular rectangular waveguide frequency band.

A functional block diagram of a typical VNA extender module is shown in ***Figure 3***. The test signal from the VNA is coupled to an amplifier-multiplier chain to increase the frequency to the desired band with an overall multiplication factor of N_{RF} as shown in the diagram. This signal then passes through a series of components before being transmitted out the test port. These components often include a variable attenuator, an isolator and most importantly, a pair of directional couplers. The local oscillator signal, coming from a second synthesizer within the VNA, is also amplified and multiplied by a factor of N_{LO} and then coupled to two down-conversion mixers through a splitter. The reference mixer, located in the "Ref." path, receives a small portion of the outgoing signal. This signal is converted to a lower frequency that can be detected and analyzed by the receivers in the VNA. This path essentially defines the magnitude and phase of the outgoing wave for the VNA. The second mixer performs the same function for any signal that is coupled in through the test port. Examples of this are signal power reflected from the input match of the DUT back to the extender mod-

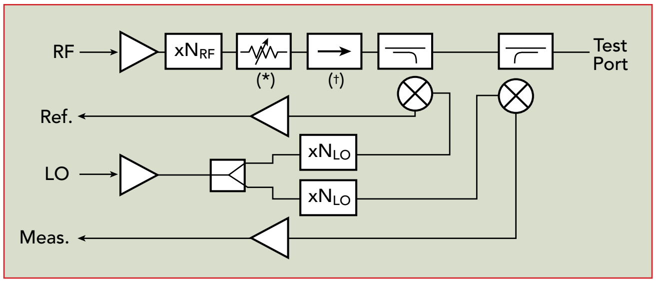


Fig. 3 Functional block diagram of a typical VNA extender module.

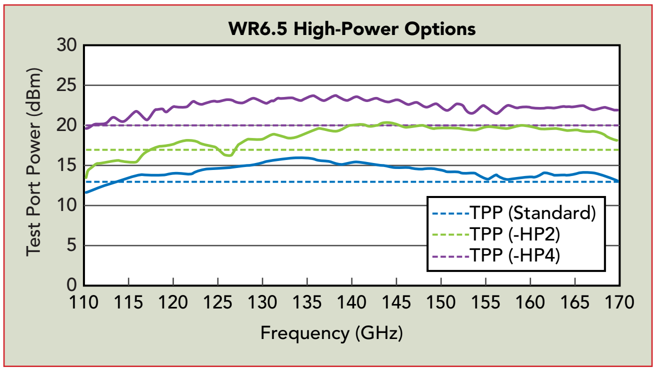


Fig. 4 Measured test port power for three VDI WR6.5 extenders.

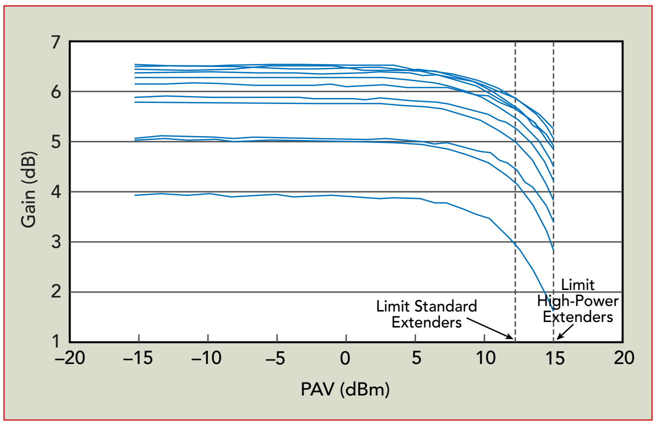


Fig. 5 Gain compression power sweep measurements at 140 GHz.

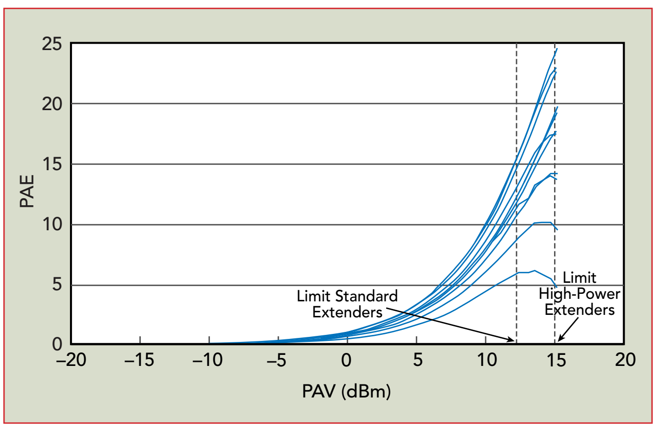


Fig. 6 PAE power sweep measurements at 140 GHz.

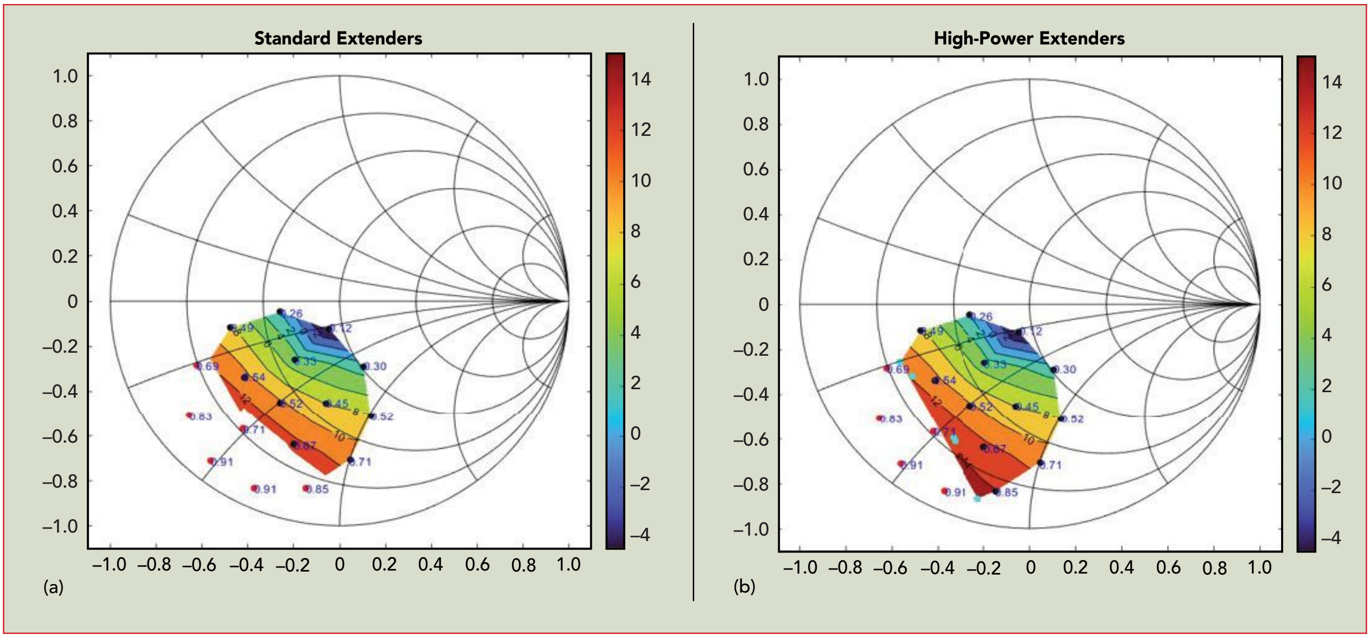


Fig. 7 (a) Load-pull iso-contours for output power using standard extender modules at 140 GHz. (b) Load-pull iso-contours for output power using -HP2 high-power extender modules at 140 GHz.

ule or signal power from another extender module that has passed through the DUT. Using two identical modules, it is possible to measure all four S-parameters of a two-port DUT.

For measurements of passive components, the S-parameters do not depend on signal power. This means that only a modest signal power is required. However, for active load-pull, power levels commensurate with the maximum power available from the DUT are desired to enable measurements that cover greater regions of the Smith chart.

New high-power VNA extender modules have been developed with higher-power multipliers and amplifiers. However, other system components must also be modified to ensure appropriate function and reliability at these higher power levels. Also, the system must be modified so that the mixers cannot be saturated under the full range of expected operating conditions. Other aspects of the module design, including thermal considerations and the module size, must also be reconsidered. The increased test port power levels for a WR6.5 extender module are shown in ***Figure 4***.

It is important to note that the measurements presented in this article used the standard and -HP2 high-power versions of the VDI extender modules. Additional power sweep saturation and load-pull contours could be achieved by using the -HP4 extender module.

GAIN COMPRESSION AND PAE POWER SWEEP MEASUREMENTS

Gain compression and power-added efficiency (PAE) power

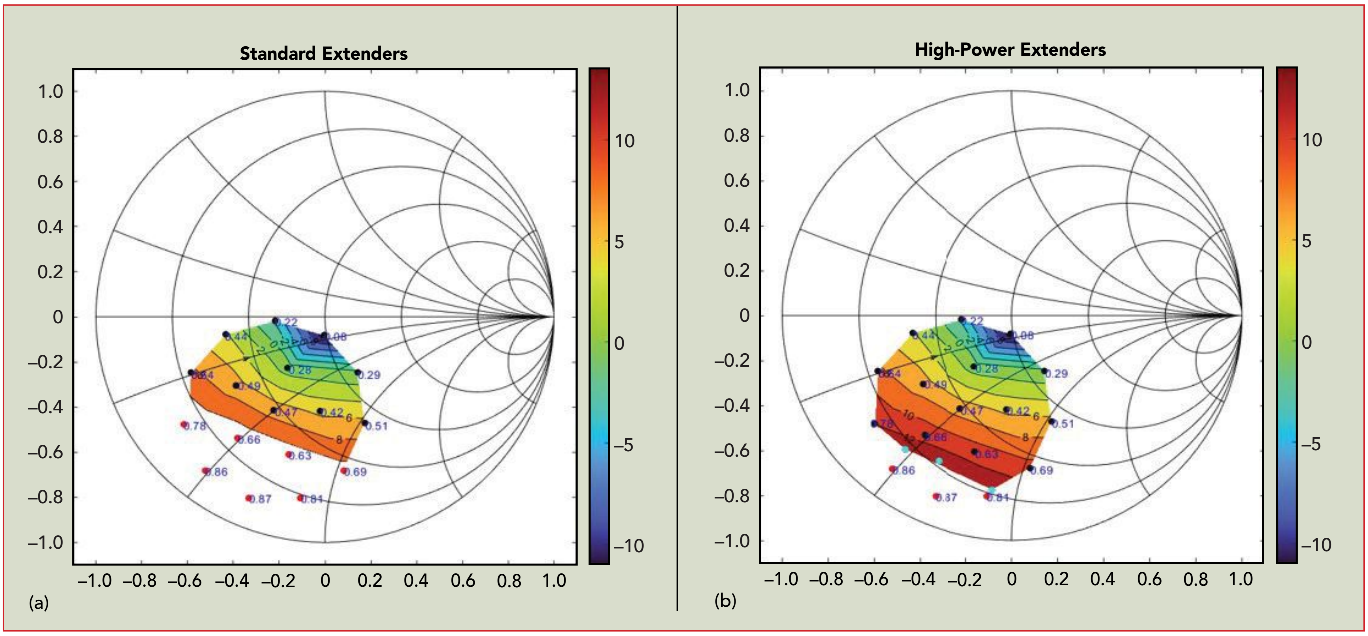
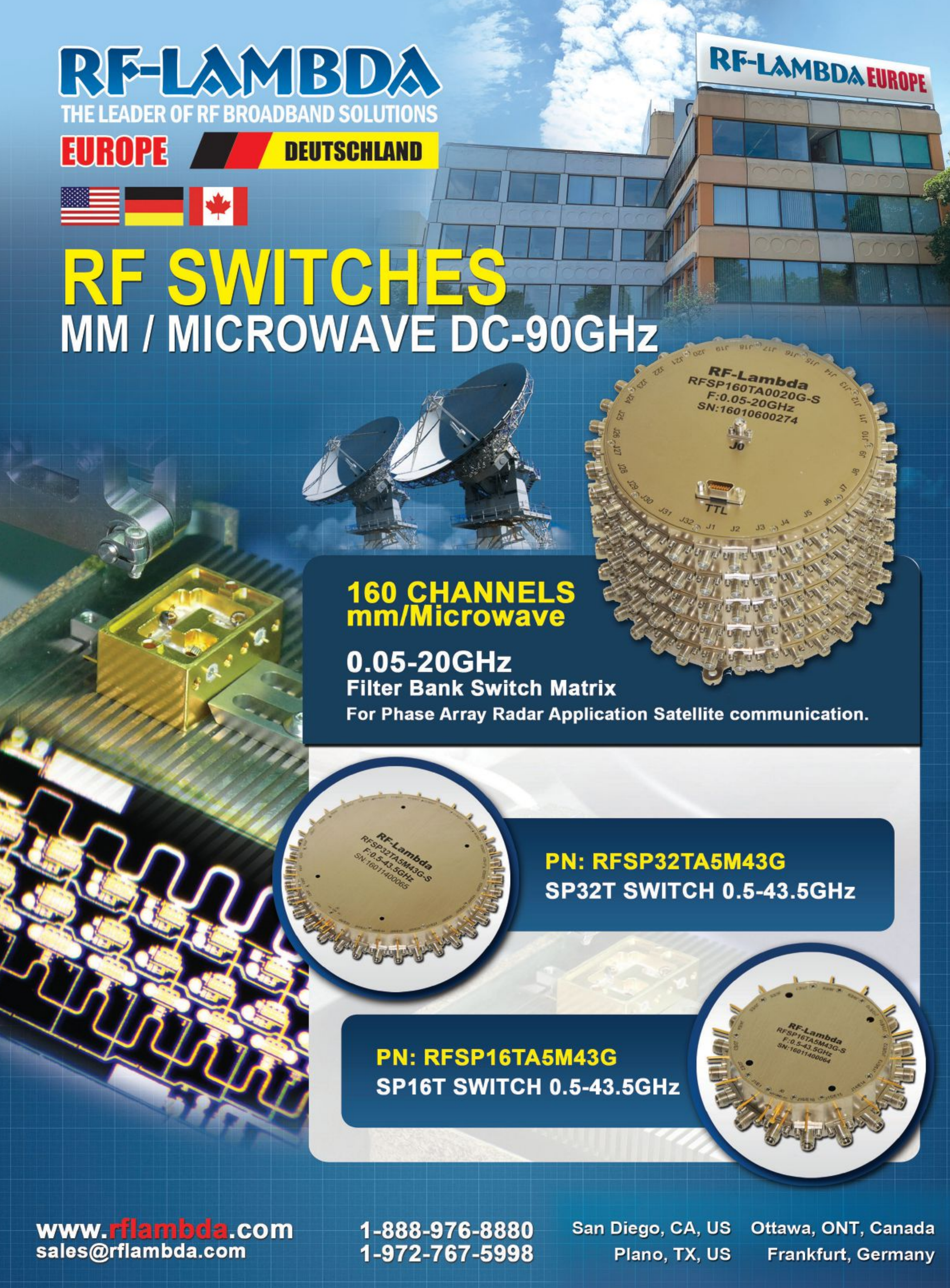


Fig. 8 (a) Load-pull iso-contours for output power using standard extender modules at 170 GHz. (b) Load-pull iso-contours for output power using -HP2 high-power extender modules at 170 GHz.

