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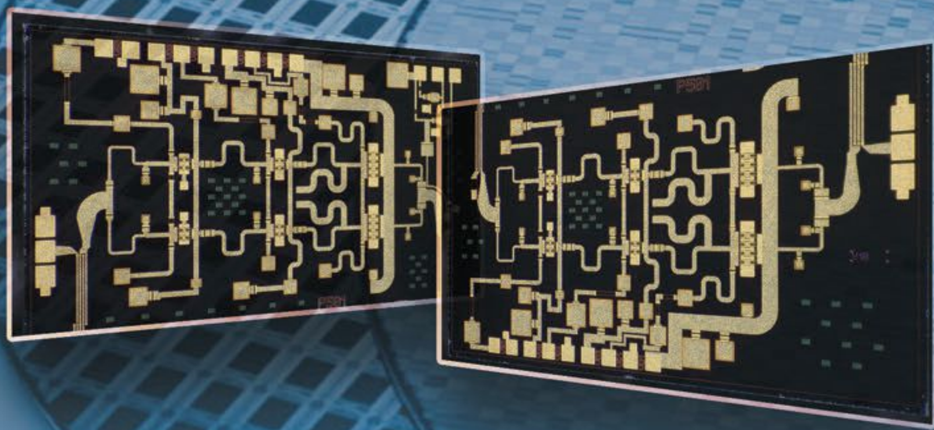

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PN: MMW5FP

RF GaAs MMIC DC-67GHz

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

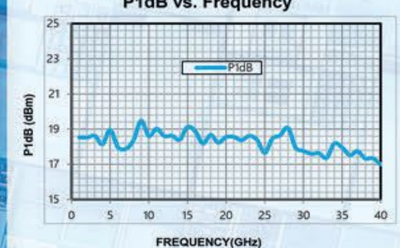
RF Driver Amplifier

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

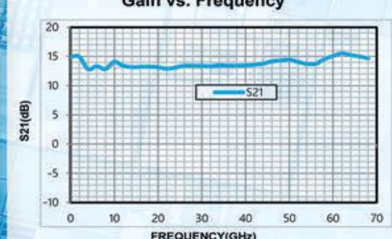
GaAs Medium Power Amplifier

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

P1dB vs. Frequency



Gain vs. Frequency



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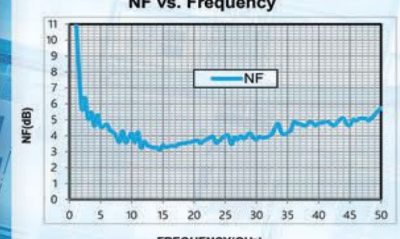

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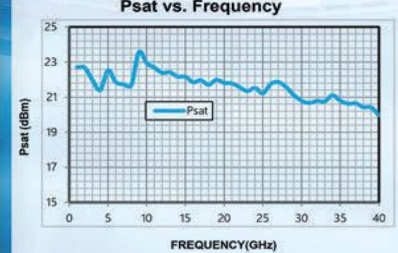

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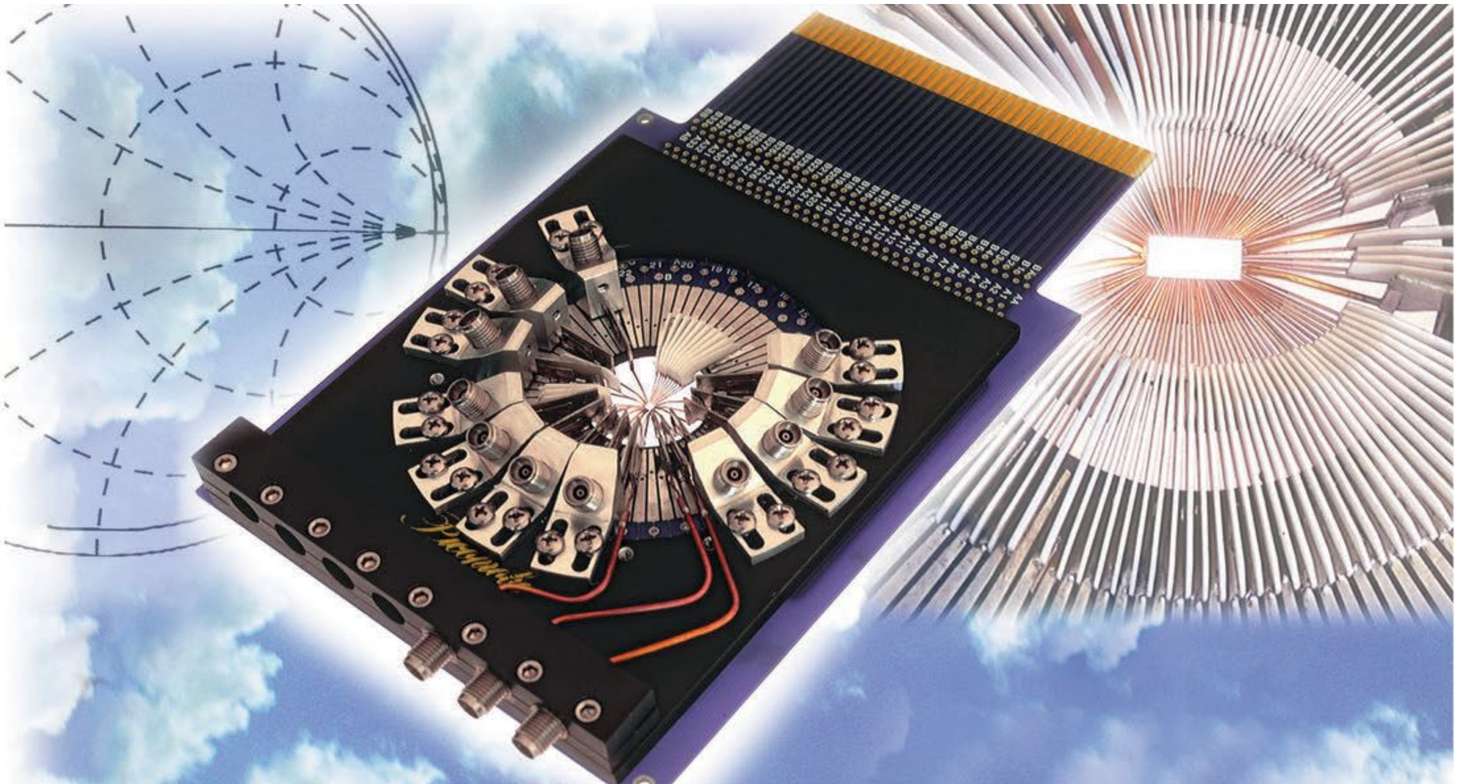


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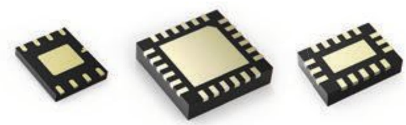

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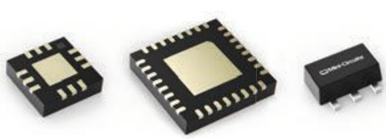

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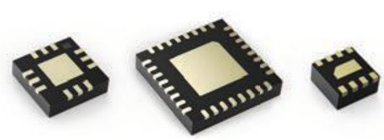

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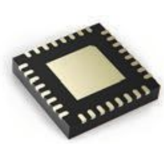

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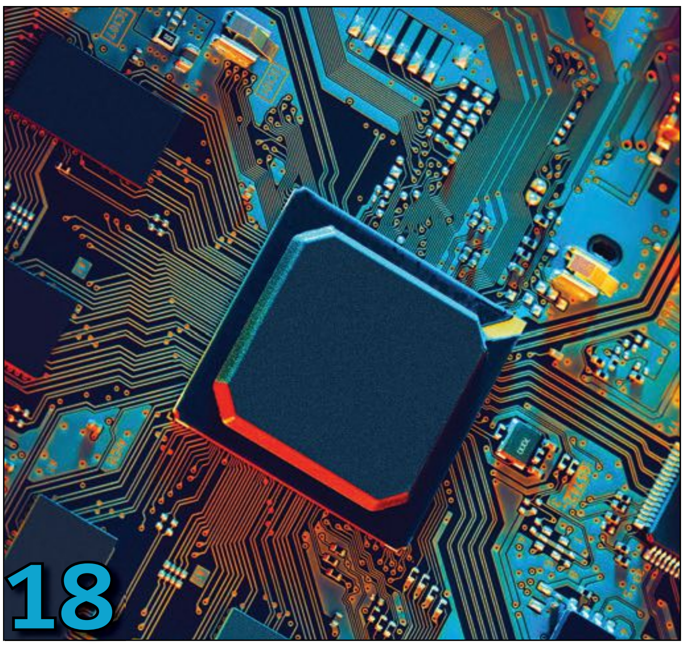

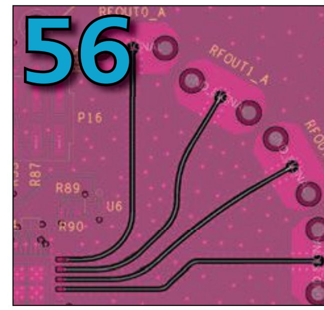

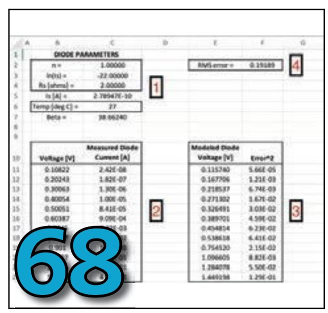

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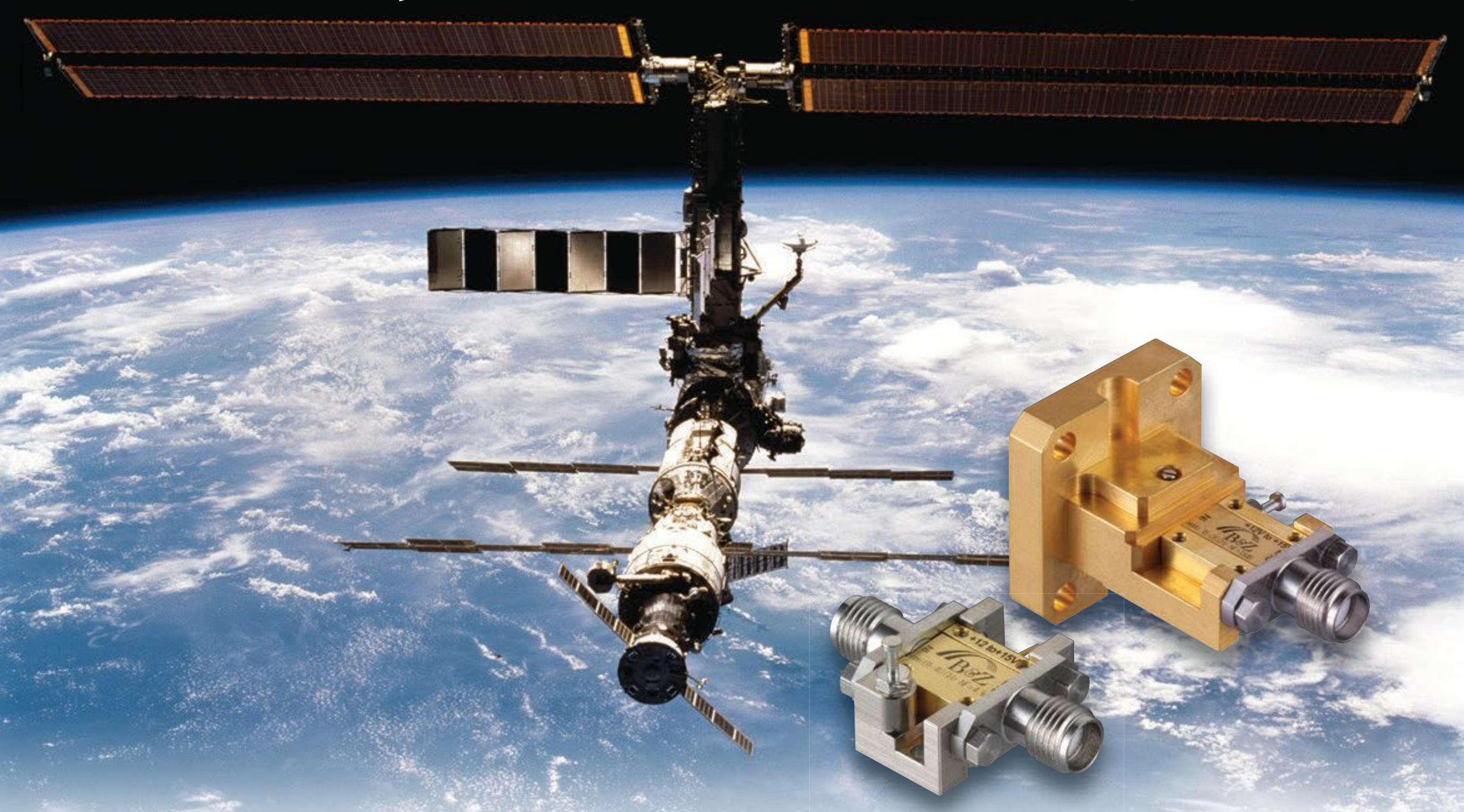
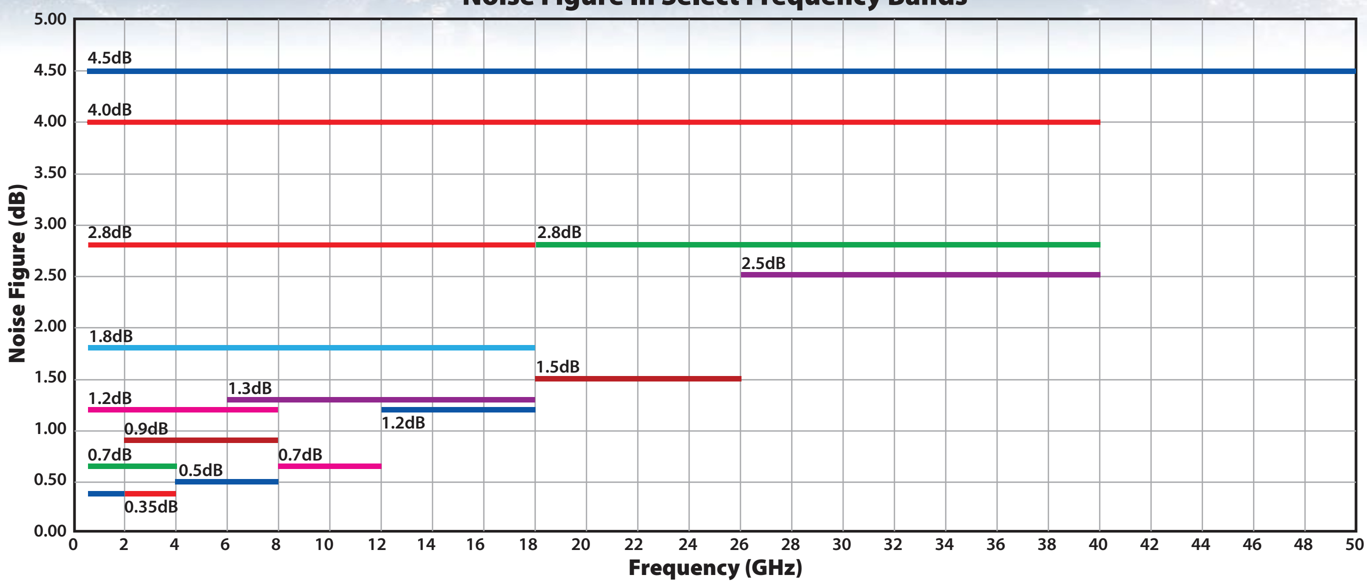


Noise Figure In Select Frequency Bands



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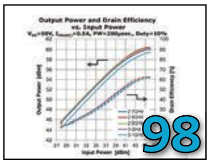

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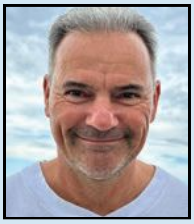

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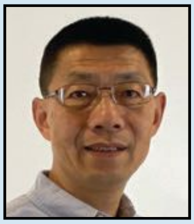

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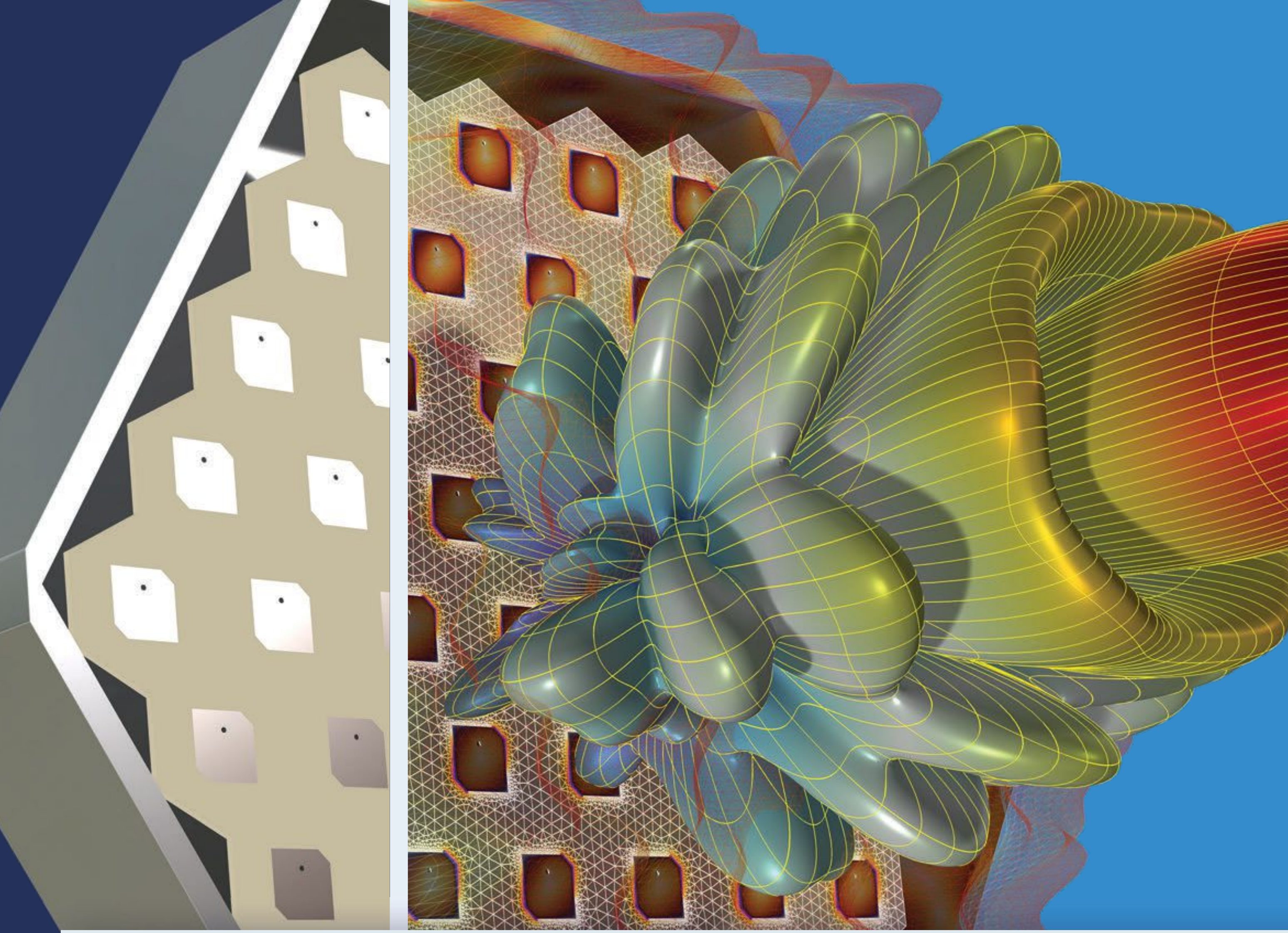

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Invited Paper

The Critical Role of Passive Components in Electronic Integration

Steven Pong
Infinite Electronics, Irvine, Calif.