Fig. 9 Active load-pull system with characterization software.

sweep measurements were performed on a four-finger InP HBT from the ETH Zurich Millimeter Wave Electronics Group. The measurements were performed at 140 GHz using both the standard and the -HP2 high-power extender modules. While the standard extender was able to drive the DUT into compression, it did not have sufficient power to meet the P1dB threshold or achieve maximum PAE. Switching to the high-power extender resulted in approximately 2.5 dB of additional transmit power, surpassing the P1dB threshold and allowing determination of the maximum PAE. Gain compression power sweep measurements are shown in ***Figure 5*** and PAE power sweep measurements are shown in ***Figure 6***. Each curve represents a gain com-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pression power sweep measurement at a unique load impedance using the same impedance pattern that will be shown in the next section of this article.

ACTIVE LOAD-PULL MEASUREMENTS

Active load-pull measurements were performed on the same four-finger InP HBT at 140 GHz and 170 GHz using the standard and -HP2 high-power extender modules. As expected, the high-power extender modules were able to achieve a higher magnitude of reflection, Γ_L, or Smith chart coverage as compared with the standard extender modules. The load-pull iso-contours for output power at 140 GHz are shown for the standard extender modules in ***Figure 7a*** and the iso-contours for output power using the high-power extender modules are shown in ***Figure 7b***. The iso-contours for output power using the standard extender module results at 170 GHz are shown in ***Figure 8a***. ***Figure 8b*** shows the iso-contours for output power using the high-power extender modules at 170 GHz.

CONCLUSION

Active load-pull is an elegant and practical method of characterizing semiconductor technologies at mmWave and sub-THz frequencies. The maximum power available to drive the DUT into compression and to perform active tuning is often limited by the output power of the VNA extender module. However, high-power models using higher-order combining techniques enable the complete characterization of larger devices as well as allowing higher magnitudes of reflection and more Smith chart coverage for load-pull measurements up to 1.1 THz. ***Figure 9*** shows an active load-pull setup that enables all the measurements and characterizations that have been discussed in this article. This setup will operate to 1.1 THz with the appropriate VNA extender modules. ■

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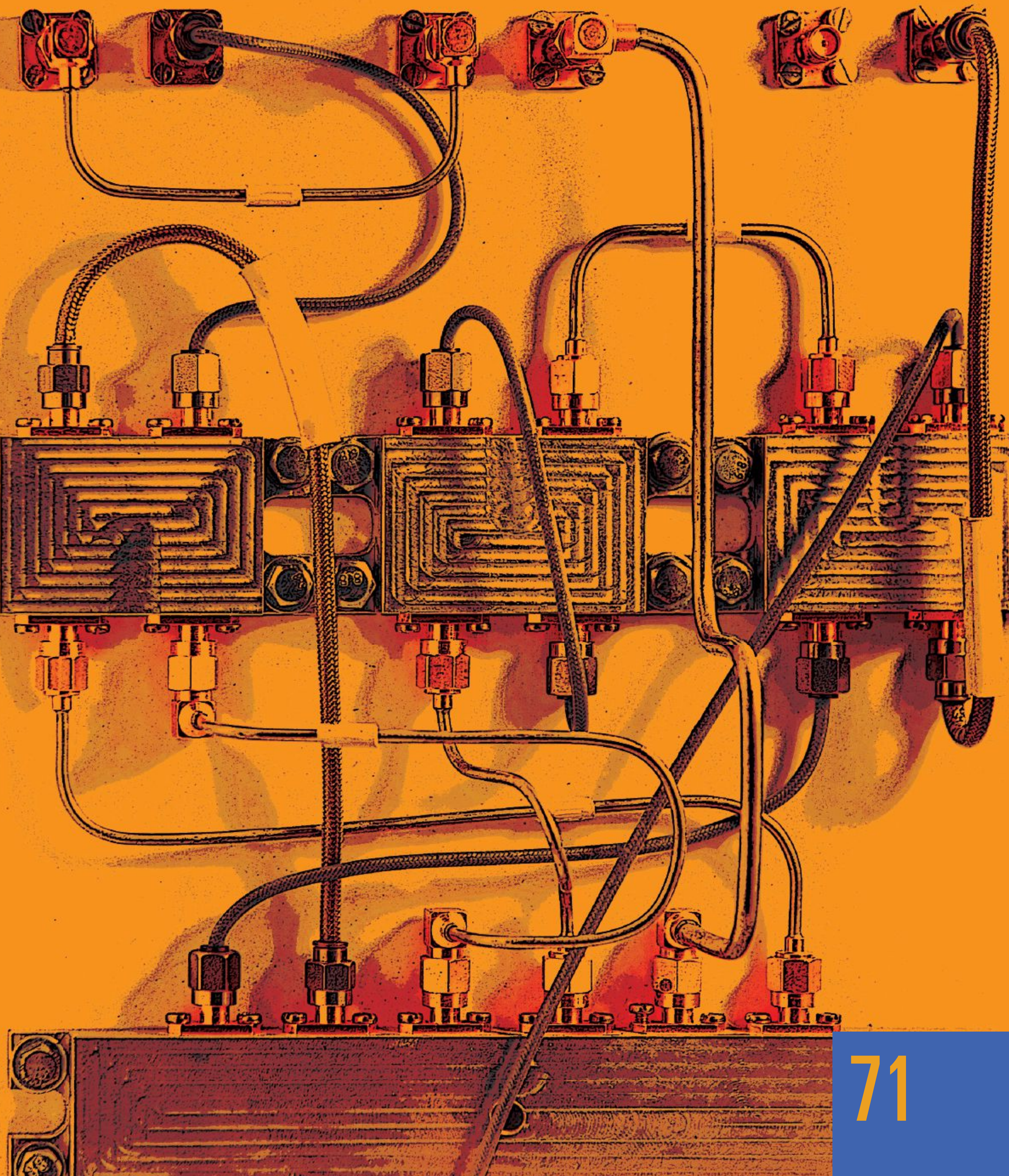

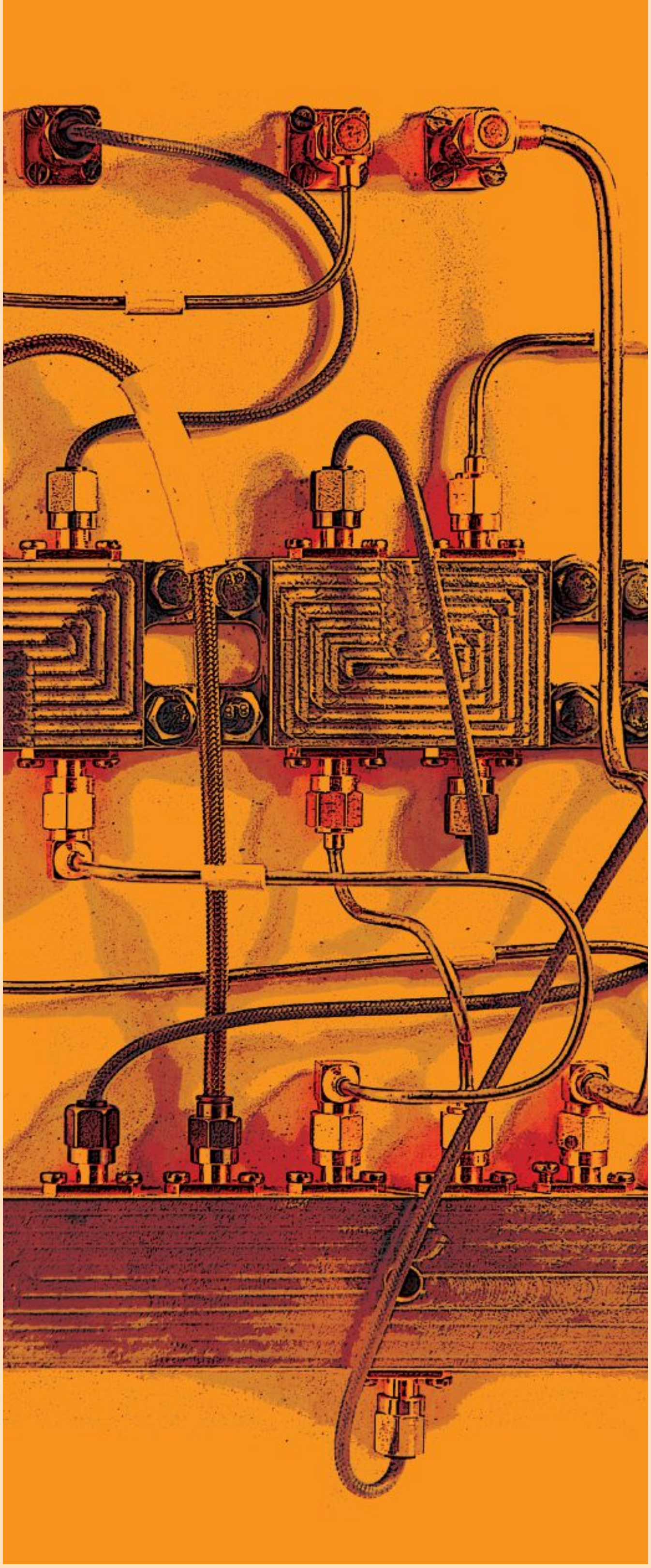

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The RF Connector Opportunity in Base Stations

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

RF board-to-board and panel-mount connectors play a key role in wireless equipment ecosystems. These types of connectors provide the internal "plumbing" to connect functions in macro radio units (RUs) and active antenna units (AAUs) in current 4G/5G mobile wireless networks as well as future 6G mobile networks that will see broader deployments by the end of this decade. These new applications become important because demand for mobile networks in the U.S. is continuing to decline since mobile operators have nearly completed their 5G deployments in the C-Band spectrum. Demand in the European region remains sluggish due to macro-economic and political events, while other regions, such as Latin America and India, have also completed initial coverage deployments across the region and country. China is the only region to see stability as the mobile operators continue to upgrade and prepare for their 5G NR Advanced (5.5G) upgrades in 2025/2026, with these deployments charting a different course than the rest of the world. The goal of 5.5G Advanced in China is to achieve 10 Gbps downlink speeds on mobile devices using a combination of FR1 and FR2 frequency bands, along with the migration to higher-order massive MIMO (mMIMO) AAUs that support 128 and 256 radio channels in frequency bands between 4 GHz and 7 GHz.

MMIMO AAU IMPACT ON RF BOARD-TO-BOARD CONNECTORS

While the wireless market may be in a downturn, the development of next-generation mMIMO AAUs continues. The majority of the global regions are using 32T32R systems for their mobile networks, while the U.S. and China have focused on 64T64R systems. The introduction of mMIMO AAUs in the 6 to 7 GHz frequency bands in China and possibly in some European countries will increase the demand for RF board-to-board connectors per system by 2× to 4×.

The expectation is that the first mMIMO AAUs in the 6 to 7 GHz frequency range will start shipping by the end of 2024 with volumes entering full production in 2025. The volumes will primarily support the rollout of 5.5G networks in China. Elsewhere, the anticipation is that there will be continued softness in demand for 32T/64T AAUs. There is the potential for volume shipments in India, should Vodafone Idea secure funding and BSNL complete its 4G rollout on time.

The latest forecast from EJL Wireless has demand for RF board-to-board connectors, like SMP and SMP-MAX, that will be used to support 5.5G mMIMO AAUs exceeding one billion units by 2026. This connector forecast is based on current AAU forecasts. This forecast is shown in ***Figure 1***.

The situation for 5G AAUs is much different, as shown in ***Figure 2***. The latest forecast shows demand for RF board-to-board connectors declining by 20 percent from 2023 levels before reaching a bottom with a stable outlook through 2027.

The migration to multi-band RUs, globally, is negatively impacting the demand for both RF board-to-board connectors as well as panel-mount connectors and RF jumper cable connectors. For this analysis, Nex10, 4.3-10 and 7/16 DIN connectors are included in the panel-mount and RF jumper cable categories. With the migration to multi-band macro RUs, the RF power levels per channel continue to increase, requiring high-power capabilities for the RF connectors.

As an example, single-band macro RU RF power per channel has steadily increased over the past 20 years to get to the current estimate of 140 W. The current gen-

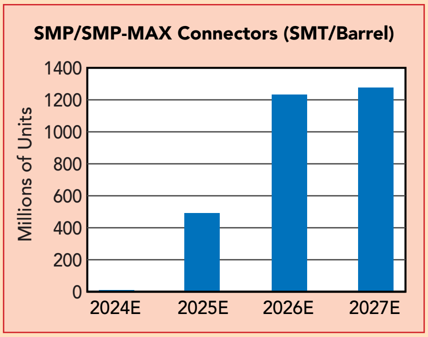

Fig. 1 5.5G AAU demand for RF board-to-board connectors. *Source:* EJL Wireless Research LLC, January 2024.

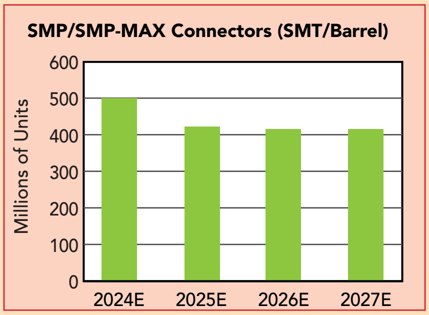

Fig. 2 5G AAU demand for RF board-to-board connectors. *Source:* EJL Wireless Research LLC, January 2024.

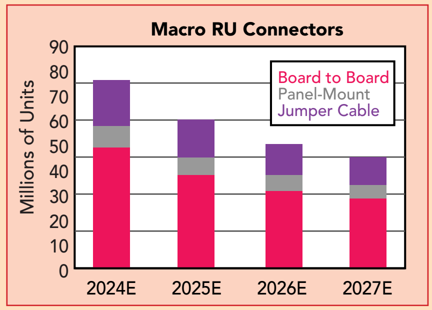

Fig. 3 4G/5G macro RU demand for RF connectors. *Source:* EJL Wireless Research LLC, January 2024.

TABLE 1
TRx CONNECTOR REQUIREMENTS PER CHANNEL FOR TRADITIONAL AAU ARCHITECTURES

Location	SMP/SMP-MAX Connector Type	Quantity
TRx PCB	Male Straight/Catcher's Mitt	1
TRx PCB-RF Cavity Filter	Female-to-Female Barrel	1
RF Cavity Filter	Male Catcher's Mitt	2
RF Cavity Filter-Antenna/Combiner PCB	Female-to-Female Barrel	1
Antenna/Combiner PCB	Male Catcher's Mitt	1

eration of multi-band macro RUs supports up to 80 W per frequency band per channel or in some cases, up to 180 W or more per RF connector port. The combined RF power output per frequency band per channel is increasing the power handling requirements for all of the RF connectors within the macro RU system. Taking these trends into account, ***Figure 3*** represents the latest 4G/5G macro RU forecast for RF connectors, segmented by the connector types.

MMIMO AAU

So where are these millions of SMP/SMP-MAX connectors being used? This section illustrates the different subsystems within an mMIMO AAU design that require the SMP/SMP-MAX connectors. In the traditional AAU architecture that uses separate multi-channel RF cavity filters, the SMP/SMP-MAX surface-mount male connectors are typically used on the main TRx printed circuit board (PCB) and the antenna/combiner PCB. The SMP/SMP-MAX female-to-female barrel connectors are used to connect the input/output of the RF TRx to one port of the cavity filter and to connect the cavity filter to the antenna/combiner PCB. Additionally, there are typically screw-in type SMP male connectors used on the RF cavity filters instead of the surface-mount versions used on the PCBs. ***Table 1*** shows the location, type and quantity of the SMP/SMP-MAX connectors.

A total of six RF SMP/SMP-MAX connectors are needed for each TRx channel. Additionally, each antenna array typically requires two sets of SMP/SMP-MAX connectors for the calibration circuits. One set of connectors is defined as 2× male + 1× female-to-female barrel. It is easy to see how quickly the quantity increases. A 64T64R mMIMO AAU requires 390 of these RF connectors per system. A side view drawing of a traditional mMIMO board assembly with cavity filters, showing the location and functionality of these SMP/SMP-MAX connectors is shown in ***Figure 4***.

The newer AAU architectures that use surface-mount ceramic waveguide RF filters eliminate the male screw-in type RF connectors for the RF filter as well as one of the female-to-female barrel connectors. A total of three RF SMP/SMP-MAX connectors are needed for each TRx channel. Additionally, each antenna array still requires two sets of SMP/SMP-MAX connectors for the calibration circuits. The elimination of the RF cavity filters does not impact the requirements for the antenna calibration circuits. ***Table 2*** shows the connector requirements for the new AAU architectures.

A 64T64R mMIMO AAU using this newer architecture would require only 198 of these RF connectors per system instead of the 390

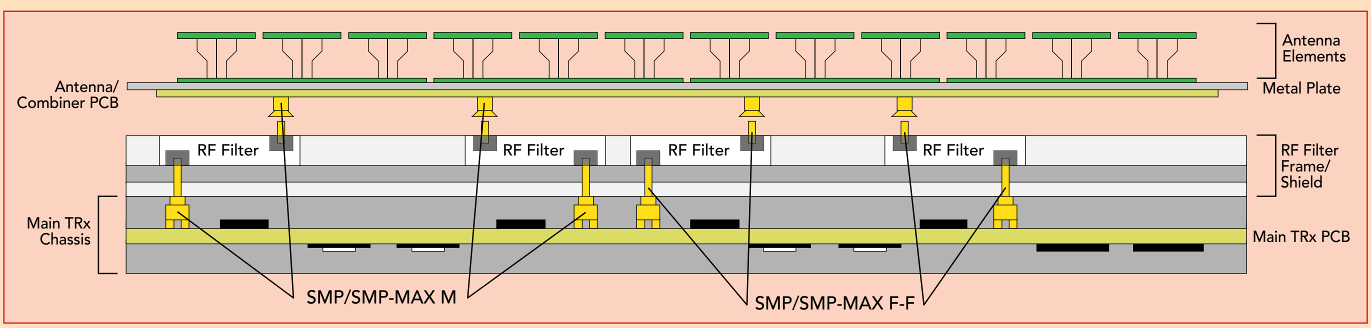

Fig. 4 Connector location in mMIMO architecture with cavity RF filters. *Source:* EJL Wireless Research LLC, January 2024.

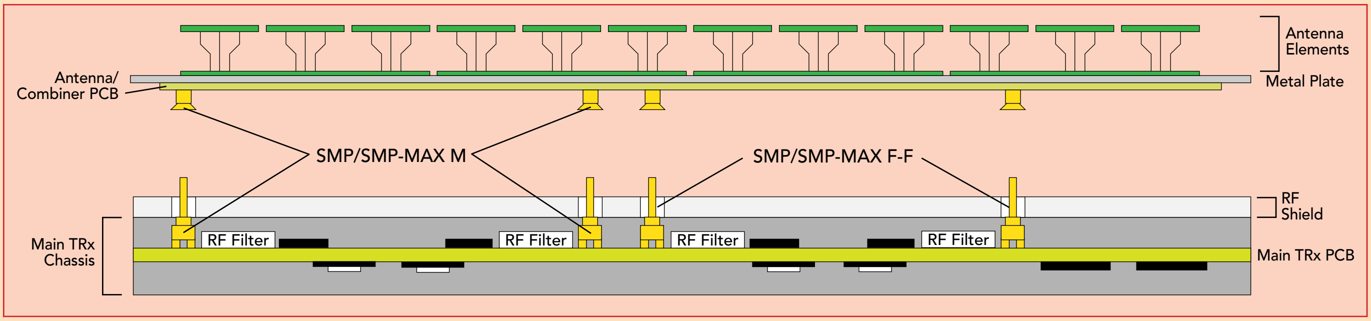

Fig. 5 **New mMIMO architecture with ceramic waveguide RF filters.** ***Source:*** **EJL Wireless Research LLC, January 2024.**

TABLE 2

TRx CONNECTOR REQUIREMENTS PER CHANNEL FOR NEW AAU ARCHITECTURES

Location	*SMP/SMP-MAX Connector Type*	*Quantity*
TRx PCB	Male Straight/Catcher's Mitt Connector	1
TRx PCB-Antenna/ Combiner PCB	Female-to-Female Barrel Connector	1
Antenna/Combiner PCB	Male Catcher's Mitt Connector	1

Fig. 6 **SMP male connector.** ***Source:*** **EJL Wireless Research LLC, January 2024.**

connectors required in the older design. This represents a reduction of nearly 50 percent in the total number of RF connectors required per system. ***Figure 5*** shows a cutaway view and the location of the SMP/SMP-MAX connectors in this new AAU architecture.

While the selling price of each connector is low, the number of connectors per system and the number of systems that are expected to be deployed make this an interesting opportunity. ***Figure 6*** shows an SMP male surface-mount connector on the TRx PCB. ***Figure 7*** shows an SMP male surface-mount connector with a female-to-female SMP barrel connector inserted on a TRx PCB.

MACROCELL RU

Current macro RU architectures shipping into the market today rely on SMP/SMP-MAX connectors to interface between the radio TRx PCB and the RF cavity filter. The frequency-division duplex (FDD) types of macro RUs have separate interfaces for the transmit (Tx) and receive (Rx) paths on the PCB. In some architectures, a diversity Rx may be used, which would increase the number of Rx paths by 2×, thus requiring more connectors.

For a typical 4T4R macro RU design with no Rx diversity, each Tx path and Rx path require an internal set of SMP/SMP-MAX connectors. Additionally, each RF port on the RF cavity filter requires a single panel-mount NEX10, 4.3-10 or 7/16 female connector. ***Table 3*** shows the rundown of connector requirements for each TRx channel of the 4T4R FDD macro RU.

For this architecture, the entire 4T4R FDD macro RU system without diversity Rx requires a total of 24 RF connectors with 20 of them being the SMP/SMP-MAX type. A cutaway view of the 4T4R FDD architecture is shown in ***Figure 8***.

The time-division duplex (TDD) versions of the macro RUs used for 5G networks are typically 8T8R configurations. Since the radio system is TDD instead of FDD, the Tx and Rx paths are the same. This reduces the number of SMP/SMP-MAX connectors by 50 percent. For a typical 8T8R macro RU design, each Tx/Rx path would require an internal set of SMP/SMP-MAX connectors. Additionally,

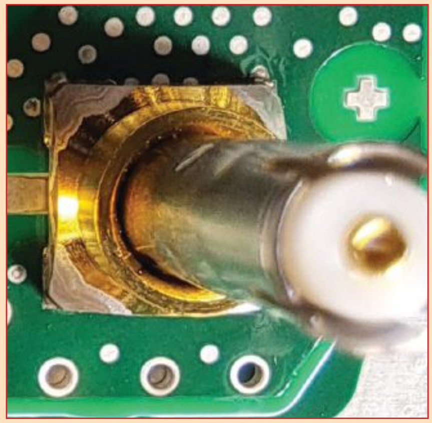

Fig. 7 **SMP male connector with SMP female-to-female barrel connector.** ***Source:*** **EJL Wireless Research LLC, January 2024.**

TABLE 3

4T4R FDD MACRO RU CONNECTOR REQUIREMENTS PER TRx

Location	*Connector Type*	*Quantity*
TRx PCB Tx Path	SMP/SMP-MAX Male Straight/ Catcher's Mitt	1
TRx Tx to RF Filter Input	SMP/SMP-MAX Female-to-Female Barrel	1
RF Filter Tx Input	SMP/SMP-MAX Male Straight/ Catcher's Mitt Screw-In	1
RF Filter Rx Output	SMP/SMP-MAX Male Straight/ Catcher's Mitt Screw-In	1
RF Filter Rx Output	SMP/SMP-MAX Female-to-Female Barrel	1
RF Filter to TRx PCB Rx Path	SMP/SMP-MAX Male Straight/ Catcher's Mitt	1
TRx PCB Rx Path	NEX10, 4.3-10 or 7/16 Female Panel-Mount	1

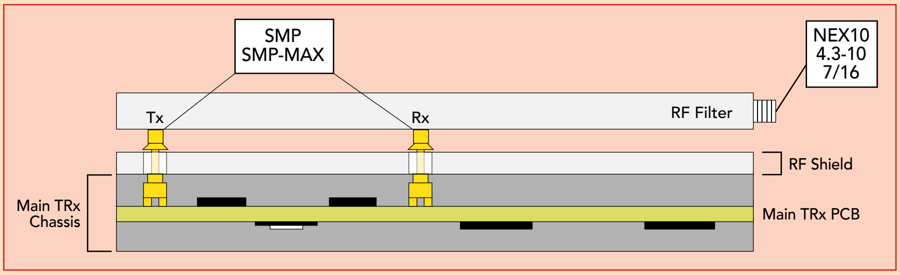

Fig. 8 4T4R macro FDD RU. *Source:* EJL Wireless Research LLC, January 2024.

TABLE 4
8T8R TDD MACRO RU CONNECTOR REQUIREMENTS PER TRx

Location	Connector Type	Quantity
TRx PCB Tx/Rx Path	SMP/SMP-MAX Male Straight/Catcher's Mitt	1
TRx to RF Filter Path	SMP/SMP-MAX Female-to-Female Barrel	1
RF Filter	SMP/SMP-MAX Male Straight/Catcher's Mitt	1
RF Filter Tx/Rx Port	NEX10, 4.3-10 or 7/16 Female Panel-Mount	1

each RF port on the RF cavity filter would require a single panel-mount NEX10, 4.3-10 or 7/16 female connector. However, the TDD 8T8R macro RUs utilize antenna beamforming, so a ninth panel-mount RF connector is needed on the RF cavity filter as well as one set of SMP/SMP-MAX connectors to interface to the radio TRx PCB for the calibration channel. ***Table 4*** shows the rundown of connector requirements for each TRx channel of the 8T8R TDD macro RU architecture.

Therefore, the entire 8T8R TDD macro RU system requires a total of 36 RF connectors and 27 of them are the SMP/SMP-MAX type. ***Figure 9*** shows the cutaway view of the 8T8R TDD architecture.

RF CONNECTOR VENDOR ECOSYSTEM

This section presents a high-level view of the vendor ecosystem for the RF connectors highlighted in this article. The list is not 100 percent complete for all vendors. Additionally, it does not include manufacturers of other RF connector types such as the multiport cluster connectors, which include the MQ series and CommScope's M-LOC solution for RU/antenna applications.

Nex10®

- Huber+Suhner AG (developing company)
- Radiall SA (developing company)
- Rosenberger Hochfrequenztechnik GmbH & Co. KG (developing company)
- Amphenol RF/Changzhou Amphenol Fuyang Communication Equipment Co., Ltd.
- IMS Connector Systems
- JMA Wireless
- SPINNER GmbH
- Telegärtner Karl Gärtner GmbH.

4.3-10

- Huber+Suhner AG (developing company)
- Radiall SA (developing company)
- Rosenberger Hochfrequenztechnik GmbH & Co. KG (developing company)
- SPINNER GmbH (developing company)
- Amphenol RF/Changzhou Amphenol Fuyang Communication Equipment Co., Ltd.
- CommScope
- Xiamen Hongfa Electroacoustic Co., Ltd.

7-16 DIN

- Everyone, everywhere in the world.

SMP/SMP-MAX

- Amphenol RF/Changzhou Amphenol Fuyang Communication Equipment Co., Ltd.
- Huber+Suhner AG
- Radiall SA
- Rosenberger Hochfrequenztechnik GmbH & Co. KG
- Samtec, Inc.
- Sichuan Huafeng Technology Co., Ltd.
- Xiamen Hongfa Electroacoustic Co., Ltd.

CONCLUSION

Since most of these types of RF connectors are used on mMIMO, macro RU and macro antenna systems, the end users are very concentrated with the major wireless equipment suppliers like Ericsson, Nokia, Huawei Technologies, Samsung Networks and ZTE Corporation. Additionally, the largest market, globally, for wireless equipment remains in China. The forecasts that were presented earlier in the article are global but the presumption is that a large percentage of the volumes of wireless equipment will continue to ship in China and therefore, will continue to be consumed primarily by Huawei Technologies and ZTE Corporation and to a lesser extent, CITIC Mobile Communication Technology Co., Ltd.[1] The anticipation is that the global wireless equipment market will remain weak in 2024 and through 2027 outside of China. However, EJL Wireless Research expects China to continue its mobile network deployments with 5.5G and remain somewhat stable or even see growth during this same timeframe. ■

Reference

1. Datang Telecom Group and FiberHome Telecommunications Technologies Co., Ltd.

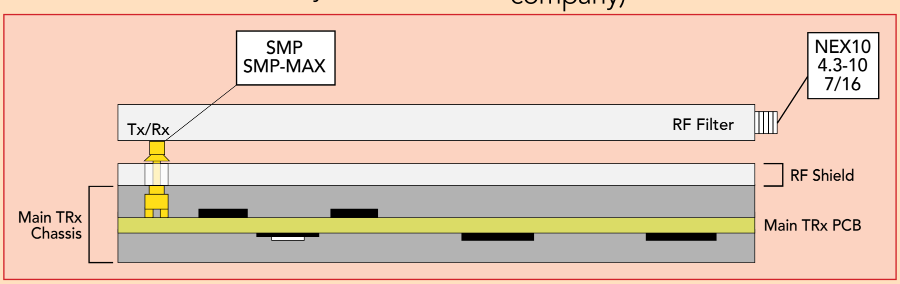

Fig. 9 Macro TDD RU. *Source:* EJL Wireless Research LLC, January 2024.