The reliability and efficiency of electronic systems depend on the fundamental role played by active and passive components. These components perform essential functions required to integrate new equipment into existing or new systems properly. While active components such as transistors and amplifiers require an external power source to supply energy to a circuit, passive components do not. Passive components provide a function integral to all these devices; they receive and store energy but do not require electricity. This article will discuss the significance of passive components, the challenges in their integration and advancements in their development.

ROLE AND COMMON TYPES OF PASSIVE COMPONENTS

Passive components are a core element in electronic systems, mainly because they do not require external power. They are indispensable to the functionality of electronic circuits. These components play a crucial role in managing the flow of the electrical current, protecting against voltage spikes and ensuring the overall reliability and performance of electrical devices. By filtering signals, matching impedance and conditioning signals, passive components contribute to the performance, stability and efficiency of electronic circuits. Without passive components to consume, store and release power, electronic systems cannot function.

Common types of passive components include:

- **Resistors:** Resistors control the electrical current by providing precise resistance, which is crucial for voltage division and signal conditioning. A resistor can only receive energy, which is dissipated as heat when the current runs continuously. This is essential for protecting sensitive components from damage and for controlling voltage levels in circuits. Resistors are common in consumer products such as electric stoves, heaters and toasters, as well as commercial and defense systems.
- **Capacitors:** Capacitors store and release electrical energy, which is essential for smoothing signals and filtering noise. Capacitors can filter out high frequency noise that could obstruct a circuit's operation. They consist of two conductive plates separated by an insulating material called

Fig. 1 **PE6TR1162 DC to 6 GHz RF termination.**

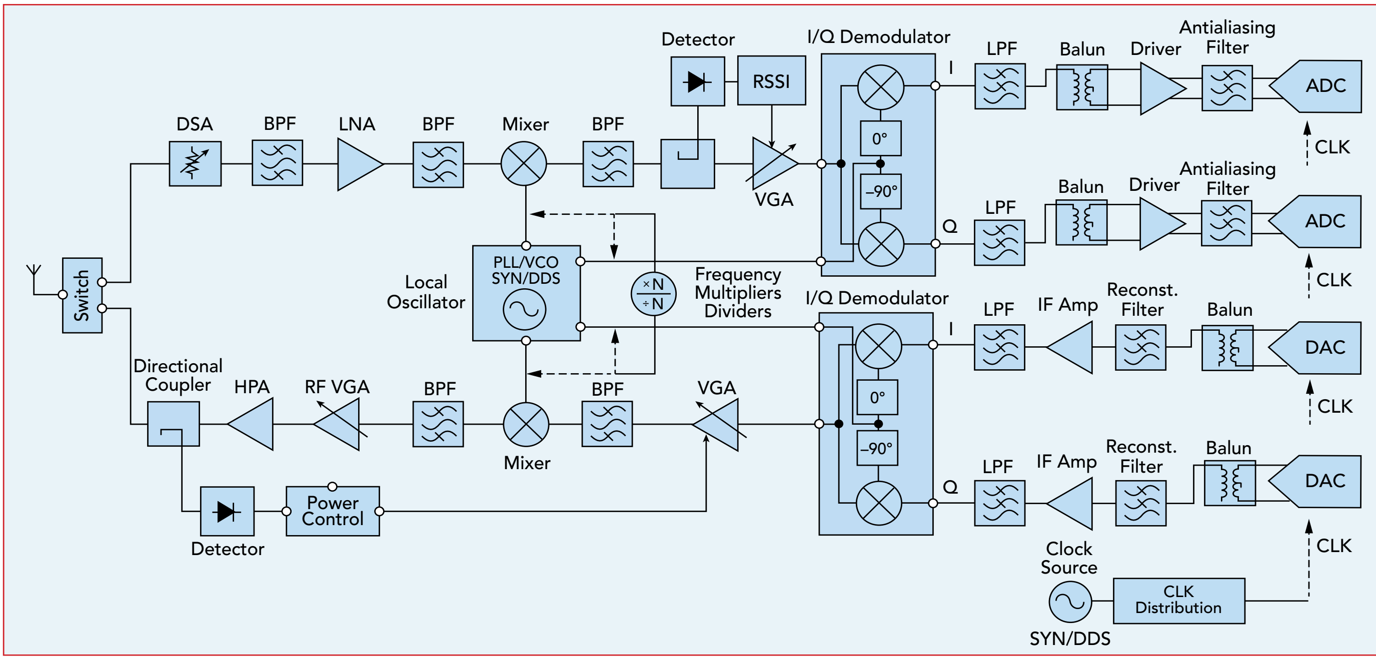

Fig. 2 **Representative wireless transceiver block diagram.** ***Source:*** **ADI.**

Fig. 3 **Pasternack PE87FL1004 bandpass filter.**

a dielectric. Capacitors are also used in a full range of consumer, commercial and defense products and systems.

- **Inductors:** An inductor stores energy in a magnetic field when an electrical current passes through it. It is also known as a reactor, choke or coil; it typically consists of a coil of wire wound around a core. Inductors resist changes in current and are used for energy storage, filtering and signal conditioning. They are critical in power supplies for filtering and energy storage, along with signal processing for noise suppression.
- **RF filters, attenuators and terminations:** These components provide essential RF connectivity and transmission functions, ensuring minimal signal loss and reflection within RF circuits and systems. Filters are used to reduce interference and block undesired frequencies by allowing or blocking specific signals. Attenuators reduce a signal's power without reducing its quality, helping to protect systems that might not be able to handle input powers over a certain level. Terminations, also known as terminators or loads, are located at the end of a transmission line and prevent the reflection of RF signals back through the line. ***Figure 1*** shows an example of an RF termination. This RF load handles 5 W of input power over the DC to 6 GHz frequency range. This version is equipped with a 2.2-5 male input connector.

Fig. 4 **PE8739A bandpass filter.**

Other passive components include transformers, switches, circuit breakers and relays. Although a diode is typically classified as a passive component, it is constructed using semiconductor methods commonly associated with active components. Each of these functional components plays a unique role in maintaining the functionality and efficiency of electronic systems, so understanding these components is essential in the design and maintenance of electronic devices. ***Figure 2*** shows a representative block diagram of a wireless transceiver. It is a good example of the widespread use of passive elements like filters, baluns and couplers. The diagram does not show individual components like resistors, capacitors and inductors that may be used to provide biasing, tuning and attenuation in some of the functional blocks shown.

The representative wireless transceiver functional block diagram of Figure 2 is generic but contains an important feature. Generally speaking, whether passive or active, higher frequency components are more expensive. A common technique used in heterodyne transceivers, like that shown in Figure 2, to support higher operating frequencies is multiplying a lower frequency signal to the transmit frequency of interest and dividing the received signal to a lower frequency. This allows more of the conversion and processing to be done at lower frequencies. These multipliers/dividers typically also contain filters and other passive components.

Figure 3 shows a connectorized bandpass filter operating from 12.2 to 12.7 GHz, and ***Figure 4*** shows a lower frequency connectorized bandpass filter operating from 4.4 to 4.8 GHz. While size and weight

are important, especially in high volume commercial applications, performance and cost considerations will influence the best system solution for passive and active components.

CHALLENGES IN INTEGRATING PASSIVE COMPONENTS

When designing circuits, engineers must balance the use of active and passive components, addressing any integration challenges through thorough testing and simulation. When integrating passive components, one difficulty can be ensuring compatibility among components from different manufacturers, which may impose limitations or specific requirements that must be addressed. Additionally, performance may be impacted by the physical layout and placement of components, necessitating careful design and planning. The potential for electromagnetic interference (EMI) and other environmental factors must be considered in the operation of components. These issues can be addressed with high-quality components.

Another challenge is the trade-off between performance and the costs of performance. Components with the best RF performance may have higher costs or longer lead times. However, optimal performance in passive components can mitigate the total cost of ownership.

There are other common challenges when integrating passive components into electronic assemblies:

- **Space Limitations:** Size is a factor when designing passive components for electronic devices. Advancements in consumer electronic devices, such as smartphones, have required a high density of components to become smaller and more compact. Fitting passive components into these designs without compromising performance presents a challenge.
- **Heat Dissipation:** Passive components in high-power applications can generate significant heat. Effective thermal management is essential to prevent overheating and ensure the long-term reliability of electronic devices. Materials and packaging designed to dissipate heat effectively are needed to protect passive components and the device's effective operation.
- **Signal Integrity:** A device's successful operation depends on the reliable transmission of electrical signals. Signal degradation can cause performance issues such as interruptions, distortions or worse, failures, especially in compact assemblies.

EMI is one specific challenge in signal integrity. EMI degrades signal integrity by causing unwanted signals and noise. High frequency applications rely on signal conditioning, which can be directly impacted by EMI. This creates a challenge when designing a system architecture that can effectively diagnose and correct signal integrity problems.

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Fig. 5 Pasternack PE2BL1001 balun.

Efficient, safe and reliable electrical system performance requires mitigating the challenges presented. Some solutions for these issues include using miniaturized components, implementing advanced materials to improve thermal management and employing precise printed circuit board (PCB) design techniques to minimize signal degradation. Careful component placement is also integral. ***Figure 5*** shows an example of a broadband surface-mount balun, operating from 20 to 520 MHz, designed to address some of these challenges.

Fig. 6 PE7467-10 (gold-plated brass) and PE7602-10 (stainless-steel) fixed attenuator pads.

ADVANCEMENTS IN MATERIALS AND MANUFACTURING TECHNIQUES

The continuous evolution of passive components in manufacturing is critical to keeping up with the technological advancements of a competitive market. Materials and manufacturing techniques have significantly enhanced the performance and reliability of passive components. ***Figure 6*** illustrates how the same function can use different approaches. Both devices are 10 dB fixed attenuator pads with SMA connectors but operate at different frequencies. The operating frequency of the gold-plated device is DC to 12 GHz, while the stainless-steel device operates from DC to 6 GHz.

Some of the advancements being made in the design and manufacture of passive components include:

- **Materials:** Advanced ceramics and composites have improved the high frequency performance and durability of passive components. Ceramics, in particular, are valuable for their insulating properties. Specific ceramic materials, such as those having piezoelectric characteristics, are easy to manufacture in various shapes and sizes. This helps fulfill the need for miniaturization in passive components. Composite phase change materials enhance heat dissipation by creating heat transfer pathways for components. These materials offer superior electrical properties, thermal stability and mechanical strength, making them ideal for high performance applications.
- **Manufacturing:** 3D printing has enabled the fabrication of

complex electronic passive components at a lower cost and weight. It also allows for more precise and smaller components essential for modern compact electronic devices. 3D printing overcomes the limitations presented by PCBs in manufacturing, enabling the creation of complex geometries and leading to components with improved performance and functionality.

- **Thin-Film Technology:** The primary advantage of thin-film technology in electronic components is its ability to control electrical properties precisely, enabling miniaturization and enhanced performance. This manufacturing technique involves depositing thin layers of conductive or resistive material onto a substrate. Common passive components produced using thin-film technology include resistors, inductors, capacitors and filters. Thin-film resistors and capacitors provide higher precision and stability than traditional thick-film components, making them ideal for demanding applications in telecommunications, aerospace and medical devices.
- **Integrated Passive Devices (IPDs):** IPDs consolidate various passive components, such as resistors, capacitors and inductors, into a single unit. This addresses the issues of limited size and signal integrity by reducing the space required for passive components and the length and number of interconnections, mitigating degrading effects.

Innovations in materials and manufacturing processes, such as ceramics, composites, 3D printing and others, have many benefits for passive devices. These materials and techniques enable smaller passive components with improved thermal regulation, better performance at high frequencies and the ability to withstand harsher environments. These improvements enhance the reliability and functionality of microwave components in demanding applications.

Passive microwave components are critical in various advanced technologies and high frequency applications. With emerging system trends and requirements, these improvements are needed more today than with previous generations of these technologies. These systems include:

- **5G Networks:** The upgrade from 4G to 5G networks increased the demand for passive components to filter signals in support of additional antenna systems. High frequency passive components, such as filters and couplers, are essential for managing the increased data rates and bandwidth requirements of 5G technology.
- **Automotive Radar Systems:** Passive components are crucial in radar systems to ensure the reliable and accurate operation essential for safety-critical applications. The transmit and receive sections of automotive radar systems rely heavily on analog component content and depend on passive components to function properly. Passive components like inductors and capacitors are used in radar systems to filter and

condition signals, ensuring accurate detection and measurement of objects.
- **Medical Imaging:** Passive components are vital in the mission-critical medical technology market. These components are engineered to perform reliably under extreme conditions, ensuring the safety and effectiveness of medical devices and equipment. Their enhanced durability, stability and precision make them ideal for critical applications in healthcare settings. Passive components are used in MRI systems to filter and condition signals, ensuring clear and accurate imaging results.

Considering the needs of these rapidly growing market opportunities, companies that design and manufacture passive components are redoubling their efforts. Infinite Electronics brands, such as Pasternak and Fairview Microwave, are expanding their RF passive component offerings to support these applications especially at high frequencies.

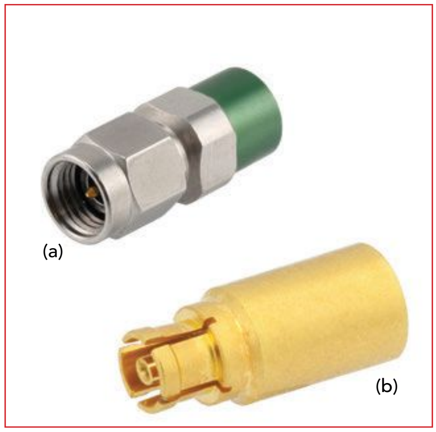

Fig. 7 **(a) PE6TR1106 2.92 mm and (b) PE6162 Mini-SMP RF loads.**

While these passive functions may seem more straightforward than their active component counterparts, the time, cost and performance-associated risks of improperly selecting the best passive component solution can easily impact system cost, performance and delivery. ***Figure 7a*** shows an example of a 2.92 mm RF load and ***Figure 7b*** shows a Mini-SMP RF load. Both RF terminations operate to 40 GHz.

Passive components are integral to the performance, reliability and safety of countless devices and systems people depend on daily. These components are indispensable in everyday electronic devices and advanced technology applications, from managing electrical current and storing energy to filtering signals and protecting against voltage spikes. The challenges in their integration, such as size, compatibility, heat dissipation and signal integrity, are met with innovative solutions and advancements in materials and manufacturing techniques. The steady progress and improvement of passive components drive further innovations in applications like 5G networks, automotive radar systems and medical imaging. As more sophisticated and high performance electronic devices are developed, passive components will remain foundational to their effective operation. ■

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The Future Is Microwave & Millimeter-Wave Power Systems

Powering The Future

The electrification of a wide range of technologies is enabling an ongoing explosion of electrical and electronic threats, opportunities, and innovation. The evolution of these technologies is significantly impacting the defense, space, medical/scientific, industrial, and energy markets as electromagnetic (EM) communications, sensing, and directed energy are key technologies for these applications. Moreover, these markets are all expanding, largely in part to enhanced capabilities and performance made possible by advances in high-power microwave and millimeter-wave technology. One such area that has garnered massive interest over the years, where significant investments continue to be made, is Directed Energy weapons and systems, deemed essential to combat present and future technological threats. For example, Directed Energy defensive weapons are considered the most viable method of thwarting drone swarm attacks from unmanned vehicles — land, air, or naval.

Surprisingly, there are very few organizations with the legacy, expertise, and equipment to design and manufacture critical elements of modern high-power and high-frequency systems. This is especially true if domestic production and the risk mitigation that vertical integration offers are prime considerations. Examples of essential high-power/frequency technologies include Magnetrons, Thyratrons, Klystrons, Traveling-Wave Tubes (TWTs), Inductive Output Tubes (IOTs), and Electron Emitters. Though solid-state power technologies are improving every year and are also key enabling technologies for some applications, solid-state technologies are still not able to reach the levels of power and efficiency at higher frequencies that tube-based and non-solid-state microwave/millimeter-wave power technologies can.