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Mini-Circuits

The Growing Challenge from Counterfeit Cables and Assemblies

Tony Fedor
Times Microwave Systems, Wallingford, Conn.

Counterfeit cables and assemblies are a growing issue in the RF market. Inferior RF interconnect products continue to appear, and since they are produced with lower-quality materials, they undercut the value of genuine products. Using inferior raw materials and components instead of quality ones can lead to costly failure. As the original manufacturer of LMR® coaxial cables, Times Microwave Systems often deals with counterfeit competitors in the market.

Thirty years ago, LMR cables were released as a reliable and efficient coaxial cable alternative to traditional RG cables and stiffer corrugated copper cables. Since then, as has happened for many popular products, counterfeits and clones have appeared on the market. These counterfeit products appear to offer a better value at a lower price. However, the value of a product goes beyond the product itself, it also encompasses quality, certifications, accessories and technical support.

Many common scenarios that lead to the purchase of counterfeit cables involve a bait-and-switch technique. This happens when one product is advertised and once a customer is interested, an inferior product is either substituted or shipped. For example, some companies will list their cables as LMR cables or an equivalent substitute for LMR cables to attract customers, but then what is provided is not an authentic product.

THE RISKS OF COUNTERFEIT CABLES

Counterfeit and clone cables may appear to be a more cost-effective option for systems, but eventually, they may pose many disadvantages and can result in system degradation or complete system failure. If the system requires long-term performance, as most systems do, a counterfeit or clone cable may not be the best choice. While these cables might have similar test results initially, the counterfeit cables may not continue to meet those specifications over the expected lifetime. Typically, these counterfeit and clone cables are not built to last and are likely made of lower-quality materials. For example, the jacket of a counterfeit cable is unlikely to have the same level of UV resistance needed to survive an outdoor environment. In a critical application, such as a hospital or a high-rise building, a low-smoke, fire-retardant cable that does not meet the UL standards for flame and smoke can potentially lead to the inability to exit a building, which can easily result in fatalities. ***Figure 1*** shows an example of the LMR line of genuine cables from Times Microwave Systems.

Beyond the safety considerations, the overall cost of counterfeit and clone cables can be substantial. A buyer must consider that

Fig. 1 **Times Microwave genuine LMR cables.**

if the counterfeit cable becomes faulty due to the materials or the construction techniques, or if the cable gets damaged, a replacement cable must be purchased and there will be additional rework or reinstallation costs incurred when the cable is replaced. Depending on the specific application, having a system or a network out of service for hours or days while the faulty cable is replaced is likely to cause a substantial loss of revenue in addition to the replacement costs. Additionally, if a cable is required to be UL-listed, it must have that marking on the cable. If the cable does not carry the appropriate UL listing, an inspector can demand that the cable be removed and replaced with an approved selection.

All cables can fail, but some of the more common failure points of counterfeit and clone cables include:

- Jacket failure
- UV deterioration
- Water penetration into the cable along the braid
- Poor cable-to-connector transition
- Degradation of performance over time due to the breakdown of the dielectric
- Cracking of the outer conductor tape resulting in poor RF performance
- Moisture migration down to the center conductor
- Poor dimensional tolerance of the dielectric causing electrical instability.

UV deterioration and failure is one of the most common system failures that inferior coaxial cables cause. Once the jacket cracks and water can breach the assembly, it becomes a matter of time before the interconnect deteriorates and becomes unusable. Other issues, like using nitrogen-injected polyethylene foam versus chemical foam dielectric, not pressuring the jacket and no adhesive on the center conductor are all things a buyer may find as issues with counterfeit cables. All these issues, along with many others, can have a significant impact on performance.

When designing and manufacturing authentic cables, there are many steps involved to guarantee high performance over a long life for the cable. Pressuring the jacket during manufacturing helps create a more mechanically stable cable and eliminates a path for water to get through the braid. Adding adhesive to the center conductor also removes a path for moisture to travel, which could result in potential RF degradation.

IDENTIFYING COUNTERFEITS AND CLONES

The terms "counterfeit" and "clone" are often used interchangeably when referring to cables that do not come from a reputable manufacturer or source. Both of these designations are umbrella terms that refer to the broad category of replica cables. However, there are differences and when counterfeit and clone cables are compared, these differences become clear.

Counterfeits are typically defined as products not produced in the U.S. The companies that make these cables advertise and promote these products as brand-name cables when they are not. These claims can range from misleading to deceptive and the result is that buyers are often misled into believing that they are buying a genuine product. As described earlier, these counterfeit products are often crafted with subpar materials that lack the strength, durability and conductivity of the genuine cables. Not only can there be substantial costs to the end users, but the brand name suffers when the end users are led to believe that they are getting a quality product and the counterfeit cable does not fulfill those expectations.

The situation with clone cables is a little different. Clone cables do not necessarily claim to be a name-brand product. They are copies of genuine products, but they are designed and manufactured without the technical expertise or quality of the genuine cable that the clone cable is imitating. These products mimic the general look and feel of a known brand-name cable, but the quality of the clone cable will always be suspect because of the quality control of the processes and the lower grade of the materials used to manufacture those cables. This path has proven to be the more popular technique in the coaxial cable industry, as clone cables are seen more frequently than counterfeit cables.

Times Microwave Systems is extremely aware of the problem of counterfeit and clone cables. The LMR brand of cables was the first of their kind. As they gained popularity, other companies attempted to copy the cables. As a result, there are many counterfeit cable versions of the LMR line of coaxial cables in the RF cable industry. Many companies advertise their counterfeit or clone cables as LMR cables. Some of these companies will even provide the LMR cable performance details, unchanged, as data from their cables.

This is not just a problem with LMR cables. There are other comparable and competitive cables on the market. The largest segment of coaxial cables, other than LMR cables, is RG cables. The RG in the cable nomenclature stands for "Radio Guide" and this designation came from World War II military specifications. These cable designs use PVC jackets, meaning they are not as robust to outdoor weather conditions. The designs also have issues with performance loss and they are not as well shielded as their more recent coaxial cable counterparts. In addition, this style of coaxial cable tends to be either very stiff or very fragile, making it more susceptible to kinking when compared to other corrugated cables of comparable size. Despite these drawbacks, RG cables are still being sold, counterfeited and cloned into market applications.

Another advantage of buying authentic cables from an authorized dealer is that most of these cable companies provide a full connectivity solution. Coaxial cables will connect to other devices at both ends or they will be terminated at one end. They may also need to be cut to custom lengths during field installations. With the full connectivity solution from authorized dealers, a user will get not only a genuine cable but connectors designed to fit with the cable, along with terminations and tools that help with the termination and installation process. Also, it is not hyperbole to say that a complete RF interconnection

Fig. 2 **Times Microwave Systems TK-195/200/240EZ-HC installation tool kit.**

of any kind is only as strong as its weakest point, so the tools for creating the cable-to-connector transition are crucial. In addition to accessories like ground kits and weather seals, authorized cable sellers provide technical support and training content for terminating and installing cables that help to maintain the consistency and performance of the genuine product. ***Figure 2*** shows a typical cable installation tool kit for Times Microwave Systems products.

Using the Times Microwave Systems LMR cable family as an example, there are several things to look for to verify that you are getting a genuine LMR cable:

- Times Microwave Systems name
- Registered trademark after LMR®
- If the seller is an authorized distributor
- If it is a UL/CSA-listed product with a qualification reference number.

TRADEMARK INFRINGEMENT

Companies use trademarks to distinguish their products from their competitors' products. A trademark identifies the brand owner of a particular product or service. This use gives companies the legal right to prevent the use of similar or identical trademarks without proper authorization. ***Figure 3*** shows a cutaway image of a Times Microwave Systems LMR-series cable showing the trademark, along with the metallic sheathing that improves shielding and performance.

In the case of LMR cables, LMR is a registered trademark of Times Microwave Systems, not a generic cable category within the industry. This means that other companies are not free to use this designation. The owner of the registered trademark is the only company authorized to manufacture the authentic trademarked product. Other suppliers may try to replicate or emulate the cables, connectors and tools, but doing so means that the supplier is knowingly producing a counterfeit or clone cable and falsely marketing inferior products as authentic cables. Any company that appropriates the trademark for products and literature not manufactured by the holder of the trademark infringes upon that trademark. Sometimes identifying and prosecuting these activities is difficult, but anyone who knowingly buys or manufactures a counterfeit or clone cable is jeopardizing their end application and creating a cost for the entire industry.

Fig. 3 **Times Microwave Systems LMR-900-LLPX cable.**

CONCLUSION

Counterfeits and clones of cables from authorized manufacturers and resellers are often the cause of failure in RF systems. A high-quality product is likely to have imitators looking to capitalize on the success of the product, often to the detriment of the end user. To ensure a system works reliably and as designed, it is incumbent on the buyer to be certain they are buying genuine cables from a reliable supplier. Paying attention to trademarks and the company selling the product can help prevent purchasing a counterfeit cable that can cause damage to an RF system and incur additional costs. ■

Interesting Technologies Enabling Future Products: Technology Innovator of the Year Award

Patrick Hindle
Microwave Journal, Norwood, Mass.

In December of 2023, Junkosha released the shortlist for its second annual "Technology Innovator of the Year Award" with the winners receiving the commemorative hardware seen in ***Figure 1***. Junkosha is best known in the RF and microwave markets for its precision cables but is also the manufacturer of advanced fluoropolymer application technologies across both the medical device and microwave interconnect sectors. Eleven entries on the shortlist are being evaluated to determine this year's winners. Each shortlisted candidate presented their entry to the judging committee in January and the winner will be announced at a ceremony in April 2024.

The winners are chosen by a panel of highly respected judges chosen for their industry credentials and the winning entrants will be awarded $25,000 to invest in their project. The Technology Innovator of the Year Awards were set up to recognize the innovative work of an individual or team working to deliver products used within interventional medical procedures or microwave/mmWave technologies. The shortlisted candidates are provided below by category.

MICROWAVE AND MMWAVE TECHNOLOGIES CATEGORY

Elahe Soltanaghai, University of Illinois Urbana-Champaign

Soltanaghai's research develops a vision of omnipresent sensing for making buildings or cities smart by repurposing the pervasive wireless communication infrastructures (such as Wi-Fi) in every building or city to function as sensors. To achieve that, the technology leverages the low-level natural behavior of radio waves when they propagate in the physical space to infer where people, devices or objects are and what is happening in the physical environment. The research leverages the interaction of these wireless signals with the environment. The signals, which mainly communicate data between wireless devices, emulate physical resources such as sensors to identify the presence of people for automated air conditioning and lighting, tracking battery-free objects such as wallets or keychains in any indoor space that has Wi-Fi networks and even enable identification and localization of roadside infrastructure such as digital lane markers and road signs for vehicles. The goal is to use these techniques to identify nodes that are obscured from view, where visual sensing typically fails. A conceptual block diagram of this concept is shown in ***Figure 2***.

Ian Roberts, Wireless Lab at UCLA

For the past century, wireless systems like 5G and Wi-Fi have been bottlenecked by their inability to transmit and receive signals at the same time and the same frequency.

Fig. 1 Junkosha Technology Innovator of the Year Award.

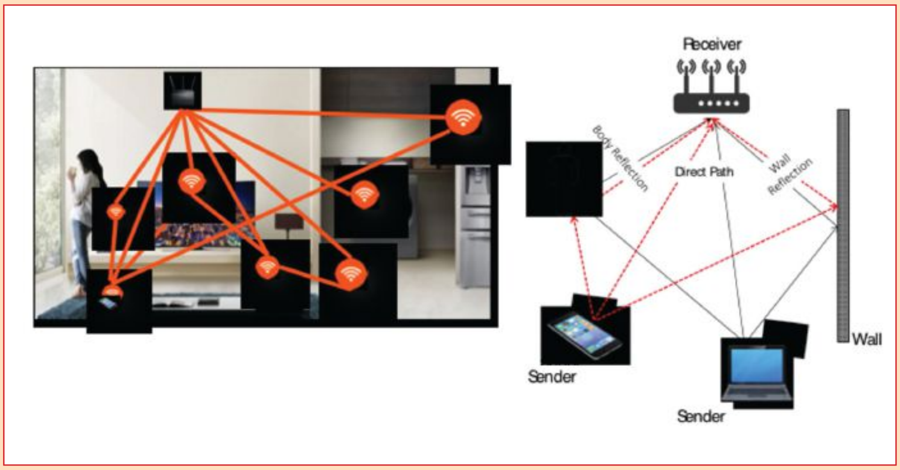

Fig. 2 Wi-Fi devices form a sensor network. *Source:* University of Illinois Urbana-Champaign.

This research changes that by unlocking true "full duplex" capability in mmWave wireless systems through beamforming techniques to eliminate self-interference. They derive new theories and implement their techniques on mmWave transceivers to validate their effectiveness in real-world systems at the lab.

Michael Hollenbeck, Optisys, Inc.

Optisys specializes in design for metal additive manufacturing, which allows for new, highly integrated waveguide antenna assemblies to be produced at a fraction of the size and weight of traditional waveguides while maintaining the highest performance. The company has manufactured antennas that are in space, on the moon, in the air and on the ground. Optisys can provide solutions from 1 to 100 GHz, from feeds and flat panel antennas to phased arrays and synthetic aperture radar so the techniques apply to many applications to improve SWAP-C. Examples of the Optisys products are shown in ***Figure 3***.

Mona Jarrahi, UCLA

The millimeter and sub-mmWave imaging/sensing systems developed by this group offer what they claim to be record-high signal-to-noise ratios that enable 3D hyperspectral imaging of unknown objects in real-time for the first time. These systems provide a powerful platform for high-throughput, non-destructive inspection of various products in the pharmaceutical, automotive, aerospace and energy industries.

Patrick Reynaert, University of Leuven (KU Leuven)

This group proposes polymer fibers for mmWave communication as an alternative to copper wireline and optical fiber transmission for robust, high speed, low-cost, low-power and medium-distance communications. They have already achieved 100 Gbps over 5 m, using low-cost polymers, making this solution well-suited for automotive communication and data centers where robustness and cost are crucial.

Professor Anthony Peyton, University of Manchester

This group works to bring im-

Fig. 3 Example of Optisys additively reduced SWAP-C antenna technology. *Source:* Optisys.

Fig. 4 Glucowear™ is suitable for anyone who needs to monitor their blood glucose levels regularly. *Source:* Afon Technology Ltd.

proved resolution in non-destructive testing and Professor Peyton was awarded the BINDT Roy Sharpe Prize in 2022. This work has been extended to landmine detection and body scanners. Frequency ranges extend from low RF frequencies up to typically 12 GHz with plans to go to mmWave frequencies where electromagnetic wave propagation allows for the application of their tomography algorithms.