High-Powered Applications

Extreme levels of power and efficiency at high frequencies are pivotal for the latest in space communications and electric propulsion. Satellite Communications (SATCOM) for commercial, civil, and military applications often require high-power microwave and millimeter-wave technologies. Moreover, defense applications rely on TWTs, Klystrons, Magnetrons, and supporting microwave/millimeter-wave power technologies to bring cutting-edge performance for electronic attack, electronic warfare (EW), electronic protection, missile defense, threat simulations, and unmanned aerial systems. Medical and scientific research efforts also are dependent on Magnetrons, Thyratrons, Klystrons, IOTs, and Electron Emitters for radiotherapy, sterilization, laser surgery, body screening, particle accelerators, electron microscopy, and many other scientific and medical instruments.

Variants of these same high-power/frequency devices are also used in industrial applications for heating, plasma generation, materials processing, weather radar, laser machining, accelerators, scanning, welding, and many other essential industrial processes. Many new industrial applications for these technologies, often now powered by renewable technologies, are designed to deliver more efficient and lower environmental impact solutions. Examples include desalination, decarbonization, catalyst processing, water purification/sterilization, waste treatment, polymer/metals recycling, etc.

Legacy Expertise

For Traveling Wave Tubes (TWTs), Magnetrons, Thyratrons, Klystrons, IOTs, and Electron Emitters to be developed, operated, and manufactured, there are a host of technological capabilities needed. This includes passive and active electronic component/device/system design, and a myriad of manufacturing capabilities and equipment. Examples of high-power RF supporting technologies are Microwave/Millimeter-Wave Power Modules (MPMs), Electronic Power Conditioners, Solid-State Power Amplifiers (SSPAs), Linearized Channel Amplifiers (LCAMPS), Low-Noise Amplifiers (LNAs), High-Power Controllers, TWT Amplifiers (TWTAs), Filters, Multiplexers, Frequency Converters, Couplers, and other Active/Passive Components/Devices and Systems.

To develop and manufacture these technologies requires substantial expertise and legacy knowledge that is

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rare and very specialized. Some of these specialized capabilities include:

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- Scanning electron microscopy with energy dispersive X-ray (SEM/EDX)
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- Hermeticity fabrication and testing
- RF chip and wire assembly (wire bonding)
- Environmental, electromagnetic, and mechanical testing
- Advanced 3D modeling
- 3D simulation of electromagnetics, mechanical, thermal, and multiphysics
- Inspection capability (traceability, MIL-Spec, space standards)

Heritage

The breadth and depth of these capabilities is extensive, and there are few single organizations that possess these capabilities and have the legacy to effectively exploit them and respond with agility to emerging microwave/millimeter-wave energy customer needs. That company is Stellant Systems, and though it may be a new name, Stellant is simply a combination of L3Harris Electron Device Division and Narda-West, acquired by Arlington Capital Partners in 2021. The heritage of this organization dates back to Charles Litton's Engineering Laboratories founded in 1932 and Howard Hughes' Electron Tube Laboratory in 1959. This heritage includes TWTAs that are still operating on the Voyager mission — active since 1977.

From the Past, Into the Future

The past near-century has seen mergers, acquisitions, consolidations, and organizational transformations that have preserved the heritage and legacy in vacuum-based microwave/millimeter-wave power electronics now embodied by Stellant Systems, and also a new era of innovation.

What is now Stellant Systems was once operated by large organizations like Sylvania, Loral, GM Hughes, Sperry, GE, RCA, Raytheon, Boeing, and others.

Vertically Integrated

Stellant Systems is currently the only vertically integrated space TWTA supplier in the world as well as the only manufacturer of space-qualified TWTs in the USA. With the acquisition of Comtech PST in October 2023, Stellant Systems not only has extensive capabilities in vacuum-based energy technologies, but also solid-state power technologies. This puts Stellant Systems in a unique position to offer microwave/millimeter-wave energy customers a diverse range of products resulting in the synergy now possible with design and manufacturing capabilities for both dominant high-power and high-frequency technologies under one roof. This includes active and passive components, devices, and systems that range to 70 GHz with output powers exceeding 300 W for space and frequencies to 95 GHz and output powers to 6 MW for defense applications.

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Stellant Systems now boasts 5 manufacturing facilities. All are ISO 9001:2015 certified, while only Topsfield is not AS9100 certified. Some facilities also feature DCMA certifications. These facilities, totaling over 800,000 square feet, also support nearly 1100 employees with over 150 engineers.

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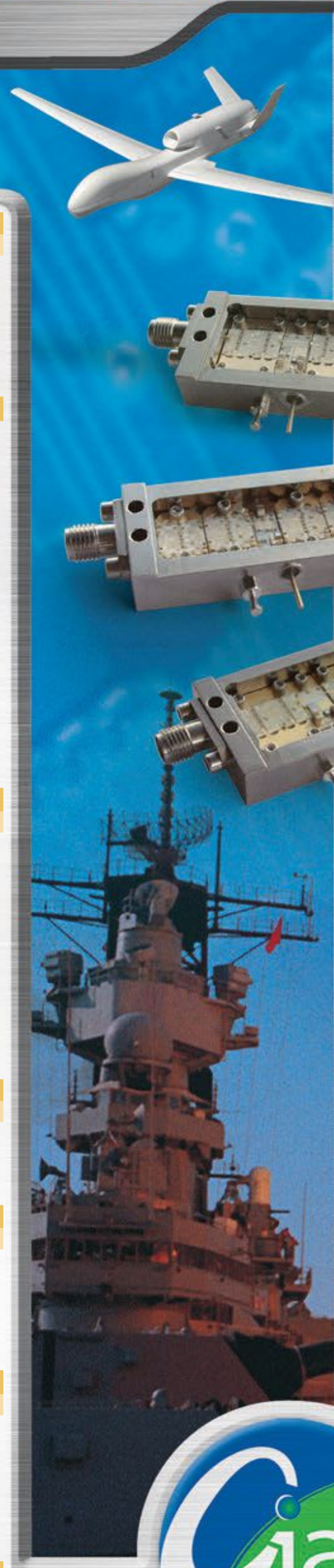

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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Cliff Drubin, Associate Technical Editor

RTX's SeaVue Multi-Role Radar Provides Critical Targeting Data at RIMPAC

Raytheon, an RTX business, successfully demonstrated the SeaVue Multi-role Radar's superior long-range target detection at the U.S. Navy's Exercise Rim of the Pacific (RIMPAC) — the world's largest international maritime exercise.

Performing a Sink Exercise (SINKEX), an MQ-9B SeaGuardian® Unmanned Aircraft System from General Atomics Aeronautical Systems, Inc. used SeaVue Multi-role Radar (SVMR) surveillance and imaging to survey multiple targets and send track data to F/A-18 E/F Super Hornet aircraft. The aircraft were able to use the data provided by the radar to successfully fire a long-range anti-ship missile at a decommissioned amphibious assault ship, the USS Tarawa (LHA-1), showcasing SVMR's net-enabled, long-range weapons employment capabilities.

SVMR is a modern, software-defined radar that provides all-weather surveillance and superior multi-mission performance for crewed and uncrewed aircraft, including fixed, rotary-wing and aerostat platforms.

SeaGuardian (Source: RTX)

Leveraging over 60 years of surveillance radar innovation, SVMR provides extended range and small target detection from operational altitudes, enabling a more capable and efficient method for monitoring and protecting. It features a modular and scalable architecture that supports affordable upgrades and sustainment and has been developed and extensively flight tested for low- and high-altitude surveillance modes.

Military 'Silent Hangar' to Help Protect Against Foreign GPS Jamming

A new test facility, one of the largest in Europe, will help military kit to be better protected from attempts to jam GPS devices. The facility will provide a key capability to develop U.K. assets that can perform in the harshest environments on operations.

Under the new £20 million contract, QinetiQ will build a RF, anti-jamming test facility at the Ministry of Defence's Boscombe Down site in Wiltshire.

The 'silent hangar' will be large enough to fit some of the biggest military assets, including Protector drones, Chinook helicopters and F-35 fighter jets — a far greater capacity than existing U.K. facilities.

Due to open in 2026, the anechoic hangar creates the perfect environment to test the integrity of the U.K.'s military equipment. The hangar also prevents testing affecting other users, such as emergency services and air traffic control. It will also offer a range of opportunities beyond defense, to wider government, industry and critical national infrastructure.

Silent Hangar (Source: QinetiQ)

It will be one of the largest facilities in Europe and roughly the size of an aircraft hangar, simulating hostile environments and putting the U.K.'s most advanced military equipment through its paces.

The specialist hangar will reduce reflections, echoes and the escape of RF waves. The GPS simulators and threat emulators inside the chamber will provide the ability for the U.K. to create hostile environments to test how well equipment can withstand jamming and other threats that attempt to confuse or disrupt assets.

NGC Successfully Demos UWB Multifunction Sensor

Northrop Grumman Corporation (NGC) successfully completed the first flight campaign of its electronically scanned multifunction reconfigurable integrated sensor (EMRIS). These flights, completed in partnership with government partners and on a government-provided aircraft, are the next stage of technology maturation for EMRIS. The flights demonstrated the open architecture nature of EMRIS by using third-party integration and operation. New software was rapidly deployed during flights, demonstrating the reconfigurable nature of the sensor.

EMRIS was designed using common building blocks and software containerization, allowing for rapid, cost-effective production, providing these advanced capabilities to the warfighters quickly. Its fully digital active electronically scanned array (AESA) uses technology from the Defense Advanced Research Projects Agency's Arrays on Commercial Timescales program, combined with the government's open architecture standards. By applying the flexibility of a digital AESA, EMRIS can perform multiple functions, including radar, electronic warfare and communications, simultaneously.

As part of EMRIS' flights, NGC demonstrated the ability to quickly leverage technologies developed for other programs to adapt multiple fielded capabilities into EMRIS. The second EMRIS array is entering testing and NGC is in the process of demonstrating its scalable nature with two smaller EMRIS apertures for lower cost and size-constrained application demonstrations.

For More Information

Visit mwjournal.com for more defense news.

EMRIS demonstrates the value of a product line designed from the beginning to leverage open, scalable software along with modular digital building blocks to enable a common sensor baseline. All work is in support of a wide range of existing platform upgrades as well as new emerging opportunities.

L3Harris Prototype Demonstrates Capabilities for Autonomous Air Defense

L3Harris' Agile Development Group has been iteratively developing a robotic-based, highly mobile, short-range air defense capability that meets today's mission needs and is inherently designed to adapt to tomorrow's threats quickly and economically. The prototype system participated in this year's Project Convergence Capstone 4 (PC-C4) field experiment and seamlessly integrated advanced long-range surveillance and electronic attack capabilities onto a fully autonomous combat vehicle, enhancing ground-based air defense with beyond-line-of-sight (BLOS) operations. The team adapted BLOS technology to an additional platform while at the event, demonstrating their ability to respond to emerging robotic system demands.

PC-C4 is a series of exercises, experiments and events to identify and refine strategies essential for transforming the U.S. Army and securing their war-winning readiness.

This testing demonstrated the precision accuracy of the WESCAM MX™-10D reconnaissance, surveillance and target acquisition multi-sensor imaging and designator system. It also included several communications tests, providing insights related to integration, performance and applicability of modular and open communication systems and true resiliency for mission-relevant data links. The communications capabilities tested included the RASOR™, modular communications chassis Mobile Ad Hoc Network WRAITH™, a satcom on-the-move antenna, the AN/PRC-158 Next Gen radio, a RF-7850W high-capacity line of sight radio and a hardened third-party commercial space internet satellite.

These field tests show the potential for air defense systems to evolve into nimble, tactical assets that enable protection to ground units at low levels. The prototype development and testing have revealed that the operational range of autonomous ground platforms performing missions can be expanded by several orders of magnitude, liberating them from the constraints of traditional data link ranges.

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Cliff Drubin, Associate Technical Editor

FCC to Reignite 5G Fund to Target Investments in Rural Communities Using Improved Broadband Maps

The Federal Communications Commission (FCC) announced it adopted new rules to move forward with targeted investments in the deployment of advanced 5G mobile wireless broadband services in rural communities. The bipartisan vote on these rules reignites the 5G Fund for Rural America using the FCC's new and improved broadband coverage map, which shows that millions of homes and businesses lack mobile 5G coverage.

For Phase I of the 5G Fund, the FCC will use a multiround reverse auction to distribute up to $9 billion to bring voice and 5G mobile broadband service to rural areas of the country. Once the FCC is ready, the expected start of the auction will be announced through a public notice.

The 5G Fund Phase I auction will rely on the mobile coverage data obtained in the Broadband Data Collection, including through the FCC's Mobile Speed Test app, and reflected on the FCC's National Broadband Map. In 2021, Chairwoman Jessica Rosenworcel established a task force dedicated to implementing long overdue improvements to the agency's broadband data and mapping tools. The task force continues to gather data and update the maps to ensure that programs like the 5G Fund effectively target its resources.

Additionally, to promote the deployment of Open Radio Access Network (Open RAN) technology and its benefits for competition, national security and supply chain reliability, the 5G Fund now includes up to $900 million in incentives for incorporating Open RAN in 5G Fund-supported networks.

This Second Report and Order, adopted by a full vote of the FCC, also modifies the definition of areas eligible for 5G Fund Phase I support and ensures that areas in Puerto Rico and the U.S. Virgin Islands that meet the new definition will be included in the auction. The item increases the overall budget for Phase I of the 5G Fund to up to $9 billion and proportionally increases the tribal reserve budget, a set-aside portion of the fund to support connecting tribal communities. The rules also require that recipients of 5G Fund support implement cybersecurity and supply chain risk management plans.

Axiom Space and Nokia Partner to Enable High Speed Cellular Network Capabilities in Next-Gen Lunar Spacesuits

Axiom Space has partnered with Nokia to integrate advanced 4G/LTE communication capabilities into the next-generation spacesuits that will be used for the Artemis III lunar mission.

Together, Nokia and Axiom Space will incorporate high speed cellular network capabilities in the Axiom Extravehicular Mobility Unit (AxEMU), supporting HD video, telemetry data and voice transmission over multiple kilometers on the Moon. This advancement will enable Artemis III crewmembers to capture real-time video and communicate with mission controllers on Earth while they explore the lunar surface.

Nokia plans to deploy the first cellular network on the Moon as part of Intuitive Machines' IM-2 mission, which is scheduled to be delivered to the launch site in 2024. During that mission, Nokia aims to demonstrate that cellular connectivity can facilitate crucial communications during future lunar or Mars missions. Nokia's Lunar Surface Communications System (LSCS), pioneered by Nokia Bell Labs' research and innovation, will be deployed during IM-2 and will be further adapted for use in the AxEMU spacesuit.

The fully autonomous LSCS has two components: a network-in-a-box combines the radio, base station and core network elements of a terrestrial cellular network into a single unit, and device modules that will be integrated into the AxEMU spacesuits. Both the network and device modules have been carefully engineered to withstand the extreme environmental conditions on the lunar surface and the dynamic stress of spaceflight. They have been optimized for size, weight and power consumption.

AxEMU (Source: Axiom Space)

Axiom Space was recently awarded $57.5 million from NASA to make this 4G/LTE network modification to the lunar spacesuit for the Artemis III mission, building upon its first Artemis task order in 2022, valued at $228 million.

Axiom Space's spacesuits will provide astronauts with advanced capabilities for space exploration while providing NASA with commercially developed human systems needed to access, live and work on and around the Moon.

What's the Killer Application for RF Metamaterials?

IDTechEx's report, "Metamaterials Markets 2024-2034: Optical and Radio-Frequency," offers an in-depth analysis of the evolving field of electromagnetic (EM) metamaterials. The report projects that the combined market for optical and RF metamaterials will reach US$15 billion by 2034.

RF metamaterials are engineered to interact with EM waves within the 600 MHz to 1 THz frequency

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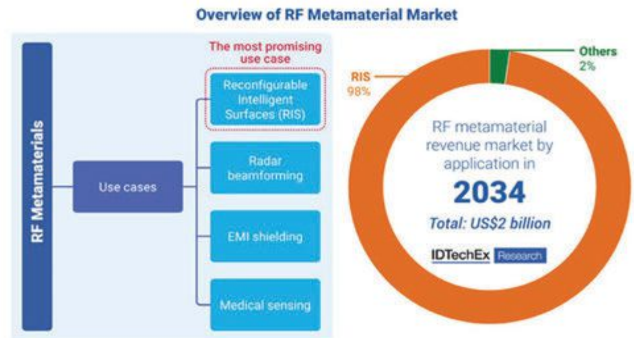
range. Their potential applications span across telecommunications, security and aerospace, automotive and healthcare sectors. IDTechEx's analysis highlights key applications in each category, including reconfigurable intelligent surfaces (RIS), radar beamforming, EMI shielding and medical sensing. IDTechEx projects that the RF metamaterial market will reach US$2 billion by 2034, with RIS driving 98 percent of this growth.

Benefits of RIS include being able to dynamically adjust signal phases and amplitudes, compensating for propagation losses over extended distances, thus improving the efficiency and reliability of signal transmission in high frequency bands.

RIS contribute to enhancing the signal-to-interference plus noise ratio, thereby boosting signal strength, extending coverage range and increasing overall network throughput. Their ability to manipulate signal propagation makes them useful in optimizing the performance of high frequency communication networks.

In addition to their technical benefits, RIS operate with low power consumption as they require minimal active components, making them energy-efficient alternatives to traditional relay systems. Their integration into existing infrastructures, such as building surfaces, further simplifies deployment and reduces the cost of establishing robust high frequency telecommunications networks.

RIS represent a key enabling technology for high frequency communication in 5G and 6G networks, addressing propagation challenges and optimizing signal performance to unlock the full potential of advanced wireless technologies in terms of speed, capacity and reliability.



Metamaterial Market (Source: IDTechEx)

The "Metamaterials Markets 2024-2034: Optical and Radio-Frequency" report from IDTechEx explores eight distinct applications of optical RF metamaterials, including RIS, metalenses and radar beamforming. Based on interactions with over 15 companies, it outlines the key technologies, establishes their readiness levels and assesses the suitability of multiple competing manufacturing methods. 33 forecast lines illustrate how the metamaterial market will evolve over the next 20 years.

Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Dover announced that it has acquired **Criteria Labs, Inc.**, a leader in RF device and microelectronic engineering solutions tailored for high-reliability applications in the space, aerospace, defense, commercial semiconductor, automotive and medical industries. Criteria Labs is now part of the Microwave Products Group (MPG) within Dover's Engineered Products segment. The company's primary location in Austin, Texas, includes a large clean room dedicated to space test engineering, assembly and packaging. Its Penrose, Colo., facility specializes in electronic component tape and reel packaging services. The acquisition of Criteria Labs will enhance MPG's ability to meet exacting size, weight and power requirements, which are crucial for electronic warfare and communication systems.

COLLABORATIONS

Axiom Space has partnered with **Nokia** to integrate advanced 4G/LTE communication capabilities into the next-generation spacesuits that will be used for the Artemis III lunar mission. Together, Nokia and Axiom Space will incorporate high speed cellular network capabilities in the Axiom Extravehicular Mobility Unit (AxEMU), supporting HD video, telemetry data and voice transmission over multiple kilometers on the Moon. This advancement will enable Artemis III crewmembers to capture real-time video and communicate with mission controllers on Earth while they explore the lunar surface. Nokia plans to deploy the first cellular network on the Moon as part of Intuitive Machines' IM-2 mission, which is scheduled to be delivered to the launch site in 2024.

ACHIEVEMENTS

Raytheon, an RTX business, successfully demonstrated the SeaVue Multi-role Radar's (SVMR's) superior long-range target detection at the **U.S. Navy's Exercise Rim of the Pacific (RIMPAC),** the world's largest international maritime exercise. Performing a Sink Exercise (SINKEX) an MQ-9B SeaGuardian® unmanned aircraft system from General Atomics Aeronautical Systems, Inc. used SVMR surveillance and imaging to survey multiple targets and send track data to F/A-18 E/F Super Hornet aircraft. The aircraft were able to use the data provided by the radar to successfully fire a long-range anti-ship missile at a decommissioned amphibious assault ship, the USS Tarawa (LHA-1), showcasing SVMR's net-enabled, long-range weapons employment capabilities.

Northrop Grumman Corp. successfully completed the first flight campaign of its electronically scanned multi-function reconfigurable integrated sensor (EMRIS). EMRIS was designed using common building blocks and software containerization, allowing for rapid, cost-effective production, providing these advanced capabilities to the warfighters quickly. EMRIS's fully-digital active electronically scanned array (AESA) utilizes technology from the Defense Advanced Research Projects Agency's Arrays on Commercial Timescales program, combined with the government's open architecture standards. By applying the flexibility of a digital AESA, EMRIS can perform multiple functions including radar, electronic warfare and communications, simultaneously. As part of EMRIS' flights, Northrop Grumman demonstrated the ability to quickly leverage technologies developed for other programs to adapt multiple fielded capabilities into EMRIS.

Texas Instruments (TI) announced it would receive up to $1.6 billion in funding from the **U.S. Commerce Department** towards the construction of three new facilities, the latest government outlay aimed at bolstering domestic chip production. The funding, under the U.S. CHIPS and Science Act, will help the company build two factories in Texas and one in Utah. TI has pledged more than $18 billion through 2029 to the projects, which are expected to create 2,000 manufacturing jobs. The chipmaker also expects to receive about $6 billion to $8 billion in investment tax credit from the U.S. Treasury Department and $10 million in funding for workforce development.

Cadence Design Systems Inc. announced the launch of Fem.AI, an initiative to propel women and the industry towards a more equitable tech sector, with an emphasis on opportunities in AI. **The Cadence Giving Foundation** has committed $20 million towards this initiative, including philanthropic and product donations over the next decade to organizations that align with Fem.AI's mission. By catalyzing the industry to invest in nonprofits, university students and programs, champion women-led ventures, drive product innovation and leverage industry influence, Fem.AI aims to close the gender gap in this critical space.

Gotonomi, a leading provider of unmanned aerial vehicle (UAV) satellite connectivity solutions, announced the completion of further successful flight trials and the opening of orders for production units of all variants of its UAV satcom terminals during Commercial UAV Expo 2024 in Las Vegas. The launch marks a significant milestone, transitioning from pre-production flight development kits to type-approved commercial terminals, enabling scalable beyond visual line of sight operations for drone operators wishing to offer services such as inspection, surveillance and delivery. Following extensive verification testing, including flight trials across the EU, U.S., Canada, Australia, U.K. and Brazil, deliveries of CE/FCC/RCC/ISED marked units will start in October 2024.

Atheras Analytics will provide Ka-Band propagation analysis to enable the **U.K. Ministry of Defence (MoD)** to determine the location of new Ka-Band ground in-

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frastructure to support the upcoming SKYNET 6 secure military satellite network. SKYNET is the MoD's satellite communications capability and is a family of military communications satellites that will provide strategic communication services to the U.K. Armed Forces and allies. The SKYNET 6 Programme is exploiting technological advances to deliver the next generation of military communication satellites to the MoD. Atheras Analytics' design software will be utilized to conduct analysis of propagation conditions for existing ground station sites.

LEO nanosatellite constellation operator **Sateliot** has launched four additional satellites as part of its 5G NB-IoT NTN constellation. These satellites extend the coverage of mobile telecom operators in 100 percent of the planet and were deployed on the SpaceX Transporter-11 mission. The technology incorporates enhancements from previous satellites. It is the first constellation to implement standard GSMA and 3GPP developments fully on satellites. In addition to providing commercial services, Sateliot aims to use these advancements to continue leading the NTN community in future innovations. Sateliot's approach, featuring its patented "Store and Forward" technology, offers global connectivity with its new orbital plane.

ICEYE, the global leader in synthetic aperture radar (SAR) satellite operations for Earth observation, persistent monitoring and natural catastrophe solutions, successfully launched four new SAR satellites. The new satellites further expand the world's largest SAR constellation, owned and operated by ICEYE. The satellites were integrated via Exolaunch and successfully lifted off aboard the Transporter-11 Rideshare mission with Space X from Vandenberg Space Force Base in California, U.S. Each spacecraft has established communication and early routine operations are underway. The satellites serve both ICEYE's commercial and dedicated customer missions and were manufactured by ICEYE in Finland and ICEYE US in the United States.

CONTRACTS

AeroVironment (AV) has been awarded a contract for the **U.S. Army's** Directed Requirement (DR) for lethal unmanned systems (LUS). The five-year contract from Army Contracting Command-Aberdeen Proving Ground is indefinite delivery, indefinite quantity (IDIQ) with a contract ceiling value of $990 million. Deliveries of the Switchblade® systems are expected to begin in months. The LUS DR is the Army's first effort to equip soldiers in infantry battalions with lethal, man-portable loitering munition systems. The combat-proven Switchblade systems will enhance soldiers' capabilities with precision flight control, greater lethality against fortified targets, such as armored vehicles and tanks, and the ability to track and engage moving non-line-of-sight targets.

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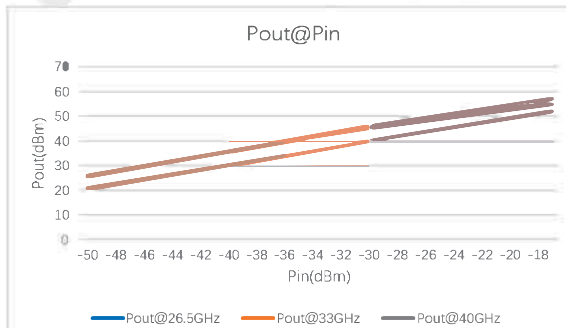

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- 40-60GHz 100W Solid State Power Amplifier
- 75-100GHz 10W Solid State Power Amplifier
- 8-18GHz 2000W Pulse Solid State Power Amplifier

Around the **Circuit**

Leonardo DRS Inc. announced that it has received an order for continued production of its next-generation thermal weapon sights for the **U.S. Army**. The production order for $117 million was made under the current Family of Weapon Sights – Individual (FWS-I) IDIQ contract. Leveraging DRS's uncooled thermal imaging technology, FWS-I is a standalone, clip-on weapon sight that connects wirelessly to helmet-mounted vision systems, including the enhanced night vision goggle binoculars and the next generation integrated visual augmentation system and provides rapid target acquisition capabilities to the soldier.

Teledyne Brown Engineering, a subsidiary of **Teledyne Technologies Incorporated**, announces the award of a $114 million task order under the Design, Development, Demonstration and Integration (D3I) Domain 1 contract by the **U.S. Army Space and Missile Defense Command**. Under this contract, Teledyne Brown Engineering will spearhead the design, build and launch of realistic-threat ballistic target missiles, crucial for use in testing advanced missile defense systems. The Tactical Range Air Defense Missile (TACRAM) 2, a follow-on contract, will extend through March 2028, continuing the company's work under the previous contract, providing target missiles since 2014.

CACI International Inc. announced that it was awarded a five-year task order valued at up to $80 million to continue providing engineering support expertise to the **U.S. Navy Naval Sea Systems Command Naval Surface Warfare Center Corona Division**. Through the Acquisition Readiness & Performance Assessment (ARPA) Engineering Support Services task order, CACI will continue delivering expertise to ensure fleet systems are tested and assessed to maintain a high level of readiness and reliability. This includes conducting performance, readiness and reliability assessments, as well as analyses and assessments of weapons, combat systems, hull, mechanical and electrical systems for surface ships, submarines and aircraft carriers.

Outpost Technologies Corp., pioneering multi-ton Earth return to advance development of the space economy, announced that the company is selected to receive a $33.2 million, four-year Strategic Funding Increase (STRATFI) contract from the **Air Force Ventures program (AFWERX)** to develop and test a scalable heat shield, payload bus and paragliding system to develop a joint precision orbital cargo space vehicle to support hypersonic testing and reentry missions. The selection notice was presented at Fed Supernova 2024, the premiere defense event in Austin, Texas, and will begin later this year.

Remcom has been awarded a Small Business Innovative Research Phase II contract to provide **NASA** with mission-critical capabilities for wireless channel simulation and coverage analysis for lunar environments. The project will enhance Remcom's Wireless InSite® 3D

Around the **Circuit**

Wireless Prediction Software with key features to predict the performance of 4G/5G and Wi-Fi systems in the complex landscape of the Moon, ensuring robust communications for future Artemis missions. NASA's Space Communications and Navigation program is working to leverage terrestrial 4G/5G technologies from the Third Generation Partnership Project (3GPP) in order to advance lunar surface communications in support of the LunaNet architecture.

The sensor solution provider **HENSOLDT** has received a further order from **Thales** for the delivery of TRS-4D naval radars for the German Navy's F126 frigates. This brings the total order value to more than 200 million euros. The initial order placed in 2022 comprised the delivery of TRS-4D naval radars for four Niedersachsen-class frigates (F126) and a radar segment for the test center. Due to the expansion, two further F126 frigates will be equipped. The TRS-4D naval radar from HENSOLDT will be installed in its non-rotating version with four fixed antenna arrays. The integration of the radar on the ships and shore installations will be carried out by Thales in order to deliver an operational and combat system that meets German requirements.

PEOPLE

▲ *Brad Whittington*

Mercury Systems Inc. announced the appointment of **Brad Whittington** as its senior vice president of engineering. Reporting to Chief Operating Officer Roger Wells, Whittington is responsible for the strategic planning, leadership and execution of Mercury's recently integrated engineering organization. Whittington has more than 25 years of experience in technical leadership roles in aerospace and defense. He most recently served as vice president of engineering and chief engineer for the defense systems sector within Leidos. Prior to that, he held numerous leadership positions at Raytheon, Lockheed Martin and NASA. He has an M.S. in engineering from Texas Tech University, along with a B.S. in physics and a B.S. in mathematics from Harding University.

▲ *Mike Towner*

Stellant Systems Inc. announced the appointment of **Mike Towner** as vice president of business development. Towner has over 30 years of aerospace and defense industry experience encompassing RF/microwave technologies in the electronic warfare (satcom, radar, missile), medical, science and industrial markets. Towner will lead business development initiatives, shape strategic direction, develop key partnerships and identify growth opportunities. He will report to Steve Shpock, Stellant's interim chief executive officer and current chief operations officer. Prior to joining Stellant,


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Towner held senior positions in engineering, program management and business development at CISCO Systems, CPI and Teledyne Technologies, including recently serving as group senior director of strategic growth and business development for Teledyne Defense Electronics.

Triad RF Systems announced the promotion of **Charles Jobbers** to managing director, a role that reflects both his outstanding leadership and his commitment to innovation within the company. Jobbers' promotion comes at a time when Triad is poised for continued growth as part of the COMROD family of companies, driven by a focus on advancing RF technologies and maintaining the highest standards of quality and manufacturing. As a part of COMROD, Triad's team strengthens their RF capability and capacity, and the combined companies are cooperating on next-generation radio range extension solutions. The objective is to push the boundaries of what is possible and explore new avenues for innovation.


▲ *Charles Jobbers*


▲ *Peter Riedel*

Peter Riedel resigned from his position as president and COO of **Rohde & Schwarz GmbH & Co. KG** and left the company at end of July 2024. He will remain associated with Rohde & Schwarz in an advisory role. After nearly 36 years at Rohde & Schwarz, Riedel has decided to take a different direction professionally and leave the company. The Executive Board of the Munich technology company now consists of Christian Leicher as president and chief executive officer and Andreas Pauly as president and chief technology officer. For the time being, Pauly will assume the tasks of COO on an interim basis.

REP APPOINTMENTS

Reticulate Micro Inc. and **ZeroAlpha Solutions Ltd.** announced that ZeroAlpha will serve as a value-added reseller for Reticulate's VAST™ video streaming and compression platform in the European military market. ZeroAlpha plans to embed Reticulate's VAST encoder within its existing ecosystem of tactical radio and satcom partners to provide resilient video streaming for a variety of missions. Initial demos are slated to begin next month with NATO and U.K. government customers. U.K.-based ZeroAlpha is a leading supplier of networking hardware, software and sustainable power solutions to major primes in the U.K. as well as European defense and security markets. The firm holds a NATO framework contract and is already serving military customers in the Netherlands, Germany, Norway, Latvia and Poland.

INVITED PAPER

Unlocking the Future of Telecoms

Tudor Williams
Filtronic, Sedgefield, England

As the telecom industry evolves toward 5.5G and beyond, the importance of x-haul in ensuring robust and efficient central structures cannot be overstated. ***Figure 1*** shows an example of tower-mounted x-haul transceivers and antennas in what is becoming an increasingly common structure across countries worldwide. While consumers might not notice significant differences in mobile data speeds, the industrial implications are profound. In the next decade, remote operations will become ubiquitous and numerous functions that are currently unfeasible will depend heavily on the proper infrastructure. This article explores critical technical aspects and challenges associated with using W- and D-Band and other frequencies in x-haul networks.

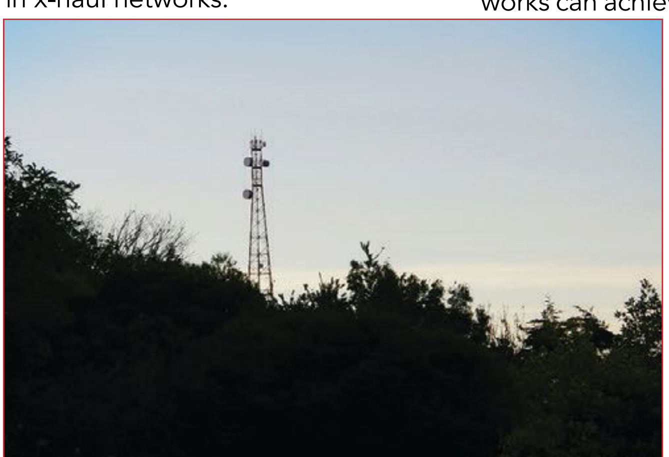

Fig. 1 **Wireless communications tower.**

The primary advantage of W- and D-Band frequencies lies in their significantly wider bandwidths compared to lower frequency bands. This broader spectrum is critical as data demand continues to surge, driven by the proliferation of connected devices and the increasing complexity of data-intensive applications. W-Band frequencies (75 to 110 GHz) and D-Band frequencies (110 to 170 GHz) provide vast, contiguous blocks of spectrum, which are essential for supporting the high data rates required by modern communication networks. These high frequency bands are particularly well suited for x-haul networks, which integrate fronthaul and backhaul connections to create a more efficient and flexible system architecture. By using these bands, networks can achieve lower latency and higher throughput, ensuring a more responsive and reliable user experience.

Specifically, the D-Band offers even greater bandwidth capabilities, potentially up to 4x that of lower frequency bands. This expanded capacity is crucial for future-proofing networks against the exponential growth in data traffic. The D-Band's ability to handle such high bandwidths facilitates enhanced performance and capacity, which is vital for supporting data-intensive applications such as augmented reality, virtual reality and IoT. These applications demand robust and high speed connections to function effectively and the D-Band's superior bandwidth makes it an ideal candidate for meeting these requirements. Additionally, the increased capacity helps accommodate the rising number of users and devices, ensuring that network performance remains optimal even under heavy load.

OVERCOMING TECHNICAL AND MANUFACTURING CHALLENGES

Harnessing W- and D-Band frequencies presents several technical challenges. These include managing inherent propagation losses, atmospheric absorption and the increased complexity that higher frequency operation brings to component manufacturing. Higher frequency signals tend to experience greater attenuation, making it challenging to maintain signal strength over longer distances. Atmospheric conditions, such as humidity and rain, can further exacerbate these losses, necessitating robust error correction and adaptive modulation techniques to maintain reliable communication.

Addressing these challenges


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involves innovating in the design and production of high frequency components. This includes developing new materials with superior electrical and thermal properties to enhance component performance and reliability. Precision manufacturing processes are essential to ensure the accurate alignment and integration of components, which is critical for maintaining signal integrity. Advanced fabrication techniques, such as additive manufacturing and high precision lithography, must also be employed to produce components that meet the stringent requirements of W- and D-Band operations.

Elevated power consumption and heat generation mean that implementing advanced strategies becomes imperative to sustain optimal performance and reliability. Among these strategies, the use of adaptive modulation schemes stands out as a pivotal approach. Adaptive modulation schemes dynamically adjust modulation parameters, such as symbol rate and constellation size, based on channel conditions and signal-to-noise ratio. By continuously optimizing modulation parameters, these schemes maximize spectral efficiency while minimizing the impact of noise and distortion, thereby enhancing signal integrity and reliability.

Furthermore, error correction techniques play a crucial role in mitigating the adverse effects of high frequency operations. Employing sophisticated error correction codes, such as Reed-Solomon or turbo codes, enables the detection and correction of errors introduced during signal transmission. These techniques enhance the robustness of communication systems by effectively compensating for channel impairments, including attenuation and fading, which are prevalent in environments with high atmospheric absorption.

In addition to adaptive modulation and error correction, integrating advanced cooling solutions is indispensable for managing the thermal challenges inherent in high frequency operations. Heat sinks efficiently regulate temperature levels using efficient heat dissipation mechanisms, preventing overheating and ensuring the sustained performance of high frequency components. Active cooling systems that employ techniques like liquid or thermoelectric cooling provide further thermal management capabilities to dissipate the heat generated during intense operational scenarios effectively.

THE CURRENT STATE OF DEVELOPMENT

One of the primary hurdles manufacturers face is the underlying semiconductor technology required to achieve the necessary high frequencies. For W-Band, existing semiconductor technologies are being stretched to their limits, but they are still within achievable tolerances. This includes precise placement tolerances, wire bonding and machining accuracy. For instance, in W-Band applications, maintaining signal integrity requires high precision in component placement and

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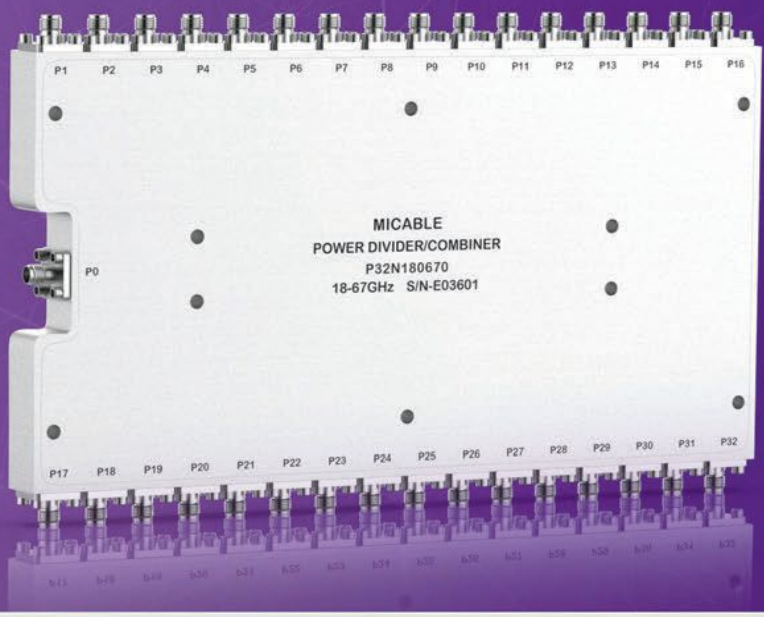

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Insertion Loss*	9.4 dB(Max.)
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Phase Unbal.	±12 Deg.(Max.)
Isolation	18 dB(Min.)
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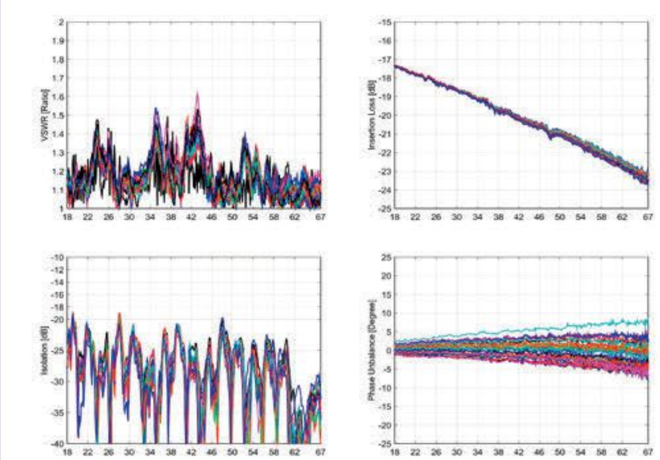
Test Curve



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However, the D-Band presents more significant challenges. Currently, commercially viable semiconductor technologies for D-Band are not yet fully developed. While boutique processes are capable of handling D-Band frequencies, they are not suitable for high volume commercial applications due to their high costs and limited scalability. This means widespread adoption of D-Band frequencies may still be several years away, pending advancements in semiconductor manufacturing technologies.

IMPORTANCE OF MATERIAL INNOVATIONS

The development of novel materials boasting superior electrical conductivity, low dielectric loss and high thermal conductivity is paramount for realizing efficient and reliable components. Engineers delve into the intricate properties of materials, including GaN and indium phosphide (InP), renowned for their exceptional electron mobility and thermal dissipation capabilities. Moreover, emerging composite materials, meticulously engineered at the nanoscale, exhibit unique characteristics like reduced electromagnetic interference and enhanced thermal stability, propelling the boundaries of component design and functionality.

TELECOMMUNICATIONS AND BEYOND

The adoption of W- and D-Band technologies is poised to significantly impact society and various industries beyond telecommunications. These high frequency bands enable more robust and reliable communication networks, which are crucial for advanced applications such as autonomous vehicles, smart cities and remote healthcare. By providing the necessary infrastructure, these technologies will support a wide range of innovative services and applications, driving economic growth and improving quality of life.

As the telecom industry advances into the era of 5.5G and beyond, the significance of x-haul in establishing resilient central structures remains paramount. While end users may not immediately perceive dramatic shifts in mobile data speeds, the far-reaching industrial implications are undeniable. The adoption of W- and D-Band technologies emerges as a pivotal step forward, offering broader bandwidths crucial for meeting escalating data demands and ensuring a smoother user experience. However, navigating the technical challenges associated with these frequencies underscores the need for continued innovation across material science, fabrication techniques and thermal management strategies. As industry leaders drive advancements in these areas, the seamless integration of W- and D-Band technologies promises transformative possibilities across diverse sectors, underscoring the enduring theme of resilience and progress in the telecom ecosystem. ■

INVITED PAPER

PCB Design for Multichannel Beamformer RF Integrated Circuits

Joel Dobler
Analog Devices, Wilmington, Mass.

Modern phased array systems are built using beamformer ICs (BFICs) that typically have multiple parallel paths on the chip with independently controllable gain and phase. Common BFIC configurations have two or more RF paths routed to pins on the same edge and/or the same corner of the IC package. ***Figure 1*** shows a four-input, four-output, 16-channel BFIC with all four inputs on the same edge of the IC package. This device architecture is used on Analog Devices' ADAR3000/1/6/7 family of Ku- and Ka-Band BFICs. Each device has four inputs, four cross-coupled outputs and a sophisticated digital control system that includes a command processor, on-chip RAM and FIFO memory.

The complexity and size of the BFIC creates challenges. The number of RF inputs and outputs and their associated ground-signal-ground configuration create close pin-to-pin placement. Routing multiple RF lines from these closely spaced pins to adjacent circuitry or other printed circuit boards (PCBs) is challenging. RF power tapering is widely used to reduce sidelobes, but since this can result in channel-to-channel power differences of up to 30 dB, channel-to-channel isolation is critical and the routing of RF lines can significantly impact isolation. In addition to routing issues, transmission line impedance is also very important. Poor transmission line impedance accuracy and poor impedance transitions between boards cause signal reflections and lower RF power delivery to the antenna. Large signal reflections can also cause instability and oscillation.

This article will discuss designing accurate RF PCB transmission lines with excellent return loss and isolation in dense, high channel count, multi-board environments. While we will focus on BFICs and phased array applications, the findings of this article apply equally to any high frequency circuit design where channel-to-channel isolation and good impedance matching are important. The article also covers the important topic of design for manufacturing.

RF TRANSMISSION LINE FABRICATION

PCB fabricators support multiple popular RF transmission line topologies, including microstrip, grounded coplanar waveguide (GCPW), stripline and the less popular buried GCPW, which resembles a hybrid of GCPW and stripline. While microstrip is relatively easy to manufacture, it is less popular for operation above 6 GHz because of its higher trace loss and poor mode suppression.[1] GCPW, buried GCPW and stripline operate better above 6 GHz because of lower radiation loss and better mode suppression. Buried line topologies improve isolation but are more challenging to fabricate and require vias to connect to them. These vias are usually blind to minimize parasitic inductance, which results in higher board costs.

Figure 2 shows a cross-section of GCPW,

buried GCPW and stripline, as well as the important geometries determining the nominal line impedance. These geometries are the line width (W1/W2/W3), the lateral distance from the edge of the line to the adjacent ground plane (G1/G2/G3), the thickness of the dielectric materials (T1/T2) and the relative permittivity of the dielectric materials ($\varepsilon_{R1}/\varepsilon_{R2}$). Figure 2 does not show the thickness of the copper used for the lines or the required ground via fencing. Copper thickness does need to be considered, but it is a secondary effect. Via fencing will be discussed later. The choice of topology depends on acceptable trace loss, frequency, required line-to-line isolation, available space and dielectric thickness of the PCB material.

HOW MANUFACTURING TOLERANCES AFFECTS LINE IMPEDANCE

Fabrication tolerances affect the accuracy of RF line topologies. ***Figure 3*** shows a time domain reflectometry (TDR) plot of a 3 mil wide stripline designed for 50 Ω but measured to be approximately 60 Ω. The initial target tolerance was ±10 percent (45 to 55 Ω), yielding a return loss of more than 20 dB.

Many PCB fabricators offer trace widths down to 3 mil (copper weight is also a factor) with a 1 to 2 mil tolerance.[2,3,4] Dielectric manufacturers usually only provide typical dielectric thickness, most likely because the PCB fabricator determines the final thickness during the board lamination process. The lateral gap to the ground can vary if the ground plane does not stop where it should. In addition, the effective lateral gap width changes if the line width varies.

The lateral gap in microstrip and stripline RF traces is large by design and does not affect the line impedance. This results in all the field lines going to the lower ground plane for microstrip topologies and the upper and lower ground planes in stripline topologies. However, for a GCPW RF trace, the lateral gap-to-ground distance is relatively small by design, causing most of the field lines to go to the lateral ground plane.

Figure 4 plots the line impedance[5] of an RF stripline trace versus line width deviation from nominal. This is done for 3, 5, 7 and 10 mil nominal line widths. The plot also shows the impedance deviation

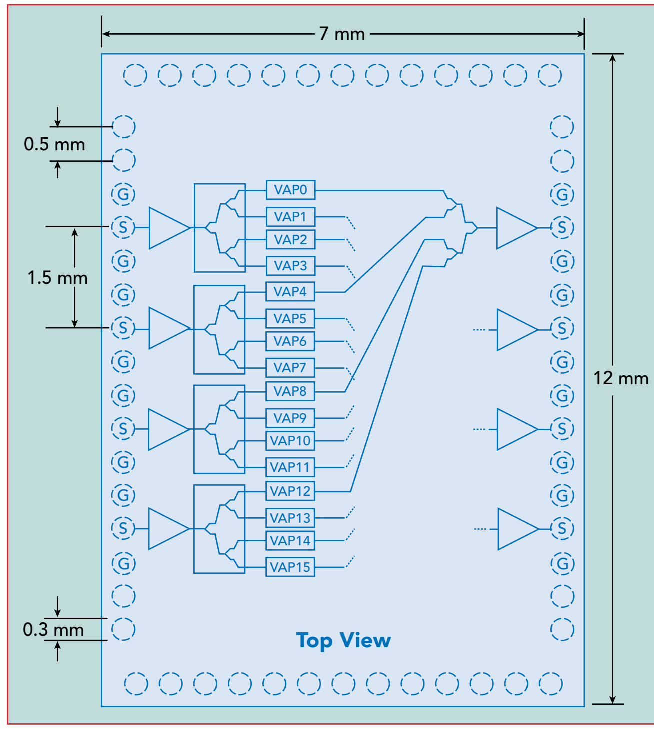


Fig. 1 Block diagram of BFIC chip in a BGA package (not to scale).

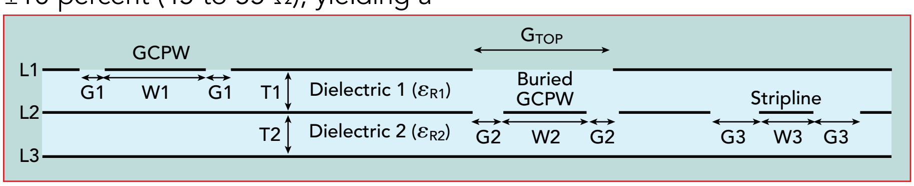


Fig. 2 Cross-section of GCPW, buried GCPW and stripline topologies.

when the dielectric is 5 percent thicker than the nominal value, assuming a stripline copper thickness of 0.7 mil and ε_R = 3.1.

Notice that the wider lines have less variance, while the impedance of the narrower lines varies more for the same absolute width deviation. Therefore, a wider nominal line width is more immune to fabrication variations. By contrast, when the dielectric thickness increases by 5 percent, the impedance shift is approximately equal, regardless of the nominal line widths. This means the PCB fabricator must meet the final pressed thickness requirements within a certain tolerance to attain the targeted line impedance tolerance. The focus in Figure 4 is on increased dielectric thickness because the observation over many PCB fabrication lots with different line topologies is that the line impedance tends to come out greater than or equal to the design target. This leads to a rule of thumb to design the line to be a few Ohms less than the target, especially when the width is thin (e.g., less than 5 mil). With this approach, the controlled impedance requirements that normally constrain the PCB fabricator may need to be waived. A reliable PCB fabricator should be chosen if a thin line must be used due to other design considerations. Confidence in PCB fabricators is established over time from multiple builds or by fabricating experimental boards with multiple lines of varying widths targeting 50 Ω ±10 percent. Measurements would then be performed to determine which line width comes closest to 50 Ω.

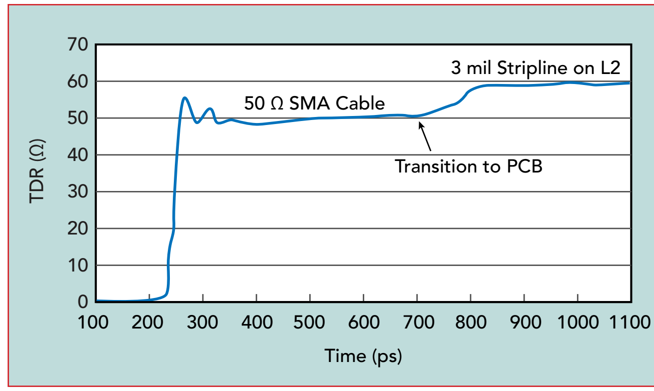


Fig. 3 TDR plot of 3 mil wide stripline on Layer 2.

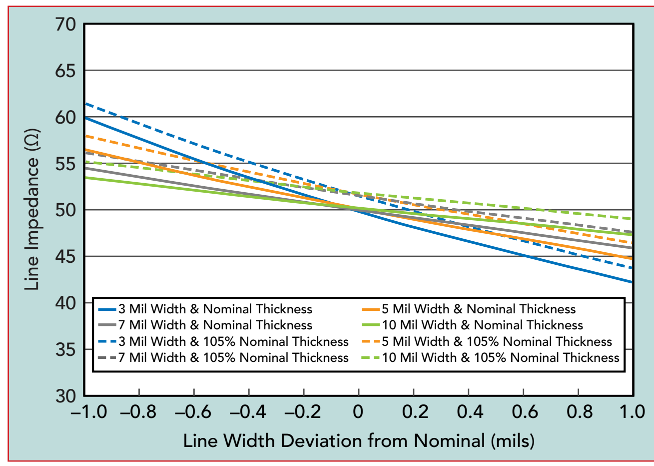


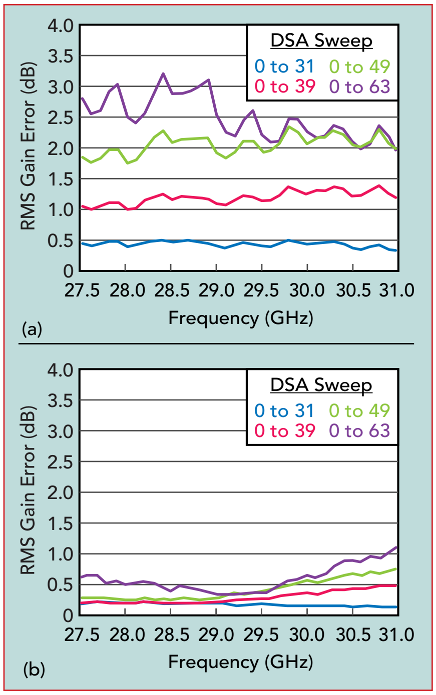
Fig. 4 Line impedance versus line width deviation.

GCPW VERSUS BURIED GCPW

On any PCB, two adjacent transmission lines will have some amount of coupling. This coupling can be electrical and/or through the electric and magnetic fields, resulting in non-infinite isolation. Poor isolation between transmission lines on a PCB is problematic, especially in applications with a significant difference in signal levels. In a phased array system using multichannel BFICs, parasitic signal coupling has been shown to degrade the linearity of the variable amplitude and phase (VAP) block's gain control function in the high attenuation path when two adjacent channels are operating at minimum and maximum attenuation. This behavior was observed on an evaluation board with GCPW transmission lines. EM simulations with Keysight RFPro showed buried GCPW transmission lines improved in-band isolation between the lines by 15 dB versus the existing GCPW PCB solution.

RMS gain error is an abstracted Figure of Merit indicator of gain control non-linearity. In this case,

RMS gain error was measured on both versions of the PCB. ***Figure 5a*** shows the RMS gain error of the original PCB with GCPW, while ***Figure 5b*** shows the RMS gain error of the redesigned PCB containing buried GCPW. In Figure 5a, the RMS gain error is worst when the VAP block's digital step attenuator (DSA) is exercised over its entire range. This is expected because the application is most susceptible to poor isolation when the delta between the DSA's attenuation levels is at its largest. The higher line-to-line isolation of the buried GCPW board improved RMS gain errors significantly, aligning with simulations and displaying the actual performance of the BFIC. These results show that even a moderate improvement in isolation of 15 dB at 30 GHz can affect the measured performance dramatically.