Sabih Chaudhry, Afon Technology Ltd.

Using a unique microwave structure, this group can detect subtle changes in blood glucose levels without penetrating the skin. Their technology will enable diabetics and pre-diabetics to better monitor their blood glucose without the pain, discomfort and other side effects associated with current glucose monitoring options. Some of the hardware incorporating this technology is shown in ***Figure 4***.

Wenyao Xu, University at Buffalo

This group's technology and product provide what they believe is an unprecedented solution for skin lesion screening, diagnosis, prognosis and treatment. The technology minimizes side effects, such as infection, compared with traditional solutions.

INTERVENTIONAL MEDICAL PROCEDURES

Matt Ginn, IQ Endoscopes

This team of clinical, medical tech and engineering specialists is committed to creating clinically effective, high performance, sustainable single-use, flexible endoscopes on a global scale. Using a patented engineering approach, their range of single-use endoscopes will deliver much-needed change within endoscopy, addressing the huge demand for the service, globally. Sustainable, single-use endoscopes provide an opportunity to meet the growing demand gap for endoscopy and to free it from an acute setting, allowing microwave/mmWave technologies and interventional medical procedures to be undertaken on a broader scale, improving patient outcomes.

Seth Harrington, Avisi Technologies, Inc.

Avisi Technologies has developed an ultra-thin, multichannel, non-fibrotic device for the treatment of glaucoma. The product is a nanotechnology-enabled aqueous shunt. Working closely with ophthalmologists and experts, Avisi is committed to introducing a reliable, safe and effective solution for glaucoma patients.

Tyler Melton, Corveus Medical

Corveus Medical is developing a one-time, catheter-based solution that provides instant relief from the symptoms of chronic heart failure by removing a single nerve branch. Their device can find and remove a nerve that has been shown to be responsible for driving intracardiac volumes and progressing heart failure.

SUMMARY

Efforts like Junkosha's Technology Innovator of the Year Award help jump-start novel technologies for future products. It is a way to enable these emerging technologies to refine and mature their products to get them into production and promote their growth for the future. ■

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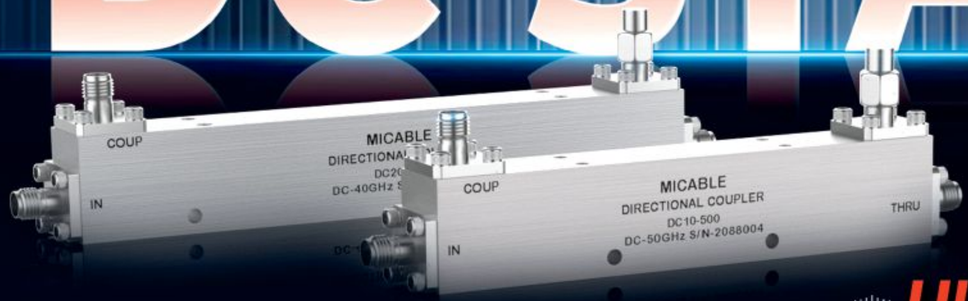

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				10dB	20dB	10dB	20dB	
DC~0.3	DC10-085 DC20-085	10/20	1.1/1.3	0.2/0.7	0.2/0.5	25/-	35/-	25/-
0.3~0.5			1.1/1.3	0.5/0.9	0.2/0.5	12/-	22/-	25/-
0.5~8.5			1.1/1.3	0.8/1.3	0.4/0.8	10/10±1.2	20/20±1.2	25/20
DC~0.3	DC10-124 DC20-124	10/20	1.1/1.3	0.2/0.7	0.2/0.5	25/-	35/-	25/-
0.3~0.5			1.1/1.3	0.5/0.9	0.2/0.5	12/-	22/-	25/-
0.5~12.4			1.1/1.3	1.0/1.5	0.6/1.0	10/10±1.3	20/20±1.3	25/20
DC~0.3	DC10-200 DC20-200	10/20	1.1/1.3	0.2/0.7	0.2/0.5	25/-	35/-	25/-
0.3~0.5			1.1/1.3	0.5/0.9	0.2/0.5	12/-	22/-	25/-
0.5~8			1.1/1.3	0.8/1.4	0.4/0.8	10/10±1.4	20/20±1.4	22/16
8~20			1.2/1.4	1.3/1.9	0.9/1.2	10/10±1.4	20/20±1.4	18/14
DC~0.3	DC10-265 DC20-265	10/20	1.1/1.3	0.2/0.7	0.2/0.5	25/-	35/-	25/-
0.3~0.5			1.1/1.3	0.5/0.9	0.2/0.5	12/-	22/-	25/-
0.5~18			1.2/1.4	1.2/1.8	0.7/1.1	10/10±1.7	20/20±1.7	18/14
18~26.5			1.2/1.5	1.5/2.2	1.0/1.4	10/10±1.7	20/20±1.7	16/13
DC~0.3	DC10-400 DC20-400	10/20	1.1/1.3	0.2/0.7	0.2/0.5	25/-	35/-	25/-
0.3~0.5			1.1/1.3	0.5/0.9	0.2/0.5	12/-	22/-	25/-
0.5~26.5			1.3/1.6	1.6/2.4	1.2/2.0	10/10±2.2	20/20±2.2	16/12
26.5~40			1.4/1.7	2.2/2.9	1.8/2.6	10/10±2.2	20/20±2.2	13/10
DC~0.4	DC10-500 DC20-500	10/20	1.1/1.3	0.2/0.7	0.2/0.6	25/-	35/-	25/-
0.4~1			1.1/1.3	0.5/1.0	0.2/0.6	12/-	22/-	25/-
1~26.5			1.3/1.6	1.8/2.3	0.9/1.5	10/10±2.2	20/20±2.2	16/12
26.5~50			1.4/1.8	2.6/3.5	1.4/2.1	10/10±2.2	20/20±2.2	11/8

More Information-
Scan the QR Code

MIcable Inc.

www.micable.cn sales@micable.cn +86-591-87382856

SMP-MAX Connector Evolves

Radiall
Paris, France

SMP-MAX Evolution is Radiall's latest expansion of the SMP-MAX series. The evolution of SMP-MAX connectors represents a significant leap forward in the realm of subminiature RF connectivity. Developed by Radiall, a renowned global provider of advanced interconnect solutions, the SMP-MAX Evolution family features a broad range of solutions for board-to-board connectors tolerating larger misalignment. With the SMP-MAX Evolution, there is a cost savings with no compromise on performance. Additionally, the SMP-MAX Evolution is fully compatible with the SMP-MAX portfolio and provides more flexibility in part number selection. SMP-MAX Evolution has an excellent cost-to-performance ratio among board-to-board connector solutions.

SMP-MAX Evolution employs innovative technology in the adapter bullet to reduce cost. A composite catcher's mitt is also used instead of a metal bowl to reduce the overall surface of gold plating. The improved design expands axial misalignment from ±1 mm to ±1.2 mm without sacrificing performance. ***Figure 1*** shows examples of the SMP-MAX Evolution receptacles and ***Figure 2*** shows examples of the SMP-MAX adapter types.

The SMP-MAX Evolution story is incomplete without understanding the origins of the family. SMP-MAX connectors have their roots in the SMP connector family, known for their subminiature design and push-on coupling mechanism. While SMP connectors have established themselves as reliable components in various applications, the evolution to SMP-MAX signified an enhancement that caters to the ever-growing demand for higher performance in smaller packages. The SMP-MAX family was a notable improvement in several areas, which are listed below.

Fig. 1 **SMP-MAX Evolution receptacles.**

Fig. 2 **SMP-MAX Evolution adapters.**

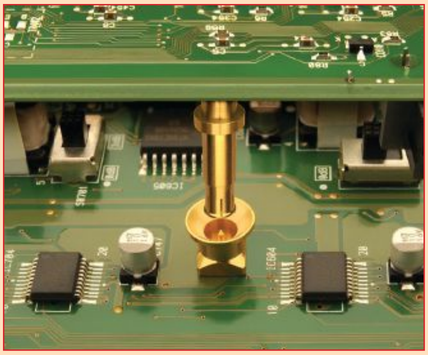


Fig. 3 Interconnecting radio unit boards in a base station.

Increased Power Handling Capability: Engineers at Radiall have refined the design to enable these connectors to accommodate higher power levels, making them suitable for applications where power requirements have escalated, such as in advanced radar systems or high-power RF modules.

Extended Frequency Range: While maintaining the subminiature form factor, the SMP-MAX connectors operate over an extended frequency spectrum, reaching frequencies up to 40 GHz. This expanded frequency range aligns with the demands of emerging technologies like 5G, where higher frequencies are becoming integral for enhanced data transmission rates.

Enhanced Durability and Robustness: The SMP-MAX connectors underwent enhancements in durability and robustness. The improvement revolved around the use of advanced materials and manufacturing techniques, ensuring that the connectors can withstand harsh environmental conditions, vibrations and mechanical stress. This robust construction is particularly crucial in aerospace and military applications where reliability under adverse conditions is non-negotiable.

Building upon the advancements of the SMP-MAX product family, the SMP-MAX Evolution connectors offer the following improvements:

- Up to 2.4 mm board-to-board axial misalignment
- Radial misalignment: 3 degrees minimum tilt
- Power up to 300 W
- Robust bullet with a larger diameter
- Expanded pour-in range to secure blind mating
- High quality with automated video quality control.

The team at Radiall has developed an extensive product range:

- SMP-MAX Evolution test probes and test cables available
- Complete range of configurations available
- Unique compatibility with legacy equipment
- Fully compatible with existing SMP-MAX connectors
- Multiple sources available.

The broad range of products and the compatibility with existing SMP-MAX solutions allow the SMP-MAX Evolution to target a variety of applications:

Test and Measurement Equipment: The enhanced power handling capability and extended frequency range of SMP-MAX Evolution connectors make them invaluable in test and measurement applications. These connectors find applications in RF testing, network analysis and other measurement systems where precision and reliability are paramount. The compact size allows for intricate designs in testing setups without compromising performance.

Aerospace and Defense Systems: The SMP-MAX connectors address the size, weight and performance challenges and the SMP-MAX Evolution family improves the cost. Their increased power handling capability and robust construction make them suitable for deployment in radar systems, communication equipment and other critical components of aircraft and defense systems.

Satellite Communication Systems: In satellite communication systems, where space is at a premium and high frequencies are often utilized, these connectors offer an optimal solution. Their miniaturized design, enhanced power handling and extended frequency range make them well-suited for integration into satellite antennas, communication modules and other space-constrained components.

Telecommunications Infrastructure: The extended frequency range aligns SMP-MAX Evolution connectors with the evolving landscape of telecommunications infrastructure. As the demand for higher data rates and increased capacity grows with the deployment of 5G technology, these connectors play a crucial role in small cell installations, base station antennas and other components of the telecommunications network. ***Figure 3*** shows a typical wireless communications application, where SMP-MAX and now SMP-MAX Evolution connectors and adapters can be used to transport signals between PCBs.

The evolution of SMP-MAX into SMP-MAX Evolution connectors continues the delicate balance between miniaturizing the footprint, enhancing power handling capability and reducing cost. These tradeoffs become particularly significant as space becomes limited in emerging applications. Despite these space limitations, there is a growing demand for connectors that can handle higher power levels without sacrificing performance.

The extended frequency range of the SMP-MAX Evolution connectors ensures that they remain relevant and effective in the face of evolving technology. Communication systems and applications are going to higher frequencies in search of more bandwidth. The ability of the connectors to operate to 40 GHz expands their usefulness for emerging high frequency applications.

The Radiall SMP-MAX Evolution product family represents an innovative stride in subminiature RF connectivity. As technology advances, these connectors stand as a testament to Radiall's commitment to improvement and meeting the evolving needs of industries such as aerospace, defense, telecommunications and satellite communication. The family exemplifies the delicate balance between size, performance and cost, paving the way for the next generation of compact, yet powerful RF connectivity solutions. The SMP-MAX Evolution represents the next step down the path of enabling higher performance solutions at a reduced cost.

Radiall
Paris, France
www.radiall.com

Adapter Operates to 65 GHz

Fairview Microwave's FMCN49821 precision Mini SMP female to SMPS female VITA 67.3 backplane adapter is part of its full line of RF components available for same-day shipping. Fairview's Mini SMP to SMPS adapter is a coaxial adapter design with a 50 Ω impedance. This 50 Ω Mini SMP adapter is manufactured to precise RF adapter specifications and has a maximum VSWR of 1.35:1 up to the maximum operating frequency of 65 GHz.

RF adapters are often used to enable connections between two connector types that would otherwise not mate. Certain adapter configurations can also be used to protect connectors on expensive equipment where the number of connect/disconnect cycles is high. An RF, microwave or mmWave adapter is connected to the equipment and the commonly changed connection is made with the adapter which can be easily replaced when it wears out after high usage.

The FMCN49821 RF adapter is constructed with beryllium copper contact material with gold contact plating. This straight Mini SMP connector adapter is an in-line RF adapter design with a female SMPM connector on one side and a female SMPS connector on the other side. The Fairview female Mini SMP to female SMPS adapter is part of over one million RF, microwave and mmWave components in stock. Fairview Microwave also offers bulkhead, panel-mount, hermetically sealed, reverse polarity and isolated ground adapter varieties to serve all your RF, microwave and mmWave needs.

Fairview Microwave, an Infinite Electronics brand, is a leading provider of high-quality RF and microwave components including adapters, connectors, attenuators, coaxial cables, terminations and much more. Specializing in immediate product needs, the company offers same-day shipping on thousands of in-stock items with no minimum purchasing requirements.

VENDORVIEW

Fairview Microwave
Lewisville, Texas
www.fairviewmicrowave.com

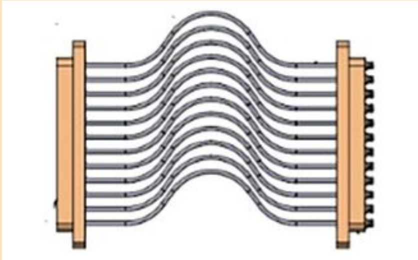
RUGGED NEW SMPS INTERCONNECTS

VENDORVIEW

Fairview Microwave, an Infinite Electronics brand, has unveiled the newest addition to its product lineup: SMPS interconnects. With a focus on compactness and high frequency, the SMPS connectors cover frequencies up to 65 GHz while meeting the rigorous demands of military and aerospace applications. Crafted as a miniature push-on connector, the SMPS interconnects are an emblem of quick assembly and ease. Their broad frequency range, spanning from DC to 65 GHz, ensures versatility, making them adaptable to a diverse array of applications.

Fairview Microwave
www.fairviewmicrowave.com

RF CABLE ASSEMBLY



The C447-ZZZ-101G from IntelliConnect, a Trexon company, is a 24-way high density SMPM plug to SMPM jack cable assembly that operates from DC to 40 GHz. This interconnect solution consists of 24 0.047-in. semi-rigid cables between each SMPM plug to SMPM jack connector. The connectors have a durability of more than 100 cycles and meet the MIL-STD-348 and MIL-PRF-39012 standards.