▲ Fig. 5 **RMS Gain Error vs. Frequency over DSA settings for GCPW (a) and buried GCPW (b) transmission lines.**

GUIDELINES ON ROUTING MULTIPLE RF TRACES

Designing PCB traces for RF beamformers with multiple RF inputs and outputs is difficult. As described, careful choice and design of the transmission line topology is required. In addition, correct ground via fencing into the device is important for good return loss and isolation. The isolation requirement and the geometries of the BFIC drive the transmission line topology decision. For example, GCPW is a good choice if the isolation needs to be around -40 dB. If it needs to be approximately -65 dB, based on experimental results stripline transmission lines are required.

Next, consider the geometry of the BFIC, focusing on the size of each pin, the pin-to-pin pitch and the distance between RF pins. For example, consider a BGA with a solder ball diameter of 5.5 mil (0.22 mm), 10 mil (0.4 mm) pin-to-pin pitch and 30 mil (1.2 mm) between RF pins with an isolation requirement of -65 dB. A good choice for this scenario would be symmetrical stripline with approximate dimensions of 6 mil line width, 6 mil thick dielectric (above and below the line) and a 10 mil lateral gap-to-ground, assuming a dielectric constant in the low threes. The rule of thumb for stripline is to have a lateral gap-to-ground distance approximately twice that of the line width since smaller gap distances start to affect line impedances. Smaller distances between RF pins require a thinner width, while larger distances between RF pins accommodate a wider line. The latter is preferable since it provides a higher chance of attaining 50 Ω in manufacturing.

ROUTING NEAR THE DEVICE

When using stripline, care must be taken when transitioning to the device pin on the top layer, as this transition can degrade the isolation significantly if appropriate grounding vias are not used. To attain the highest isolation, the ground wall of vias should extend around the end of the stripline at the device transition, as shown in ***Figure 6***. This technique extends the critical ground wall required for best isolation performance. The device should also have ground pins, bumps and/or a ground paddle that surrounds the signal pin and should roughly coincide with the extended ground wall vias.

RF pins located a short distance from each other may not provide enough area for each transmission line to maintain its same via fencing into the device. Depending on the

available area, the typical options for the via fencing are:

- Use smaller vias if they do not violate the fabricator's aspect ratio rules for the dielectric thickness
- Stagger the vias in a sawtooth pattern where there is a moderate amount of area if the absence of a via on one of the lines at the device interface will not degrade isolation
- Use a single row of larger size vias between the lines while maintaining the same distance between the edges as the smaller via holes to optimize isolation performance, as shown in Figure 6
- Use a single row of same-sized vias when space between the lines is very limited.

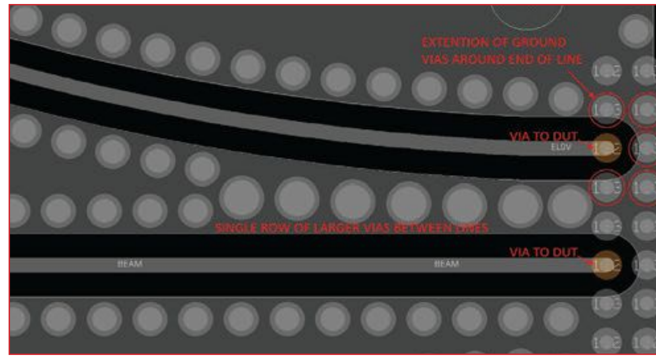


Fig. 6 **Ground wall vias extending around the transmission line.**

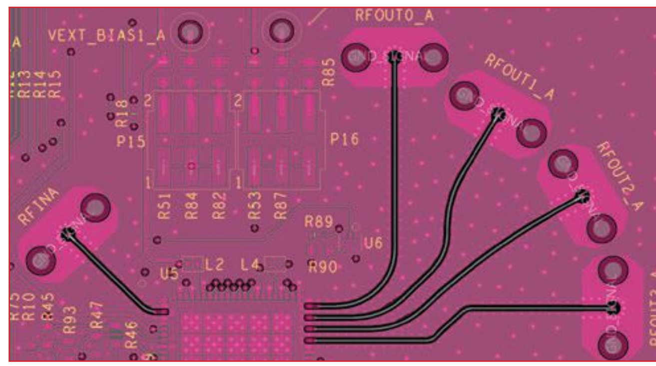


Fig. 7 **Fanout of multiple RF outputs.**

The decision of when and how to fanout traces depends on where the RF I/O pins are in relation to each other on the device. The general rule of thumb is that fanout should happen as soon as it is feasible to reduce parallel runs, which maximizes isolation. As seen in Figure 6, the fanout can happen immediately because of the RF pin positions. However, ***Figure 7*** shows the fanout of different parallel run distances of four outputs. In this case, the fanout is constrained by the non-RF I/O routing and associated circuitry shown on the top side of the device (L2, L4, P15, P16, etc.) and the RF outputs on the right side of the device.

INTRA-BOARD CONNECTIONS

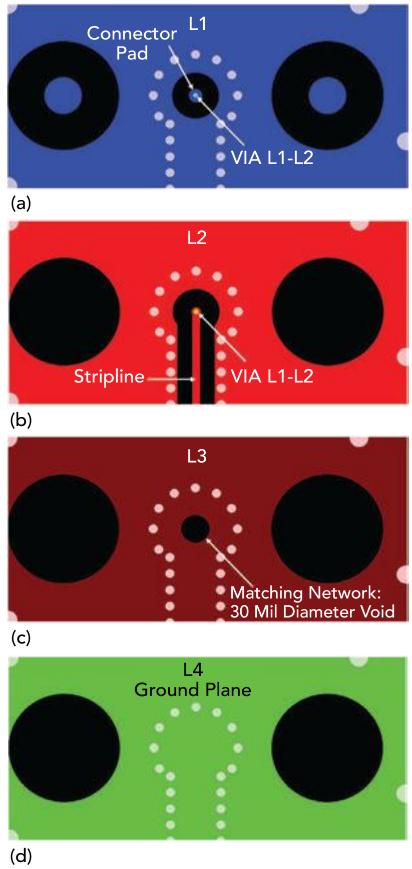
RF impedance discontinuities between RF transmission lines and the RF connectors are as important as the trace-to-device transition. When transitioning between boards, there are two physical interconnect options:

- Edge launch connectors that mount laterally onto the edge of the PCB
- Vertical launch connectors that mount vertically onto the PCB.

Both types are available in SMA, SMP, SMPM, 2.92 mm and 2.4 mm interfaces.

The equipment form factor strongly influences the choice of edge launch versus vertical launch connector. Edge launch connectors imply laterally-arranged interconnecting PCBs. This arrangement may be the best choice if the system sits in a single metal chassis/heat sink. Vertically launched connectors offer the possibility of stacking multiple boards. This may result in a more compact form factor but this configuration may also require air cooling since the individual boards are unlikely to have heat sinks. A combination of one board having an edge launch while the other has a vertical launch results in the boards connecting orthogonally in a slotted style.

While edge launch connectors are widely used, they have potential drawbacks stemming from being attached at the board edge. Edge connectors require that the top



▲ Fig. 8 **(a) Layer 1 ground plane, pad and via. (b) Layer 2 stripline. (c) Layer 3 30 mil void matching network. (d) Layer 4 solid ground plane.**

ground plane of the PCB and, preferably, the bottom ground plane extend to the board's edge. Most PCB fabricators can only guarantee a 2 mil distance between the edge of the ground plane and the board's edge at the connector locations when using standard edge milling/routing and etch pullback techniques. This manifests as an impedance discontinuity due to the lack of ground return in the 2 mil, or larger, gap and degrades the return loss.

Because they are not bound to a board edge, vertical launch connectors are not susceptible to these edge routing issues. On simple, single-device boards, the connectors can be placed close to the device to minimize insertion loss. In addition, the transition onto the board can be matched so that impedance discontinuities are minimized. Some connector vendors will create a custom footprint for a given line design and stack up. ***Figure 8*** shows four PCB layers for an SV Microwave vertical launch connector interface to a stripline RF trace.

One challenge of vertical launch connectors is achieving good alignment between the connector and the PCB footprint during assembly. Ideally, the connector's circular center pin connects to its circular pad on the PCB with the centers aligned. However, left-to-right and forward-to-back movement is possible when mounting the connector on the 2D ground plane. Movement in either of these two directions will cause the center pin to be misaligned with the PCB pad. The best alignment method is a tight tolerance on the mounting hole size to minimize the movement of the connector.

CONCLUSION

Modern, high frequency BFICs are making PCB design more challenging. To maintain high channel-to-channel isolation, some RF trace designs are forced to migrate from surface-level GCPW to buried stripline. Even when using buried stripline, care must be taken to maintain isolation between adjacent traces using closely spaced via fencing that fully encircles the device's pins. When approaching these challenging designs, PCB designers can preempt potential manufacturing problems by avoiding very thin RF traces or designing the characteristic impedance slightly below the target value. When designing board-to-board interconnects, top launch or edge launch interconnects will most likely be chosen based on the form factor of the end equipment. Top launch interconnects are less susceptible to manufacturing limitations at the board's edge. ■

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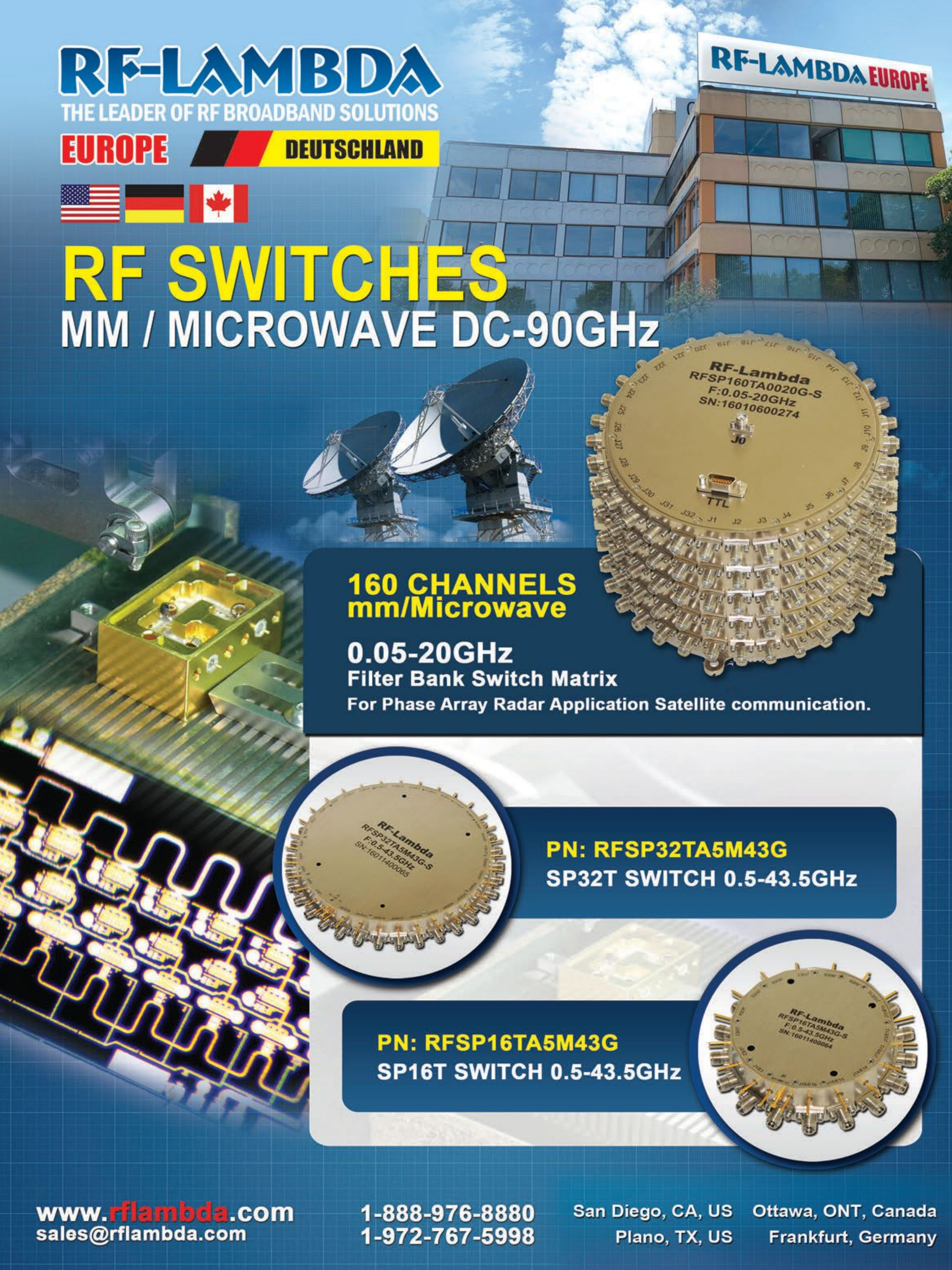
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INVITED PAPER

Extracting Diode Parameters Using Optimization in Excel Part 1: DC Parameters from I-V Measurements

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The diode is a fundamental circuit device used in a variety of RF and microwave applications, from switching to attenuation, limiting, mixing, frequency multiplication and protection against electrostatic discharge, to name a few. The diode is also a highly nonlinear device, as the voltage across it, V_d, will induce one of two states: ON ($V_d > 0$), where it generally acts like a variable resistor and OFF ($V_d < 0$), where it acts like a variable capacitor. As a result, a nonlinear model is required to predict the diode's behavior and some very accurate ones have been developed over the years. These models are generally well understood, so this tutorial does not discuss changes or updates to such earlier work. Instead, in this two-part tutorial, procedures to extract the pertinent parameters of these models from device measurements using Excel are discussed. Part 1 focuses on the ON region and Part 2 discusses the OFF region. Part 1 begins by considering the Shockley diode model and reducing it into a workable equation. Then, DC I-V measurements are presented for a silicon 1N4148 diode and the procedure to extract the pertinent parameters using Excel is described in detail. Finally, the result of this extraction and its limitations, especially concerning Schottky diodes fabricated on GaN, are discussed.

THE DIODE MODEL

A fundamental relationship between the voltage across and current through a diode in the forward or ON region is given by the well-known Shockley equation shown in ***Equation 1***:[1]

$$I_d = I_s\left(e^{\frac{q(V_d - I_d R_s)}{nKT}} - 1\right) \qquad (1)$$

Where:

I_d = current through the diode

I_s = diode saturation current

K = Boltzmann's constant (1.38e-23 Joules per Kelvin)

n = diode ideality factor

q = charge of an electron (1.602e-19 coulombs)

R_s = ON resistance of the diode

T = temperature (in Kelvin)

V_d = voltage across the diode

Of these parameters, V_d and I_d are measured directly as the I-V curve; q, K and T are known beforehand and n, I_s and R_s are the unknowns that must be determined to complete the model.

Before discussing how to extract these parameters, there is a complication with the Shockley equation: the diode current on the left side of Equation 1, I_d, is a nonlinear function of the same diode current on the right side of the equation. In other words, Equation 1 cannot be used in its present form to relate directly the diode current to the applied voltage, V_d. Some algebraic manipulation is required to transform Equation 1 into an equation that can be utilized in an optimization routine.

Readers familiar with Equation 1 will recognize that the contribution of the parallel conductance, G_x, which describes the leakage current through the diode at very low voltages, has been discarded. In almost all circumstances, the diode is operated at voltage levels where this leakage current can be ignored. Some circuit simulation tools do not include G_x in their intrinsic diode model.

Additionally, including the conductance term in Equation 1 does not allow for separating the diode voltage from the diode current. As a result, the conductance parameter, G_x, will be ignored for this tutorial.

Reducing Equation 1 into a form that will be useful for optimization is relatively straightforward. It starts by performing some simple algebra and then takes the natural log of both sides. The result is shown in Equation 2:

$$\ln(I_d + I_s) = \ln(I_s) + \frac{q[V_d - I_d R_s]}{nKT} \quad (2)$$

For simplicity, a new variable, β, which is a function of temperature and has units of 1/Volt, is introduced in Equation 3:

$$\beta = \frac{q}{KT} \quad (3)$$

Solving Equation 2 for V_d as a function of I_d, the known parameter, β and the unknown parameters, n, I_s and R_s, results in Equation 4:

$$V_d = I_d R_s + \frac{n}{\beta}[\ln(I_d + I_s) - \ln(I_s)] \quad (4)$$

Equation 4 is useful since the diode voltage, V_d, has been separated from the diode current, I_d. This is precisely the form that will be implemented in the Excel optimization routine.

DIODE MEASUREMENTS, COMPLETE WITH WARNINGS

Although the diode is described mathematically by a complicated-looking equation, measuring the device's DC I-V relationship is very straightforward, one of the simplest to perform and understand. Since numerous methods exist to accomplish this task, no particular measurement approach will be discussed, except to say that do not let the simplicity fool you.

Plenty of problems can creep up due to the following issues:

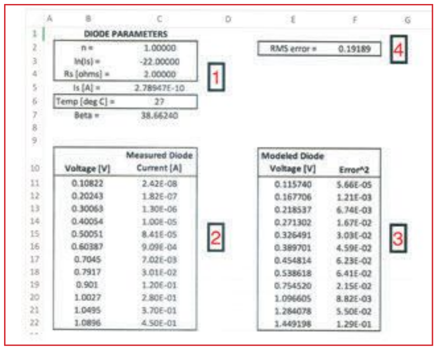
- Not calibrating out the resistance of the leads, cables, probes, etc.
- Taking too little data, such as measuring only a single device or using too few voltages
- Not keeping the temperature constant
- Keeping the lights on when measuring devices directly on a semiconductor wafer
- Using bias tees, which often have high leakage current and skew the measurement
- Not setting a maximum current for the voltage source can lead to device destruction.

Issues with keeping the temperature constant can be the hardest to spot unless you can sense the diode temperature in real-time. This is not an issue for most automated measurement systems because the measurement is quick enough to avoid self-heating in the diode. In other words, you can assume the temperature is constant during the measurement unless the data tells you otherwise. For example, look to the temperature if you get a poor fit to the diode equation shown in Equation 4 and cannot understand why.

Concerning lights being on during measurements, this is a potential issue with on-wafer measurements of diodes because a microscope light is often needed to align the wafer probes. It is very common to leave the light on or, as often happens, forget to turn the light off during the subsequent I-V measurement. However, in most applications, the semiconductor diode will be packaged in some manner and can operate in the dark. The presence of light can affect the performance of the diode as compared to operation in the dark, so make sure

TABLE 1
I-V MEASUREMENTS

Applied Diode Voltage V_d [V]	Measured Diode Current I_d [A]
0.10822	2.42E-08
0.20243	1.82E-07
0.30063	1.30E-06
0.40054	1.00E-05
0.50051	8.41E-05
0.60387	9.09E-04
0.7045	7.02E-03
0.7917	3.01E-02
0.901	1.20E-01
1.0027	2.80E-01
1.0495	3.70E-01
1.0896	4.50E-01



DIODE PARAMETERS				
n =	1.00000		RMS error =	0.19189
ln(Is) =	-22.00000			
Rs [ohms] =	2.00000			
Is [A] =	2.78947E-10			
Temp [deg C] =	27			
Beta =	38.66240			

Voltage [V]	Measured Diode Current [A]	Modeled Diode Voltage [V]	Error^2
0.10822	2.42E-08	0.115740	5.66E-05
0.20243	1.82E-07	0.167706	1.21E-03
0.30063	1.30E-06	0.218537	6.74E-03
0.40054	1.00E-05	0.271302	1.67E-02
0.50051	8.41E-05	0.326491	3.03E-02
0.60387	9.09E-04	0.389701	4.59E-02
0.7045	7.02E-03	0.454814	6.23E-02
0.7917	3.01E-02	0.538618	6.41E-02
0.901	1.20E-01	0.754520	2.15E-02
1.0027	2.80E-01	1.096605	8.82E-03
1.0495	3.70E-01	1.284078	5.50E-02
1.0896	4.50E-01	1.449198	1.29E-01

Fig. 1 **Excel spreadsheet with measured versus modeled diode parameters.**

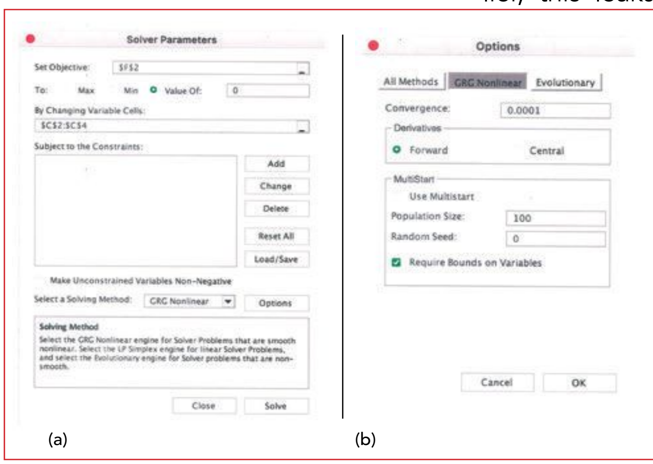
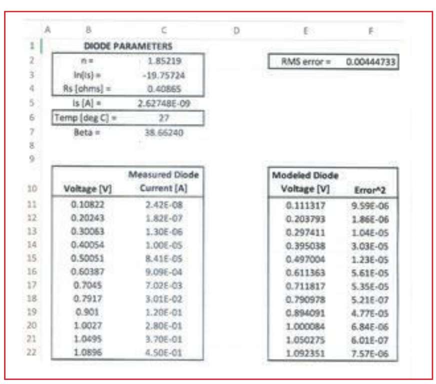


Fig. 2 **(a) Solver function initial menu. (b) Solver function Options menu.**



DIODE PARAMETERS				
n =	1.85219		RMS error =	0.00444733
ln(Is) =	-19.75724			
Rs [ohms] =	0.40865			
Is [A] =	2.62748E-09			
Temp [deg C] =	27			
Beta =	38.66240			

Voltage [V]	Measured Diode Current [A]	Modeled Diode Voltage [V]	Error^2
0.10822	2.42E-08	0.111317	9.59E-06
0.20243	1.82E-07	0.203793	1.86E-06
0.30063	1.30E-06	0.297411	1.04E-05
0.40054	1.00E-05	0.395038	3.03E-05
0.50051	8.41E-05	0.497004	1.23E-05
0.60387	9.09E-04	0.611363	5.61E-05
0.7045	7.02E-03	0.711817	5.35E-05
0.7917	3.01E-02	0.790978	5.21E-07
0.901	1.20E-01	0.894091	4.77E-05
1.0027	2.80E-01	1.000084	6.84E-06
1.0495	3.70E-01	1.050275	6.01E-07
1.0896	4.50E-01	1.092351	7.57E-06

Fig. 3 **Solver function results for the diode parameters in cells C2, C3 and C4.**

to handle external light appropriately when performing a measurement. Once those problems have been conquered and voltage versus current measurements have been obtained for your diode, it is time to determine n, I_s and R_s.

PARAMETER EXTRACTION THROUGH EXCEL OPTIMIZATION

The optimization process is demonstrated through an example. ***Table 1*** shows the I-V measurements of the 1N4148, a workhorse silicon diode first manufactured in 1960 that is still in use today.

Note that the measurements start at 0.1 V since the leakage current begins to appear below this range. Since Equation 4 cannot model the leakage current, this data must be ignored to obtain a good fit for the equation. It could be argued that this is not a valid approach because seemingly important data is being ignored. However, as discussed earlier, this leakage current will have little to no effect on diode behavior in the overall circuit in most situations. In addition, Table 1 is only a subset of the data offered by 2N9304blog.com, with additional data reduced for illustrative purposes. In practice, an I-V measurement would likely include more data points over the operating range.

The next step is to move to Excel and set up the optimization problem. ***Figure 1*** presents the data section of an example spreadsheet with section numbers added to aid in the description.

The spreadsheet is broken down into four sections to understand the process better:

Section 1: Cells C2, C4 and C5 contain the diode parameters, n, R_s and I_s, to be determined. In a slight twist, the saturation current, I_s, will not be used in the optimization; rather, it will be its natural log, $\ln(I_s)$, placed in cell C3. Unfortunately, optimization routines in Excel can fail when the parameters have vastly different magnitudes. This problem is avoided by taking the natural log of I_s and generating a number of the same order of magnitude as n and R_s. These values must also be seeded for the optimization to work. Values of n = 1.0, $\ln(I_s)$ = -22 and R_s = 2.0 Ω are chosen as the seed values. These seed values work best when reasonably close to the expected result. Finally, cell C6 contains the

temperature at which the diode was measured. This temperature is then used to calculate β in cell C7 using Equation 3.

Section 2: Cells B11 to B22 contain the applied voltage, V_d, and cells C11 to C22 contain the measured current, I_d. These values are the measured data from Table 1.

Section 3: Cells E11 to E22 contain the calculated value of diode voltage, V_d, based on the measured current and the relevant parameters using Equation 4. This may seem counterintuitive since the measurement was most likely performed by applying a diode voltage and measuring the current. Now, the measured current is being used to develop a model for the diode voltage. However, as mentioned earlier, this approach works best given the nature of Equation 4, where the voltage across the diode can be determined by the current through it.

Equation 5 is entered into Excel cell E11 to set up the model. This can then be copied to cells E12 to E22:

=C11*$C$4+($C$2*(LN(C11+$C$5)-$C$3))/$C$7 (5)

Finally, in cells F11 to F22, the squared difference between the modeled voltage in Column E and the applied voltage in Column B is computed.

Section 4: Cell F2 contains the root-mean-square (RMS) error of the data contained in cells F11 to F22. This single number is used to drive the optimization engine.

With the measured and modeled data now set up in the spreadsheet, the next step involves the Excel Solver function. This function is located under the "Tools" menu but can be enabled using the "Excel Add-Ins" function if it does not appear. Installation instructions for this function are readily available in the Excel Help section and online. The goal is to have the Solver function vary the parameters in cells C2, C3 and C4 to bring the RMS error in cell F2 as close to zero as possible. ***Figure 2a*** shows the initial Solver function menu and ***Figure 2b*** shows the Solver function options, along with the initial values that are entered to start the optimization process:

In Figure 2a, the Objective cell, F2, is set to a value of zero rather than choosing "Min." This is done because the Solver function performs

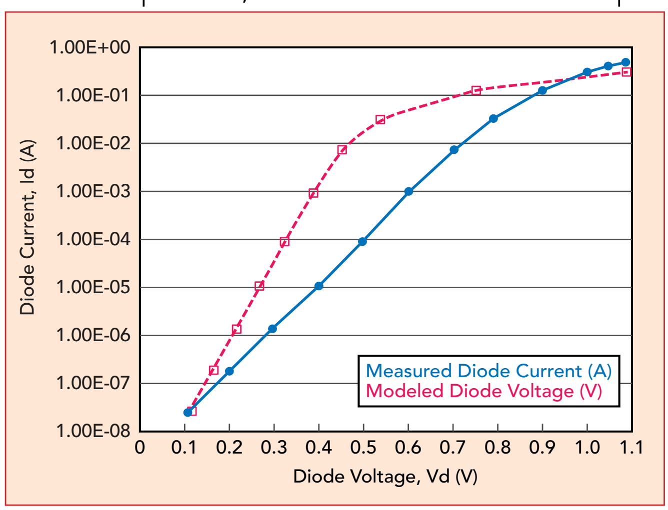


Fig. 4 Comparison of measured versus modeled DC I-V curve using the initial seed parameters.

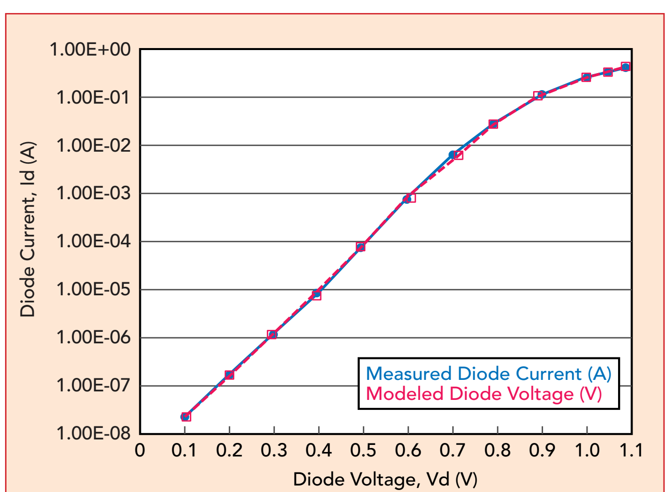


Fig. 5 Comparison of measured versus modeled DC I-V curve using the final optimized parameters.

better with a specific numerical goal. Next, uncheck the "Make Unconstrained Variables Non-Negative" box since ln(I_S) will be a negative number. If this box is left checked, the optimization will fail. The "Select a Solving Method" box is the optimization engine. Choose "GRG Nonlinear" and keep all the associated options at their default values of convergence = 0.0001 and population size = 100, as shown in Figure 2b.

Figure 3 shows the updated spreadsheet results after running the Solver function.

From the results, the Solver function has varied n, ln(I_S) and R_S from the seed values to generate an RMS error below 0.005. The final values for our parameters are: n = 1.85219, I_S = 2.62748e-09 and R_S = 0.40865 Ω.

Figure 4 shows the measured versus modeled results for the initial comparison using the seed values for the diode parameters. ***Figure 5*** shows the measured versus modeled comparison using the final optimized values. Both figures use a logarithmic scale on the y-axis for diode current to aid in visualization. We note that the Solver function has found a very acceptable solution in Figure 5, as the modeled result is a near-perfect match to the measured data, especially at the upper end of the voltage range.

FINAL THOUGHTS

After the diode parameters have been extracted, the results can be compared to published values or a DC model may be created for use in a circuit simulation tool. However, there is a note of caution regarding the modeling of Schottky GaN diodes constructed from field-effect transistors. These diodes often have an inflection point in their DC I-V curve at a voltage level near the turn-on point, defined as the point where the diode current is 1 mA. While the reasons for this phenomenon are beyond the scope of this article,[3] such behavior in GaN diodes invalidates the Shockley model in Equation 1, so it cannot be used to model the DC I-V characteristic.

To complete the diode model, the OFF capacitance must be considered. The approach to determining the parameters associated with this capacitance is similar to what the article has presented. However, there is an added difficulty since the OFF capacitance can take on one of two distinct patterns and most commercial circuit simulation tools can only handle one type of relationship in their diode models. This phenomenon and subsequent modeling of the OFF capacitance will be discussed in Part 2 of this tutorial.

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Custom Thermocouple-Based Power Sensing Solutions

LadyBug Technologies
Boise, Idaho

RF power sensors are essential for precisely measuring RF signal power. Their applications span various industries, including avionics test systems, semiconductor testing, telecommunications infrastructure, medical systems, satellite communications, radar and 5G technology. Systems typically measure power using various complex waveform adaptive modulation techniques, such as OFDM, CDMA and QAM. Often, systems incorporate an internal reference sensor to establish an absolute power level for verifying proper operation. An example of a LadyBug Technologies thermocouple RF power sensor is shown in ***Figure 1***.

Fig. 1 **Custom thermocouple RF power sensor.**

Understanding RF power levels at various points within a system ensures the safe and proper functionality of test systems. In addition to stringent performance requirements, size and weight constraints are essential in systems. LadyBug Technologies manufactures custom thermocouple-based RF sensors with better than 1 percent linearity and less than 0.2 percent readout movement per degree Celsius to enable high performance, lightweight system requirements. These sensors maintain precision performance over a wide -40°C to +80°C operating range.

TECHNOLOGY OVERVIEW

Modern RF sensor transducers are typically either diode-based or thermally-based. Diode-based sensors rectify an RF signal to produce a DC voltage, while thermally-based sensors convert RF energy to thermal energy for measurement by a secondary transducer. Thermal sensors are desirable due to their true RMS nature, allowing for high-accuracy power measurements independent of waveform characteristics. LadyBug has developed a process for producing custom thermal power sensors based on thermocouples. With this process, LadyBug can create custom products to meet industry needs at relatively low volumes.

Thermocouple-based sensors leverage the Seebeck effect, a well-characterized phenomenon where a voltage is generated at the junction of two different metals when there is a temperature difference between the junction and the ends of the metals. This effect occurs because the electrons in the metals diffuse from the hotter to the colder metal, creating a potential difference. In LadyBug sensors, the RF load has an integrated thermocouple that generates a volt-

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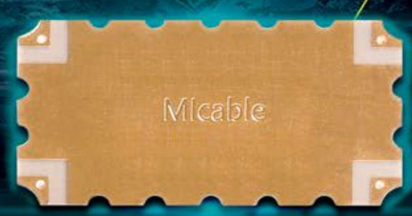

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*Above Theoretical 3dB and Amplitude Unbalance

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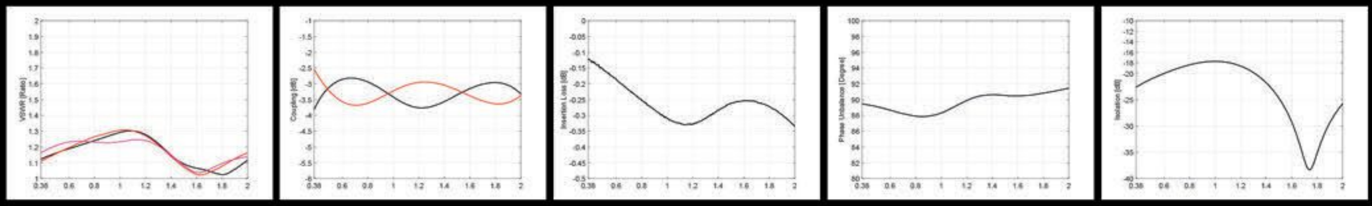

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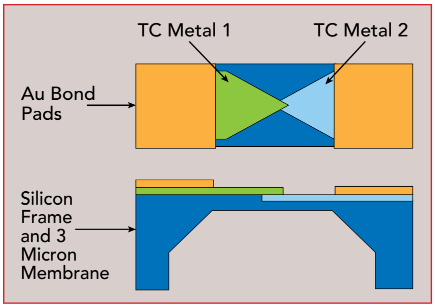


Fig. 2 **Integrated thermocouple diagram.**

age proportional to the RF power input. A diagram of the construction of this integrated thermocouple is shown in ***Figure 2***.

Due to the inherently small signals being measured, the thermal mass that is being heated must be minimal. As shown in Figure 2, a 3 micron silicon membrane device serves as the transducer substrate to minimize the thermal mass the RF energy must heat. A 50 Ω termination resistor is built on top of this substrate and serves two purposes. It is an RF termination with the matching characteristics necessary to meet the intended system requirements. It is also a thermocouple built from metals selected to meet the system output voltage requirements. The thermocouple device is manufactured using standard MEMS processes and then flip-chip bonded to a low loss substrate.