IntelliConnect
www.intelliconnectgroup.com

VECTOR NETWORK ANALYZER

VENDORVIEW

The Rohde & Schwarz vector network analyzer series provides precise, fast and versatile solutions for RF and microwave measurements. With a frequency range up to 1.1 THz and multiport options up to 48 ports, these high performance analyzers are ideal for analyzing passive and active components like filters, amplifiers, mixers and multiport modules. Offering excellent RF characteristics and a range of analysis functions, Rohde & Schwarz network analyzers empower users to assess crucial parameters efficiently.

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

RUGGEDIZED CABLE LINE

VENDORVIEW

HASCO's new ruggedized cable line includes high-quality, low loss, phase-stable cable assemblies constructed with robust connectors, internally ruggedized with multi-layer copper spiral and braided armor, offering excellent phase and amplitude stability with flexure. The ruggedized series of armored cables is RoHS compliant and available in male-to-male and male-to-female configurations, with a range of connectors and frequencies: SMA, 2.92 mm, 2.4 mm and 1.85 mm from 26.5 GHz up to 67 GHz.

HASCO
www.HASCO-Inc.com

SP4T TTL SWITCH ROUTES 0.1 TO 18.0 GHZ

VENDORVIEW

Mini-Circuits' model TTL-1SP4T-183 is a single-pole, four-throw (SP4T) switch with low loss from 100 MHz to 18 GHz. With female SMA connectors on all RF ports, the absorptive switch exhibits typical insertion loss of 2.5 dB to 10 GHz and 4.0 dB or less to 18 GHz. Typical isolation between ports is at least 65 dB to 10 GHz and 60 dB to 18 GHz. TTL control simplifies integration into radios, radar and test systems while enabling 100 ns switching time.

COAXIAL AMPLIFIER GAINS 0.5 TO 18.0 GHZ

Mini-Circuits' model ZX60-R5183P+ is a coaxial amplifier with 3 dB positive gain slope from 0.5 to 18.0 GHz. Typical gain is 6.5 dB from 0.5 to 5.0 GHz, increasing to 9.5 dB from 15.0 to 18.0 GHz. Noise figure drops with frequency, typically 6.1 dB from 0.5 to 5.0 GHz and 4.5 dB from 1.50 to 18.0 GHz. The RoHS-compliant amplifier, with female SMA connectors, provides at least +10.2 dBm typical output power at 1 dB compression across the full bandwidth.

COAXIAL DIPLEXER SCREENS DC TO 40 GHZ

Mini-Circuits' model ZDSS-K10G13G+ is a suspended-substrate-strip line coaxial diplexer for isolating signals within DC to 40 GHz. Equipped with 2.92 mm connectors, it is ideal for ECM and ELINT systems. Insertion loss is typically 1.0 dB across the lowpass passband of DC to 10.5 GHz and typically 1.5 dB for the 13.5 to 20.0 GHz highpass passband. Stopband rejection to 40 GHz is as much as 90 dB in the highpass channel and as much as 70 dB to 40 GHz in the lowpass channel.

Mini-Circuits
www.minicircuits.com

MULTI-PORT SMPM SOLUTIONS

Magnum RF™ is Samtec's new line of ganged multi-port connectors. Magnum RF™ delivers an SMPM interface into a tightly packaged solution, offers 40 percent greater density, decreased processing time and better positional alignment versus single channel options. Cable-to-board and board-to-board mated sets are available.

Samtec
www.samtec.com

NARROW BODY EDGE LAUNCH CONNECTOR

Signal Microwave's line of higher performance edge launch connectors is designed for the thinner substrates used today. 1.15:1 maximum connector VSWR through 40 GHz with 23 dB return loss. The new design of the connector is intended for substrate thicknesses between 5 to 10 mil (.005 to .010 in.), (.127 mm to .254 mm).

Signal Microwave
www.signalmicrowave.com

CONDUCTIVE FIBER BRAIDING MATERIAL

Liberator® conductive fiber braiding material provides cable manufacturers with the lightest-weight alternative to traditional silver-plated copper braiding available today. Cables using Liberator® weigh 30 percent less on average. The fi-

works with existing braiding equipment and is provided on spools or cores. Liberator® can be soldered or crimped and has proven shielding effectiveness equal to or better than traditional copper braiding. Superior flex-cycle durability over 1,000x that of equivalent size copper provides an added benefit for repetitive bend applications.

Syscom Inc.
www.syscom.com

130 CABLE ASSEMBLIES

The best of low loss cables has a new member, the dB Miser 130. The new cable form factor preserves the ultra-low loss cable construction and still offers the same great performance and stability over flexure. With excellent connector retention and thermal stability, we are confident this cable will meet your power handling needs. Armoring options are available to withstand the harshest environments while maintaining flexibility. Let us know how dB Miser 130 will fit your system needs.

Teledyne Storm
www.teledynestorm.com

Eight-Channel Oscilloscope With Digital Triggering

Rohde & Schwarz
Munich, Germany

The R&S MXO 5 from Rohde & Schwarz is the first eight-channel oscilloscope that can detect 4.5 million acquisitions and 18 million waveforms per second across multiple channels. This acquisition rate is the fastest in the world, allowing the instrument to capture up to 99 percent of real-time signal activity. As the first eight-channel oscilloscope with digital triggering, the R&S MXO 5 is exceptional at isolating small signal anomalies. This makes it a powerful tool for efficient debugging across applications, from power conversion to automotive analysis.

POWERFUL EMI TESTING FEATURES

The R&S MXO 5 has a minimal blind time that is ideal for EMI diagnostics during product design phases, helping to avoid costly redesigns during pre-production. It is also the first oscilloscope to feature 45,000 FFTs per second. This exceptional speed provides engineers with outstanding RF signal visibility and enables efficient debugging across a wide range of applications.

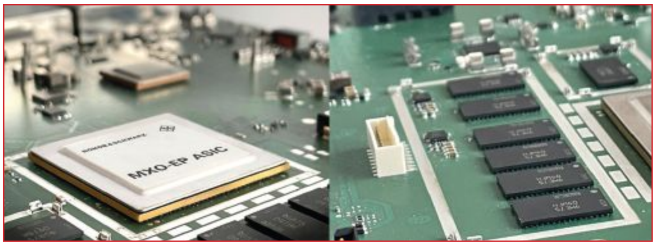
▲ Fig. 1 Different range displays for the same signal.

A normal sine tone can conceal many spectral elements. The R&S MXO 5 can display four simultaneous spectra, as shown in ***Figure 1***, enabling it to reveal spectral elements that would normally remain hidden. It shows how the instrument displays different ranges for the same signal, allowing the user to observe various frequency details.

EASIER POWER SEQUENCING

Power sequence verification is a key application for multi-channel oscilloscopes. Normally, when a device under test (DUT) has more power rails than available channels, repeated measurements or a second oscilloscope are needed and measurements need to be synchronized for a complete picture of power timing. The eight-channel R&S MXO 5 makes synchronization easier by eliminating the need for separate measurements or devices.

This oscilloscope series has many automotive measurement applications. It supports automotive Ethernet along with the basic triggers for automotive buses and decod-



▲ Fig. 2 **Inside the R&S MXO 5.**

ing. Current and high-voltage probes are often needed when designing electric drive trains and the number of available measurement channels often imposes limits. The R&S MXO 5 addresses this challenge by providing enough current for eight active probes at the same time.

DEEPEST-IN-CLASS STANDARD MEMORY

Looking inside the R&S MXO 5 in ***Figure 2*** reveals internally developed next-generation MXO-EP processing ASIC technology and a generous memory block. Each channel of the R&S MXO 5 has 500 Mpoints of acquisition memory; more than 5× the standard memory of other scopes in its class. The instrument also features segmented memory to capture signals separated by inactivity. This is useful for applications like laser pulses, serial bus activities and RF pulses. It enables signal capture over long observation periods, up to 10,000 segments.

The standard history mode can access previous acquisitions. For applications that require long observation periods, a 1 Gpoint of memory (channels interleaved) and 1 million segment upgrade is available.

RADAR PULSE ANALYSIS

With a maximum bandwidth of up to 2 GHz, the R&S MXO 5 might seem insufficient for RF and radar applications. However, through a down-converter, the DUT's high frequency carrier can be mixed down with a modulation bandwidth up to the oscilloscope's rated bandwidth. With real-time capture rates of 99 percent, the oscilloscope records like a real-time spectrum analyzer. Recorded data can be transferred to an external PC for deeper analysis. Providing pristine RF performance with a wide dynamic range is a strength of the R&S MXO 5. Uniform bandwidth flatness also contributes to capturing clean pulse shapes. This is useful when investigating pulse compression. The oscilloscope excels in phased-array antenna applications by providing a time-synchronized multiple-channel capture.

EVERY DETAIL RECORDED

Input channels have a 12-bit ADC with a vertical resolution of 4096 quantization levels at all sampling rates, ensuring that signal details are captured without compromise. The hardware has an 18-bit architecture with an HD mode to enhance ADC resolution, as shown in ***Figure 3***. The improved resolution does not reduce the sampling rate. Bit resolution enhancements usually cause decimated samples, but a moving average filter eliminates aliasing noise components and maintains high resolution for precise capturing and triggering.

The R&S MXO 5 is sensitive down to 500 µV/div without any bandwidth reductions. At 1 mV/div, the maximum noise is 130 µV at 2 GHz bandwidth. Precision and accuracy are further enhanced with the patented digital trigger architecture, featuring controllable trigger sensitivity and sample-based event detection. An ±5 V offset at higher sensitivity vertical scales simplifies voltage ripple measurements where 10× passive probes can easily offer a ±50 V offset range. Further offset range and higher sensitivity can be achieved with higher bandwidth power rail probes like the R&S RT-ZPR.

▲ Fig. 3 **Noisy signals on the left improved with the 18-bit HD mode on the right.**

EVOLVED USER EXPERIENCE

The oscilloscope features an intuitive user interface. The 15.6 in. full-HD capacitive touchscreen reduces learning curves, providing a seamless and engaging visual experience. The instrument stands 314 mm high with a 153 mm × 445 mm footprint, ideal for lab benches that are short on space. The optional VESA mount plate can save even more space.

The scope suits office workstations, with a noise level 1 m in front of the instrument of 25 dBA. Working remotely with the instrument is easy, as the built-in webserver interface allows users to control and observe waveforms directly on a standard web browser.

GET THE BIG PICTURE FASTER

The R&S MXO 5 is a versatile, market-leading instrument that provides engineers with in-depth analysis of designs. With at least 100 MHz of bandwidth, this oscilloscope covers entry-level applications where more channels are needed for faster insight.

The base model comes with a deep memory of 500 Mpoints per channel. This supports recording long events with high sampling rates but does not compromise the vertical resolution crucial for power integrity measurements. With a 12-bit ADC and the 18-bit HD mode, the instrument allows accurate power ripple quantification while maintaining excellent noise performance. The synergy of these features enables fast acquisitions, facilitating swift data accumulation and efficient statistical result correlation.

Rohde & Schwarz
Munich, Germany
www.rohde-schwarz.com/product/MXO5

Addressing Signal-Fidelity Challenges With High-Resolution Oscilloscopes

SIGLENT Technologies
Solon, Ohio

New high-resolution oscilloscopes are becoming more popular for a variety of applications including benchtop debugging, analysis and visualization of small signal details. Designing a quality oscilloscope for applications requiring high signal fidelity takes more than adding resolution. Care must be taken throughout the design process to ensure high signal fidelity from the probe to the display and the engineer. From component selection, layout and low noise power supply design, improving the overall performance of an oscilloscope necessitates expertise throughout the design process. SIGLENT's design team brings years of industry knowledge to bear on the challenges of improved signal fidelity with our newest high-resolution oscilloscopes. Through careful design, these oscilloscopes showcase low noise, improved isolation and excellent gain error to assist engineers in improving signal fidelity. Improved visualization capabilities, including vertical zoom, deep memory fast Fourier transforms (FFTs) and dynamic scale offset, deliver signal fidelity improvements directly to the engineer. SIGLENT's newest high-resolution oscilloscopes bring high fidelity signal quality to measurements from 70 MHz to 4 GHz with our newest additions. The SDS800X HD, SDS1000X HD and SDS3000X HD join the recently launched SDS7000A to bring improved signal fidelity to customer applications.

Overall design quality is more important to signal fidelity than just the number of bits on the analog-to-digital converter. SIGLENT's design for signal quality means we have some of the most accurate high-resolution scopes on the market. High signal fidelity starts with improved noise performance. Low noise design requires careful component selection, EMI and power cleanliness in the front-end. An oscilloscope's noise can be characterized by range, bandwidth and configuration. High sample rate and deep memory are important because filtering modes can be applied to optimize the noise floor for the bandwidth and noise requirement of a particular application. For example, an

SDS7304A 3 GHz oscilloscope can sample at 20 GSa/sec and deliver 200 µVrms noise at full bandwidth. Because of the oversampling, memory depth, bandwidth limits and ERES filtering, it can also be configured to make measurements with 200 MHz of bandwidth and less than 40 µVrms noise. This flexibility is an important design characteristic of all SIGLENT's new high-resolution oscilloscopes.

Channel-to-channel isolation is important to signal fidelity as more applications require comparing multiple channels at different amplitudes. Accidentally coupling in adjacent signals directly reduces measurement fidelity. The SDS3000X HD shown in ***Figure 1*** implements 1000:1 isolation at 200 MHz, reducing coupling by 10× versus some competitive high-resolution oscilloscopes.

Fig. 1 **SDS3000X HD oscilloscope.**

Gain accuracy is the amount of error added to a signal as the voltage moves from 0 V to the top of the ADC range. This is usually represented by a percentage and is related to the specifications of the ADC itself. SIGLENT's high-resolution oscilloscopes, including the SDS1000X HD family, have a DC gain accuracy of ±0.5 percent on ranges at or above 5 mV/div. This is as much as 4x more accurate than other high-resolution models.

This design philosophy brings unmatched signal fidelity to oscilloscope applications from 70 MHz to 4 GHz. Engineers access this improved signal fidelity through visualization enhancements that include vertical zoom, dynamic scale offsets and a deep memory FFT.

Fig. 2 **20x vertical zoom inset view.**

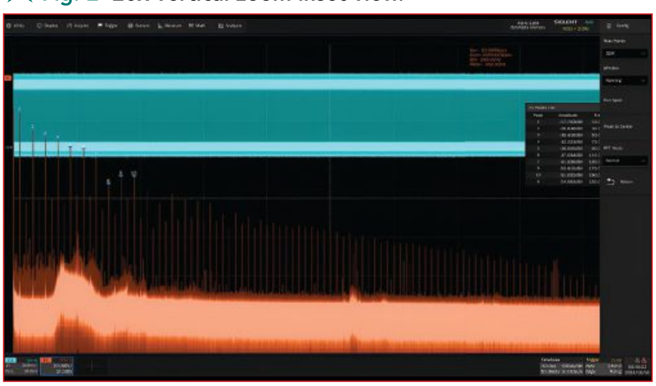


Fig. 3 **32 Mpt FFT visualization.**

Vertical zoom is an important capability for any high-resolution oscilloscope. Above 10 bits, the resolution is more precise than a single pixel on a typical display. To fully utilize high resolution or the benefits of enhanced averaging, being able to zoom in on the voltage axis becomes necessary. Some oscilloscopes only let you achieve this in stop mode, but SIGLENT's fully implemented vertical zoom lets you adjust the zoom range on the fly on live measurements without changing the vertical scale of the ADC. ***Figure 2*** shows a 20× vertical zoom that makes it possible to view small signal artifacts without saturating the ADC. Combine this with our 7 in., 10.1 in. or 15.6 in. displays to get the best view for your bench or lab.

Dynamic scale offsets work together with the zoom to further increase access to difficult-to-capture signals. With a leading 11 offset ranges built into the oscilloscope, SIGLENT provides up to 8x higher offset on a given voltage scale. With this extended ability, engineers can view small signals offset from the ground on a more precise range to further improve fidelity. With some competitive high-resolution scopes and certain signals, engineers lose three effective digits of resolution because they are forced to use an 8× wider range to view the same signal.

Deep memory FFTs extend the value of high-resolution oscilloscopes into RF applications. With 50 Ω inputs and 12-bit resolution, use an SDS7000A to capture and analyze RF signals up to 4 GHz for emissions debugging or functional testing. All SIGLENT high-resolution oscilloscopes have deep memory FFTs with the SDS7000A using up to 32 million points in the calculation to improve signal fidelity over a wide frequency span. ***Figure 3*** shows a display of this FFT visualization.

Combining advanced visualization capabilities with SIGLENT's dedication to designing for signal quality makes our newest high-resolution oscilloscopes some of the most flexible and powerful instruments available. The combination of capability and value from 70 MHz to 4 GHz also makes SIGLENT's offering the broadest in the industry. Whatever your application, SIGLENT provides a high-resolution oscilloscope built with signal fidelity, quality and advanced visualization that will more than meet your needs.

Go to www.siglentna.com to learn more about the new SDS800X HD, SDS1000X HD, SDS3000X HD and SDS7000A families of high-resolution oscilloscopes.

SIGLENT Technologies
Solon, Ohio
www.siglentna.com

Reimagining 5G Device Testing

Marvin Test Solutions' GENASYS Semi is the most advanced open-architecture semiconductor device test platform in the industry, eclipsing proprietary "big iron" semiconductor test systems with exceptional configuration flexibility, test speed, measurement performance and ease of use. The TS-900e-5G Series is the first production 5G mmWave semiconductor device test solution capable of providing vector-correlated, gap-free measurement performance across the entire frequency band to 53 GHz. Featuring Keysight PXIe VNA instrumentation and supporting up to 20 independent, parallel measurement channels, the TS-900e-5G delivers exceptional measurement performance, repeatability and scalability.

The modular, open platform architecture delivers exceptional flexibility when faced with changing test needs. It simplifies digital, analog and RF test resource expansion and updates. The compact design can be configured as a benchtop system or with an integrated manipulator without impacting measurement performance or system throughput. The innovative test interface delivers proven, repeatable high performance connectivity to the device under test, with field-configurable receiver interface pin blocks that enable users to easily upgrade the receiver interface as test needs change or new application requirements emerge. From DC to mmWave, GENASYS Semi can do it all.

GENASYS Semi solutions are compatible with industry-standard probe stations, device handlers like Opus 3, TEL and Seiko Epson E8040/ E8080 and manipulators like Reid-Ashman OM-1069 and inTest. This approach simplifies integration into existing production facilities. It also meets the high throughput production demands of outsourced semiconductor assembly and test.

All GENASYS Semi solutions include the ATEasy® Test Executive and Integrated Development Environment. This provides an easy-to-use software development environment and integrated, customizable test executive for execution, sequencing, debugging and fault analysis of tests. Additionally, it provides a full suite of digital and parametric test capabilities, allowing users to quickly develop and maintain test applications.

Marvin Test Solutions
Irvine, Calif.
www.marvintest.com/5G

Benchtop AWG Contains Expanded Waveform Memory

The Berkeley Nucleonics (BNC) Model 670C Arbitrary Waveform Generator (AWG) has a new waveform memory module, allowing up to 512 MSa/s of waveform memory in a benchtop research instrument. This doubling of memory means more complex waveforms are readily produced, giving expanded testing opportunities to lab personnel. A large waveform memory allows users to create and store long, complex waveforms that simulate realistic signals or various test scenarios. It also enables longer waveform play time before it repeats.

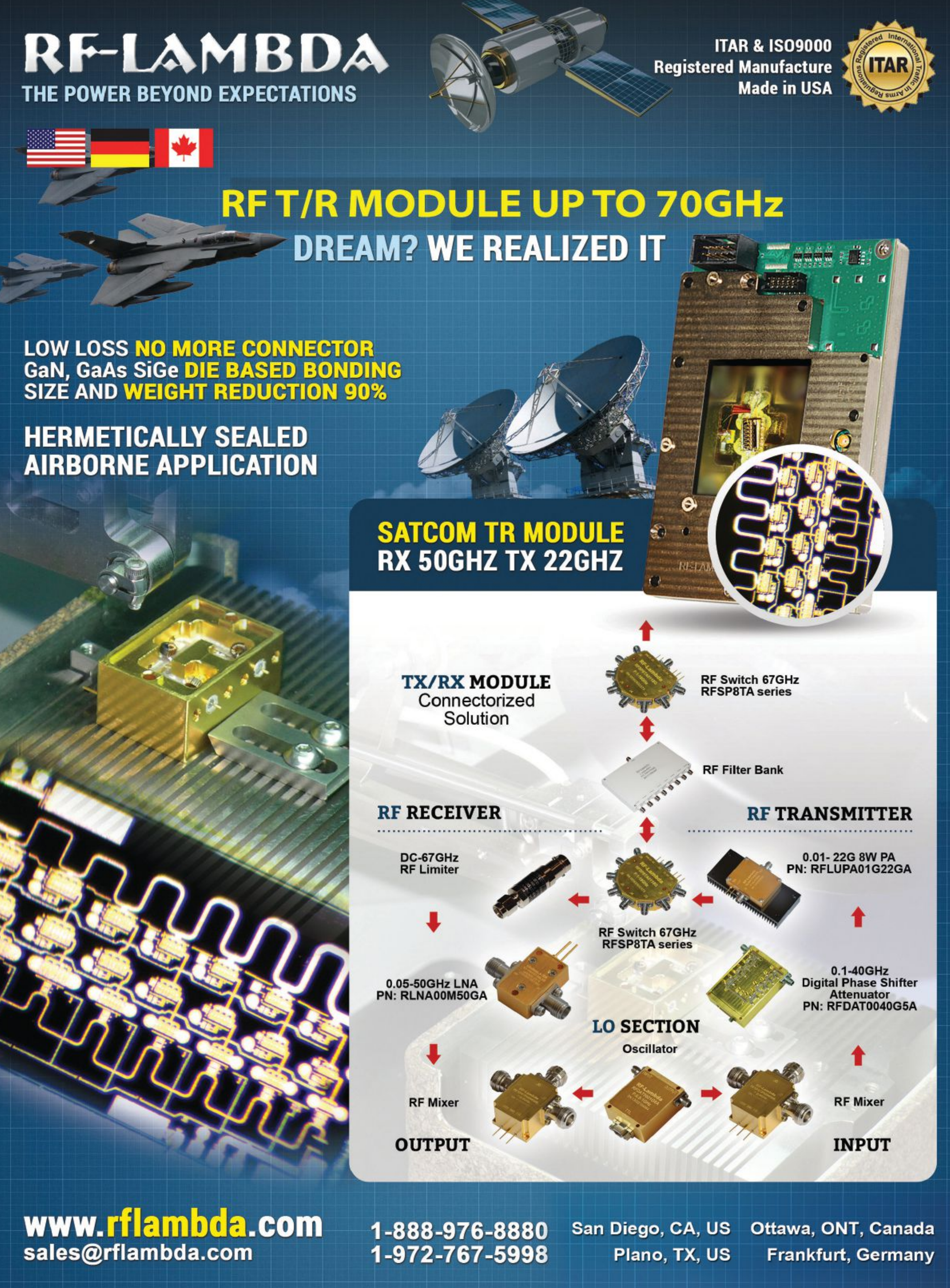
The Model 670C is also well-suited as a baseband generator. The AWG produces a time-domain signal that can be applied to an external RF modulator. For simple signals where pulses are generated by controlling the carrier envelope, the Model 670C single output can be applied to an amplitude modulator. If the carrier is phase- or frequency-modulated, the Model 670C offers two channels that can be applied to an IQ modulator.

The Model 670C starts at about $12,000 for a dual-channel system. It delivers performance and a feature set unparalleled in the entry-level test equipment field.

BNC is a leading manufacturer of precision electronic instrumentation for test and measurement, radiation detection, nuclear research and RF/microwave applications. From signal generators to spectrum analyzers, BNC offers the widest range of signal generation and analysis tools from a single manufacturer. Application engineers are available to discuss specific needs. BNC offers product demonstrations to aid in the selection process.

Our corporate headquarters are in San Rafael, Calif., with additional manufacturing facilities and sales offices located throughout the U.S. In addition, BNC maintains an international network of manufacturer's representatives to satisfy precision instrumentation needs globally.

Berkeley Nucleonics Corporation
San Rafael, Calif.
www.berkeleynucleonics.com


RF-LAMBDA
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ITAR & ISO9000
Registered Manufacture
Made in USA
ITAR
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Adapters Support High Temperature Applications

Pasternack, an Infinite Electronics brand and a leading provider of RF, microwave and mmWave products, offers a complete line of high temperature-rated RF and microwave adapters to address a wide range of demanding applications found in military, aerospace and industrial applications. With extended operating temperature ranges and robust construction, these RF and microwave adapters promise exceptional performance even in the most extreme conditions. Adapter options include between-series and in-series models with both male and female 1.85 mm, 2.4 mm, 2.92 mm and 3.5 mm interfaces. Both brass and stainless steel body options are offered. Adapter configurations include straight-through, bulkhead-mount and four-hole flange designs. These adapters also feature maximum VSWR values as low as 1.2:1 and frequencies ranging from 34.5 to 67 GHz. These robust adapters conform to the MIL-STD-348B interface standard, providing high reliability, quality and compliance with military system requirements. Built for extreme applications, these high performance RF adapters can function effectively within a broad temperature window ranging from -50°C to +170°C, ensuring their efficiency even in the most rigorous environments. Pasternack's high temperature RF and microwave adapters are in stock and available for same-day shipping with no minimum order quantities.

Founded in 1972, Pasternack is a global supplier of RF and microwave components supported by a growing list of 19 international distributors in more than 35 countries worldwide. Pasternack has an inventory of more than 40,000 in-stock products. Pasternack is part of the Infinite Electronics family of brands, which serves a global engineering customer base with deep technical expertise and one of the broadest inventories of products available for immediate shipment.

VENDORVIEW

Pasternack
Irvine, Calif.
www.pasternack.com

A New Era of Real-Time Spectrum Analysis

Aaronia presents the SPECTRAN® V6 ECO, a real-time, high performance, spectrum analyzer and monitoring receiver. The basic USB version offers real-time bandwidth (RTBW) of 44 MHz, an extended frequency range of 9 kHz to 6 GHz with an option for 7.25 GHz for Wi-Fi 6E measurements. The powerful RTSA-Suite PRO for data analysis is included, along with a variety of 2D and 3D views, triggers, IQ processing and recording.

An alternative ECO version has an integrated vector signal generator and a 44 MHz TX output to enable simultaneous transmit and receive operation. The dual RX SPECTRAN® V6 ECO 200XA-6, shown in the image, achieves 2 x 44 MHz RTBW with inputs that can be used independently. A patented high speed LO function allows record-fast sweep speeds of over 3 THz/s.

All V6 ECO models can be extended with an optional 8 GHz power meter. This may be integrated into the Rx1 path and can be used simultaneously. It has a frequency range of 1 MHz to 8 GHz with an accuracy of ±1 dB, an impulse response time of 10 ns and a dynamic range of 70 dB.

Other expansion options include a low noise preamplifier, a shock-resistant oscillator (OCXO) with a time base of 5 ppb and GPS location and/or time functions. A variety of other functions can be installed later via a software license to expand the range of functions of the RTSA-Suite PRO and the device. The SPECTRAN® V6 ECO connects to a PC or laptop with a USB cable using the USB PD specification.

VENDORVIEW

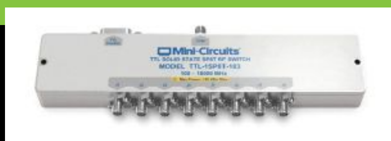
Aaronia AG
Strickscheid, Germany
www.aaronia.com

TTL-Controlled Solid State Switches

Mini-Circuits has expanded its lineup of switching solutions for test applications with new 4-way and 8-way TTL-controlled solid-state switches.

Mini Circuits

https://blog.minicircuits.com/ttl-controlled-solid-state-switches/



Dive into Qorvo's Technologies & Solutions for Consumer IoT

Elevate your next smart home design with Qorvo's Connectivity Playbook Interactive Brochure. Uncover all the exciting products and solutions that are defining smart living.

Qorvo

www.qorvo.com/feature/seamless

Here's What's Up for Microwave Technology in 2024

RFMW CEO Joel Levine focuses on important technological applications evolving in 2024 in this blog post.

RFMW

https://rfmwblog.com/2024/01/22/heres-whats-up-for-microwave-technology-in-2024/

New Coonrod's Corner

Check out the latest episode of Coonrod's Corner, titled "What RF Engineers Need to Know About PCB Fabrication for Optimal Results."

Rogers Corporation

https://www.rogerstechub.com/login.php?redirect=/video/coonrodscorner.php

Talking RF EMC Pre-compliance

Signal Hound's Talking RF is a series where we dive into our products, software and relevant topics in the RF industry, giving insight into areas of interest and providing an in-depth look at how and why we offer unrivaled value.

Signal Hound

www.youtube.com/watch?v=ODy8Gh2HyPY

Thermopad Selector Tool

Smiths Interconnect announced the launch of a new temperature variable attenuator selector that can automatically generate the overall performance of the selected Thermopad product.

Smiths Interconnect

www.smithsthermopadtool.com

NEW PRODUCTS

FOR MORE NEW PRODUCTS, VISIT WWW.MWJOURNAL.COM/BUYERSGUIDE
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DEVICES/COMPONENTS/MODULES

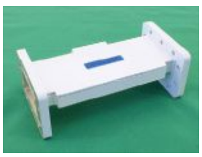
Quadraplexer

VENDORVIEW

Two of the most important design characteristics of RF filter technology are size and performance. 3H designs all of its filters based on specific design and performance requirements provided by its customers. 3H's quadraplexers are no exception. XCCQ101-124 is a high-power 4-channel multiplexer that serves, but is not limited to, the following applications: law enforcement UAV and UGV ground stations, 5G connectivity, satellite communication, Wi-Fi, telemetry and surveillance.

3H Communication Systems
www.3hcommunicationsystems.com

5G Mitigation Filter for C-Band



A1 Microwave has expanded their range of C-Band receiver filters for satellite ground installations to include off-the-shelf components that are fully-compliant with the RED and BLUE spectrum masks. In addition to the close-in 5G rejection, they also feature transmit band rejection as well as X-Band radar for use in naval applications. This includes a recent trial for the U.K. Royal Navy as well as hundreds of installations on cruise ships and terrestrial news-gathering equipment.

A1 Microwave
www.a1microwave.com

Direct-to-Digital RF Converter

CAES expanded its product offerings with a new direct-to-digital RF converter designed to optimally meet the bandwidth and form factor requirements of radar, electronic warfare and C4ISR mission applications. The CAES TORNADO converter, the latest in CAES' investment in direct RF sampling architectures, has eight transmit and eight receive channels paired with the Intel Agilex®9 FPGA Direct RF Series in a 3U, SOSA-aligned configuration. CAES provided early access to design a product based on Intel's advanced technology.

CAES
www.caes.com

Power Divider/Combiner

VENDORVIEW

MIcable's 6 to 40 GHz ultra-wideband 16-way power divider/combiner can accept a 6 to 40 GHz signal and deliver 16 output signals with equal amplitude and phase. Due to its extremely wide bandwidth, excellent VSWR, insertion loss and isolation, it can be widely applied in 5G, testing, instrumentation and other fields.

MIcable Inc.
www.micable.cn

Ohm Transformer

The MRFXF0089 transformer is designed for applications that require small, low-cost and highly-reliable surface-mount components. Applications may be found in broadband, wireless and other communications systems. These units are built lead-free and RoHS compliant and feature welded wire construction for increased reliability. S-parameters are available upon request.

MiniRF
www.minirf.com/transformers

Electromechanical Relay Switches

VENDORVIEW

Pasternack introduces its quartz fusion series of surface-mount electromechanical relay switches. Incorporating modern design with advanced technology, the series showcases a blend of functionality and resilience in a sleek, surface-mount package, addressing an extensive frequency range up to 26 GHz. Pasternack's fusion series is a leader in engineering excellence, achieving optimal performance across multiple benchmarks. Its capabilities extend from robust power handling to its oxidation-resistant gold-plated mounting surface, ensuring durability and long-term connection reliability.

Pasternack
www.pasternack.com

NewProducts

Cellular Band High-Power Directional Couplers

RLC Electronics Inc. manufactures a line of cellular band high-power directional couplers. These devices typically operate below 2500 MHz and can be provided with custom coupling values from 20 to 50 dB. Typical units exhibit low loss (< 0.2 dB), high directivity (> 30 dB), can handle 500 W CW minimum and can be customized to customer specific requirements. RLC can also manufacture form/fit/function replacements for similar obsolete devices from Microlab and Narda.

RLC Electronics Inc.
www.rlcelectronics.com

Power EMI Filters

Spectrum Control Inc. introduced a family of modular power EMI filters bringing high performance and design flexibility to a variety of MIL-STD-461 designs with size, weight, power and cost requirements. The chassis mount filters have a wide -55°C to 75°C operating temperature. Superior mid- and high frequency attenuation up to 1 GHz (common mode) is achieved in a compact package that provides up to 30 percent space savings. A variety of models available in standard rack heights present many configuration options for design flexibility.

Spectrum Control Inc.
www.spectrumcontrol.com

CABLES & CONNECTORS

Rotary Joints

VENDORVIEW

Eravant's SAN Rotary joints offer in-line, L and U configurations for coupling signals from 110 to 170 GHz. The phase variation over rotation is typically 4 degrees. Typical insertion loss is 2.5 dB with less than 0.4 dB variation. Typical return loss is 15 dB with less than 3 dB variation. Minimum power handling is 100 W and the operating temperature range is -40°C to +85°C.

Eravant
www.eravant.com

AMPLIFIERS

Ultra-Broadband 100 W Amplifier

VENDORVIEW

Exodus AMP2073ADB-LC is a rugged compact 1.0 to 10.0 GHz, 100 W amplifier. It is a Class A/AB broadband design for all applications and industry standards. This broadband amplifier produces a minimum of 100 W with 50 dB gain. Unprecedented performance as compared to TWTs. Forward/reflected power monitoring in dBm and watts, VSWR, voltage/current/temperature sensing for extreme reliability. It weighs 30 kg in a compact 5U chassis measuring 8.75 × 19 × 27 in.

Exodus Advanced Communications
www.exoduscomm.com

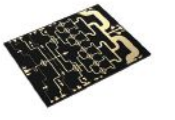
Amplifiers

Guerrilla RF Inc. announces the formal release of two ¼ W linear power amplifiers (PAs) and two low noise amplifiers (LNAs) earmarked specifically for the automotive market. All four devices were qualified to meet rigorous AEC-Q100 quality standards — a critical benchmark for semiconductor devices used within automotive applications. These new PAs and LNAs are used primarily in cellular compensators (essentially cellular 'signal boosters' serving to amplify and enhance cellular signals within the cabin of vehicles).

Guerrilla RF Inc.
www.guerrilla-rf.com

Ka-Band GaN Power Amplifier

VENDORVIEW

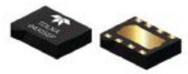


Nxbeam expands its Ka-Band MMIC portfolio with the release of a new GaN

New**Products**

Ka-Band power amplifier MMIC. The NPA2004-DE operates from 25.0 to 27.5 GHz and provides an average saturated output power of 40 W, average power-added efficiency of 34 percent and average linear gain of 24 dB. This MMIC is ideal for Ka-Band satellite communications and point-to-point communication networks.
Nxbeam
www.nxbeam.com

Low Noise Amplifier



Teledyne e2v HiRel announced the availability of a rad-tolerant UHF to S-Band low noise amplifier (LNA), model TDLNA0430SEP, that is ideal for demanding high-reliability space applications where low noise figure, minimal power consumption and small package footprint are critical to mission success. This new LNA is developed on a 90 nm enhancement-mode pHEMT process. It is available in an 8-pin dual-flat no-lead 2 × 2 × 0.75 mm plastic surface-mount package and is qualified per Teledyne's Space enhanced plastic flow.
Teledyne e2v
www.teledyne-e2v.com

Broadband Low Noise Amplifier

Model ABL2000-01-2220 is a MMIC-based low noise amplifier module cover the frequency range from 50 MHz to 20 GHz. It offers 22 dB of linear gain and 2.0 dB typical noise figure with excellent gain flatness and input/output return loss. The unit has a built-in voltage regulator and operates with a single DC power supply voltage. The package size of the amplifier is 1.2 × 1.0 × 0.4 in.
Wenteq Microwave
www.wenteq.com

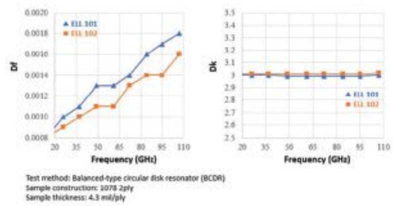
SYSTEMS

High-Power Repeater

Advanced RF Technologies Inc. (ADRF) announced the first-of-its-kind SDRX-43-N77H carrier-grade high-power repeater to support the upper C-Band spectrum. Together with SDRX-43-BTF, which provides connectivity for 2.5 GHz broadband radio service, the SDRX Series supports some of the most critical 5G mid-band spectrum for U.S. wireless networks. The SDRX Series provides a cost-effective alternative to base stations, offering a quick and affordable means of delivering indoor and outdoor 5G coverage in metropolitan and rural areas.
Advanced RF Technologies Inc.
www.adrftech.com

MATERIALS

Laminate and Prepreg Material



AGC Multi Material is now offering the ELL family of laminate and prepreg material. ELL offers high speed, extreme low loss and high-reliability for new and extreme applications. The ELL family is based on a new, proprietary polymer formulation and is available with NE (ELL 101), NER (ELL 102) or L2 (ELL 103) fiberglass. ELL is UL registered with a UL flame rating of UL-94V0 and an RTI of 130C. It meets IPC 4103/240 laminate and /540 prepreg specifications.
AGC Multi Material
www.agc-multimaterial.com

Gel-Probe Products

Gel-Pak, a Delphon company and a leader in elastomer-based materials and protective carriers for the semiconductor, medical and electronics industries, announced the launch of its Gel-Probe products. This new line features enhanced probe tip cleaning and polishing solutions designed for semiconductor test applications. In the late 1990s, Gel-Pak pioneered the Gel-Wafer, the first elastomer-based probe tip cleaning product. The company is making a strategic reentry into the market with its enhanced Gel-Probe line, which currently includes the Gel-Probe ReMove and Gel-Probe ReFine products.
Gel-Pak
www.gelpak.com

ANTENNAS

Multiband Cellular Antenna

Antenna Company announced customer sampling and availability of its AC97002 multiband cellular antenna designed for ease of installation with indoor smart meter gateways and other IoT applications. As countries, such as Germany, mandate the rollout of smart meter gateways, reliable connectivity is essential to providing secure data communication between the premise equipment and the wide area network. The AC97002 antenna offers reliable radio coverage over frequency bands of 698 to 960 MHz and 1700 to 2690 MHz, with efficiencies up to 75 percent in sub-GHz bands.
Antenna Company
www.antennacompany.com

EW 104: Electronic Warfare Against a New Generation of Threats

David L. Adamy

As a professional working in the field of interference mitigation for communications, this book serves as a fantastic overview of the current new generation of threats. It made me want to read the first three books of the series because it was so well written. The author does a fantastic job comparing cyber warfare to electronic warfare (EW) and draws parallels between the two, clearly showing the similarities in functionality of the two. He also gives a detailed explanation of legacy radars and associated weapons and presents the new upcoming communications threats and their effect on EW operations. I strongly recommend this book.

ISBN 13: 9781608078691

466 pp.

To order this book, contact:
Artech House
us.artechhouse.com

2024 IEEE Texas Symposium on Wireless and Microwave Circuits and Systems

April 3-4, 2024, Waco Texas

(date is subject to change)

www.TexasSymposium.org

Authors from academia, industry, government labs, and other organizations around the world are invited to submit papers in the areas listed below:

- RF and microwave circuits and systems
- 5G/6G and millimeter-wave/THz wireless technologies
- Wireless technologies for biomedical applications
- Computational electromagnetics
- Antennas, propagation and electromagnetics
- Spectrum management and coexistence
- RF active and passive devices
- Microwave metrology
- Wireless power transfer
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(dates are subject to change):

Paper Submission Deadline: Feb 5, 2024
Author Notification: March 4, 2024
Final Manuscript Due: March 13, 2024
Advanced Registration Deadline: March 25, 2024
Conference Sessions: April 3-4, 2024

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Mini-Circuits

FABS and LABS

Signal Hound: Designed With You in Mind

Signal Hound designs and builds high performance test and measurement equipment in their production facility in Southwest Washington state. Founded in 1996 at a small shop, the company built a following by releasing a compact, high-quality USB-based spectrum analyzer. Today, Signal Hound is a global company with a robust product line and customers across all segments of the RF industry. Their company leadership has an eye toward growth and a continuation of the gains they have seen recently. All of this combines to make Signal Hound a significant player in the industry with big goals in the coming years.

In 2022, Signal Hound was purchased by Harrison Osbourn, a U.S. Navy veteran and experienced entrepreneur with ties to some of the most successful companies in the Pacific Northwest region. This new phase of ownership has brought tremendous growth in a short period and opened new avenues of pursuit regarding product development and expansion. The company has always prided itself on providing the best possible products with exceptional specifications and performance to a wide range of users. Outfitting an entire test lab or mobile workforce can be very costly but with the lean, high performance equipment Signal Hound provides, technicians and engineers can reach their design and production goals quickly, with confidence and on budget.

Many other corporations in the RF space offer accompanying software in conjunction with their hardware. However, there is often a significant cost associated with those software options. Signal Hound sets itself apart and continues their commitment to value solutions by providing powerful spectrum analyzer software at no cost. Spike™, the company's flagship RF software, gives industry professionals powerful analysis tools such as LTE monitoring and scanning, WLAN modulation measuring, RF mapping tools for drive testing and much more. The software is continually updated to add new features and functionality.

Recently, the company announced an expansion of its operations to occupy an additional 11,000 square feet at its headquarters. This next phase marks a significant leap forward and substantial investment in the future. The expansion is a direct result of the tremendous growth the company has seen over the past 18 months. The additional space will allow for increased production capacity, expanded research and development, more product storage, added office space and future capacity to support continued growth.

Signal Hound has long been known for premium spectrum analyzers and signal generators. In 2023, it launched the SM435-series, an mmWave spectrum analyzer that tops out at 43.5 GHz. Signal Hound believes that this opens a pathway to high frequency analysis for many who were previously unable to work in that space. The coming year will see the release of new products in market segments not previously occupied by the company. As performance and customer demands increase, the innovative approach Signal Hound takes to developing new offerings will continue to pay dividends. In addition to the company's award-winning suite of spectrum analyzers and signal generators, the RF test and measurement industry can look forward to exciting new offerings across diverse product segments in the coming months.

https://signalhound.com/

WERLATONE

RF SOLUTIONS
WE SEE THE BIG PICTURE

Werlatone actively pursues the most complex RF applications. We supply the most advanced, High Power Passive Components, and fully Integrated Sub-System Architectures.

THE WERLATONE ADVANTAGE

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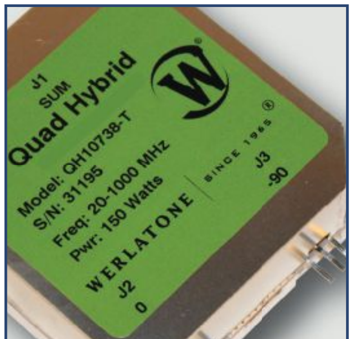
Directional Couplers

Coaxial Combiners

Radial / E-Plane Combiners

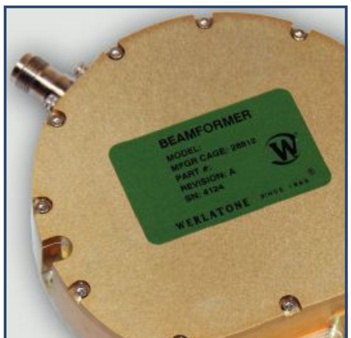


90° Hybrids

180° Hybrids

Digital Power Meters

Absorptive Filters



New Technology

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