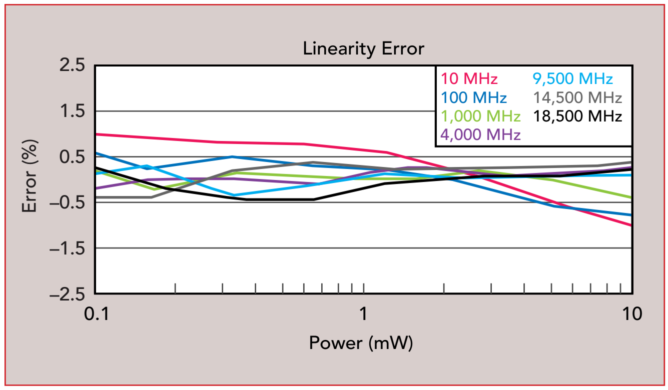


Fig. 3 **Linearity error versus power level at different frequencies.**

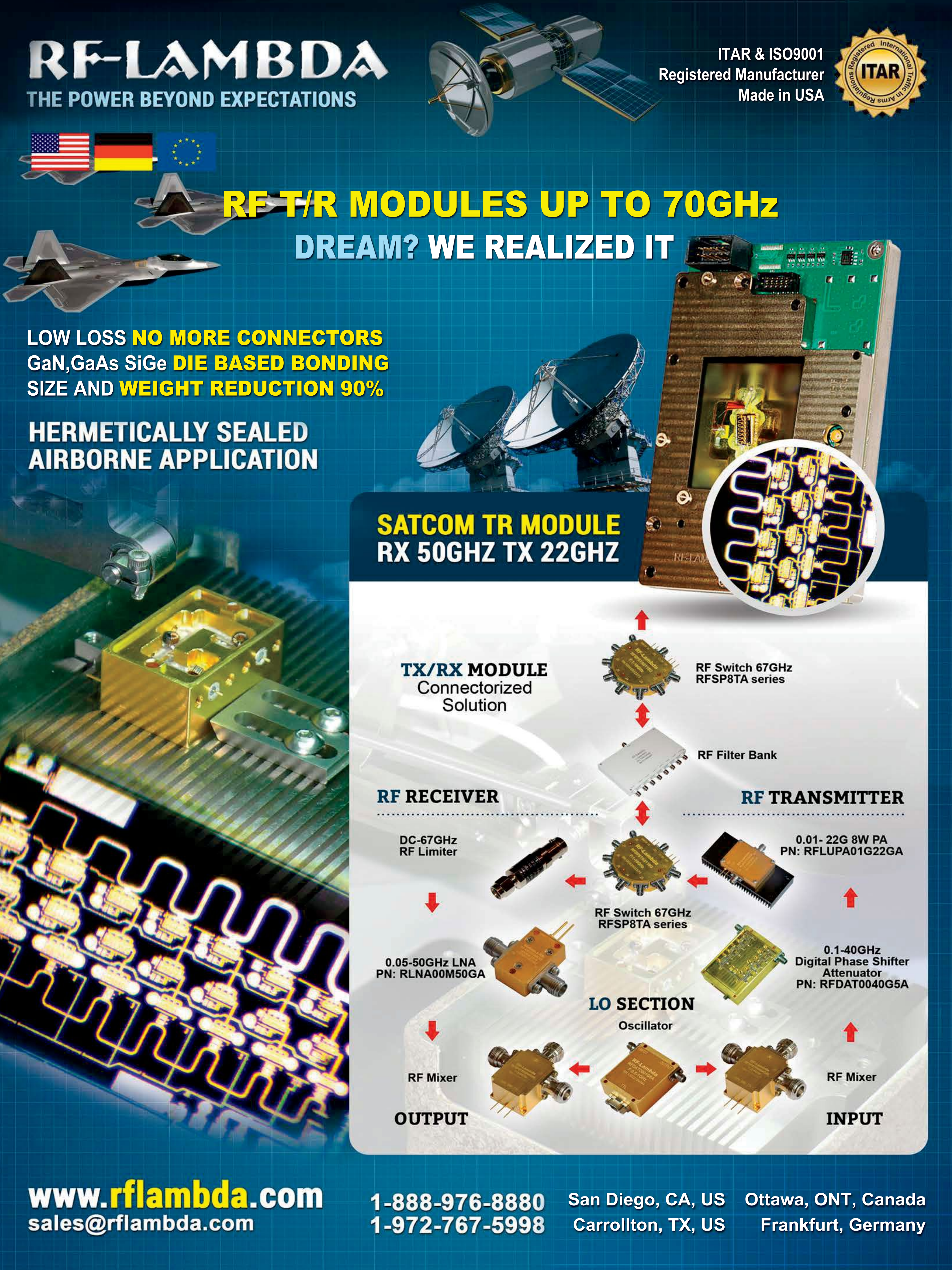
DESIGN CONSIDERATIONS

Key requirements for custom thermocouple-based RF power sensors include:

Sensitivity: The sensor's typical output of 0.25 mV/mW is well-suited for high-resolution measurement of any RF signal within its range.

Linearity: The sensor output should be proportional to the power input over a wide range. LadyBug sensors achieve exceptional 1 percent linearity due to our innovative thermocouple-based technology. An example of linearity error at three different power levels over a broad frequency range for a thermocouple-based RF power sensor is shown in ***Figure 3***.

Temperature Stability: The sensor maintains accuracy over a wide temperature range. Thermocouple sensors are inherently immune to ambient temperature changes as thermal gradients within the sen-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sor remain intact, resulting in exceptional temperature stability. The output voltage variation versus frequency for a typical thermocouple-based RF power sensor is shown in ***Figure 4***.

Maximum Power Rating: Thermocouple-based power sensors generate voltage proportional to RF power through thermal transduction. For every 3 dB power increase, the thermal gradient across the detector doubles in temperature. Consequently, the thermal gradient within the sensor can exceed hundreds of degrees Celsius. Careful balancing of dynamic range and sensitivity is crucial.

LadyBug thermocouple power sensors meet these requirements and provide optimal performance when integrated into embedded systems.

IMPLEMENTATION

The custom thermocouple-based RF power sensor uses a thermocouple to detect temperature changes, which are then converted into voltage changes. To prevent device temperatures from exceeding safe levels, which will occur with RF input levels of approximately 20 dBm, a protection diode is added to mitigate risk and enable the full dynamic range. This protection diode shunts high-power RF signals to ground to maintain device temperature and protect the silicon and metal films.

When bonding the device to the carrier PCB, a highly thermally conductive silver solder compound is used. Thermal energy dissipated within the thermocouple device is efficiently transferred. After mounting to the RF circuit, devices are encased in a waterproof package, maximizing durability. Following final assembly, each unit undergoes testing to ensure proper functionality and is accompanied by a full traceability report.

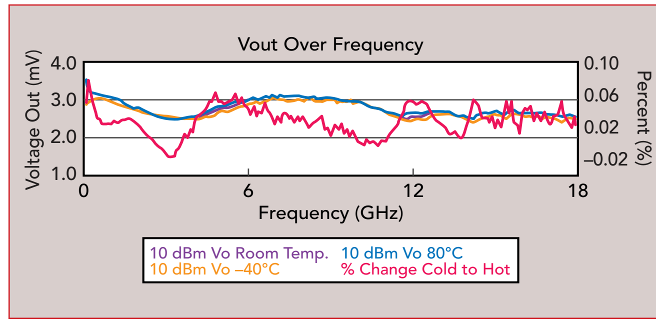


Fig. 4 **Output voltage versus frequency.**

LadyBug Technologies uses a unique development and assembly process to design and implement custom thermocouple-based RF power sensors to meet customer specifications. By utilizing cutting-edge industry standards for calibration, design and implementation, LadyBug provides customized solutions to address unique customer requirements in RF power sensing.

VENDORVIEW

LadyBug Technologies
Boise, Idaho
www.ladybug-tech.com

Ensuring Peak Performance with Phase-Stable Cables

Times Microwave Systems
Wallingford, Conn.

Phase is a key parameter in many RF and microwave systems. Accurate phase control is essential for coaxial cables and connectors in applications ranging from radar and missile defense to satellite communication and instrumentation. Engineers can design and implement systems that achieve superior performance and reliability by understanding phase and exploring advanced cable technologies.

COAXIAL CABLE CHARACTERISTICS

Electrical length is the physical length of a cable divided by its wavelength. It varies with frequency, signal delay and physical properties like dielectric material and dimensions. While the dielectric provides stable performance, environmental factors like temperature fluctuations and physical stress can significantly impact electrical characteristics. Temperature changes primarily affect the dielectric, altering the signal propagation speed. The cable's center conductor impacts its physical length, while the braided outer conductor has minimal influence.

Insertion loss is critical in applications requiring long-range communication or data transfer. Minimal signal loss allows the signal to travel farther before becoming unreliable.

RF coaxial cables often use PTFE dielectrics for wide operating temperatures (-50°C to 150°C) and low dielectric loss. However, PTFE exhibits a phase transition near room temperature, creating non-linear phase length variations and significant hysteresis with temperature fluctuations. These pose challenges for phase-sensitive systems in varied thermal environments. Most high-quality, high performance coaxial cables use materials with stable dielectric constants across a wide temperature range. As temperature changes, the metal conductors undergo thermal expansion/contraction. To address these issues, Times Microwave Systems has developed specialized cables using silicon dioxide and proprietary dielectrics (TF4® and TF5™) to minimize temperature-induced phase changes.

PHASE STABILITY

Phase-stable cable assemblies are crucial for increasingly sophisticated electronic systems. Phased array antennas, synthetic aperture radars and other aerospace and space applications are sensitive to phase variations. Cable assemblies form the backbone of these systems. Performance inconsistencies directly impact overall functionality and can compromise the system.

Electronically steered antennas shape the radiation pattern by manipulating phase relationships between radiating elements. Beam accuracy depends on maintaining precise phase relationships. Slight phase deviations change the pattern, hindering the antenna's ability to track or direct signals effectively.

Accurate phase control is also critical for time-sensitive applications like GPS and radar. These systems rely on precise timing and synchronization that depend on consistent phase relationships. Components, like phase-stable cable assemblies, must be carefully managed within these complex electronic systems.

The interconnecting coaxial cables should have identical electrical lengths. In addition, ensuring consistent phase matching requires battling temperature fluctuations. Even after calibration, cables are susceptible to thermal expansion and contraction at different rates. These changes can introduce phase mismatches, degrading overall system performance.

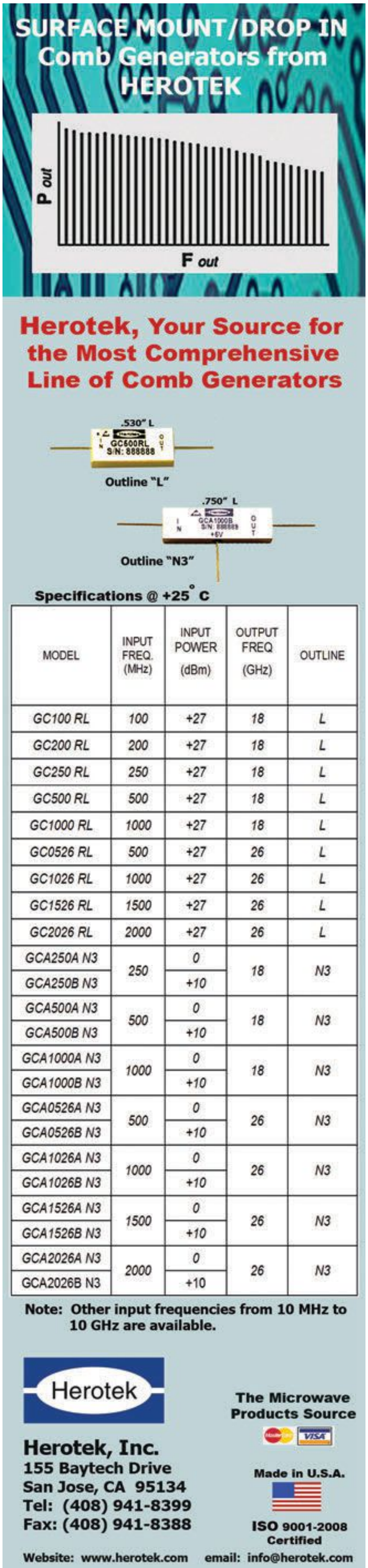
Mitigating temperature-induced phase mismatches requires careful cable design and phase tracking becomes crucial. Phase-matched cables minimize phase tracking variations over temperature and frequency. Variations are influenced by electrical length and operating temperature, further compounded by initial phase matching tolerances. Understanding these factors and utilizing advanced cable technologies to optimize system operation can mitigate phase instability concerns. Some members of the Times Microwave PhaseTrack® family are shown in ***Figure 1***.

PHASE-STABLE COAXIAL CABLES

Specific cable designs can prioritize phase stability. These cables often use materials with consistent electrical properties across temperatures. Factors affecting phase stability in coaxial cables include:

- **Cable Length:** Physical length influences electrical length and phase shift. Longer cables introduce a larger phase shift.
- **Bending:** Cable bends can introduce phase variations. Tight bends or kinks can disrupt signal propagation, leading to phase inconsistencies.
- **Temperature:** Dielectric core material can be temperature sensitive. The dielectric's electrical properties can change with these fluctuations, causing phase changes.
- **Dielectric Material:** Dielectric materials have different electrical properties. Some, like PTFE, exhibit a significant phase shift around room temperature, creating instability. Other materials, like TF4 or TF5 foam fluoropolymers, offer superior phase stability

Fig. 1 PhaseTrack® family.



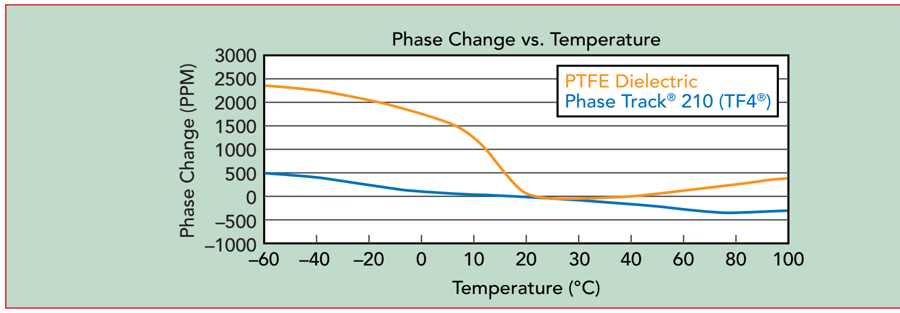


Fig. 2 Phase change versus temperature.

Fig. 3 PTLS cables.

with minimal variation across a wider temperature range.

- **Connectors:** Design and quality impact phase stability. Loose connections or poorly designed interfaces can introduce unwanted reflections and phase changes.
- **Frequency:** Higher frequencies are typically more sensitive to phase variations.

Phase stability over temperature necessitates accurate phase tracking. Higher frequencies improve resolution and accuracy and amplify the importance of minimal phase change and consistent phase tracking. Phase-stable cables extend calibration intervals and reduce performance drift. The demanding nature of some applications requires robust outer jackets for abrasion resistance and double shielding to minimize signal interference in harsh environments.

TIMES MICROWAVE SYSTEMS ASSEMBLIES

PhaseTrack cable assemblies excel at controlling phase. These cable assemblies provide minimal phase change over temperature. The proprietary TF4 and TF5 dielectrics improve phase stability over temperature by eliminating the drastic phase change between 15 and 25°C caused by PTFE dielectrics. This performance is shown in ***Figure 2***.

PhaseTrack cable assemblies have diameters from 0.047 to 0.318 in., covering a broad frequency range. PhaseTrack's 150°C operating temperature range exceeds polyethylene (85°C), making them ideal for demanding environments. Compatibility with standard SMA, TNC, N-type, 2.92 mm and 2.4 mm connector designs enhances versatility and compatibility with a wide range of equipment. PhaseTrack caters to diverse needs with standard FEP, space-grade ETFE, low smoke zero halogen and a semi-rigid version with either copper or tin-lead plated copper tubing jacket material options. The PhaseTrack family performance is shown in ***Table 1***. PhaseTrack low smoke cables are shown in ***Figure 3***.

CONCLUSION

As technology advances and system requirements become increasingly stringent, the demand for phase-stable components grows. From radar and missile defense to satellite communication and instrumentation, maintaining accurate phase relationships in systems is essential. By mastering the complexities of phase management, engineers can mitigate phase instability and enhance overall system reliability by carefully selecting cable materials and minimizing environmental influences. With advanced technologies like Times Microwave's PhaseTrack® assemblies, systems that push the boundaries of performance and innovation become possible.

Times Microwave Systems
Wallingford, Conn.
timesmicrowave.com

TABLE 1 PHASETRACK FAMILY PERFORMANCE

Specifications	Standard	Space	Low Smoke	Semi-Rigid
Diameters (in.)	0.066 min. / 0.315 max.	0.066 min. / 0.332 max.	0.200 min. / 0.600 max.	0.047 min. / 0.141 max.
Max. Frequency (GHz)	Up to 40 GHz	Up to 40 GHz	Up to 30 GHz	Up to 40 GHz
Operating Temperature (°C)	-65 min. / +150 max.	-150 min. / +150 max.	-40 min. / +85 max.	-150 min. / +125 max.
Dielectric Material	TF4®	TF4®	TF5™	TF4®
Jacket Material	FEP	ETFE	Low Toxicity Polyolefin	Bare Copper
Application	**Standard**	**Space**	**Low Smoke**	**Semi-Rigid**
Airframe	•	•	•	•
Satellite		•		•
Radar	•	•	•	•
Ground Communication		•	•	•
Shipboard and Naval			•	•
Test and Measurement	•			
Operating Environment	**Standard**	**Space**	**Low Smoke**	**Semi-Rigid**
Dynamic (Vibration, Shock Flexure)			•	•
Wide Temperature Range	•	•	•	•
High Power Transfer Efficiency			•	
High-Density (Space Constrained)	•	•	•	•

QML Class P: A New Standard for Radiation-Hardened Electronics in Plastic Packaging

Texas Instruments
Dallas, Texas

Texas Instruments (TI) worked with NASA and other industry experts to lead the development of Qualified Manufacturers List (QML) Class P, a new plastic packaging standard for space electronics. Electronics in space must meet government standards set forth in the QML, ranging from radiation-tolerant or radiation-hardened devices in either ceramic or plastic packaging. The QML assures that parts will operate as intended in harsh space environments.

TI'S SPACE PORTFOLIO

QML Class P is a packaging standard that TI recently added to its portfolio of space products. It defines the qualification flow used for radiation-hardened semiconductors in plastic packages. TI spearheaded the initiative, along with NASA and other industry experts, to create the QML Class P standard. ***Table 1*** shows the different ratings TI offers for mission quality requirements, ranging from new space to deep space, in low Earth orbit, medium Earth orbit and geostationary orbit applications.

THE NEED FOR QML CLASS P

The use of plastic packages is not new in space applications. However, the lack of a QML standard in the industry meant that there was no standard assurance that radiation-hardened products in plastic packages would operate as intended in the harsh environments of space. That situation has changed with the development of the QML Class P standard and products.

Table 1 illustrates how QML Class P products follow a similar qualification flow to QML Class V products. The 100 percent production burn-in and the standard microcircuit drawing make QML Class P products almost compatible with QML Class V products, with the added benefits that plastic packages offer. The usage of gold bond wires and outgassing tests, according to the American Standard of Testing and Materials E595, address concerns specifically related to plastic packages.

BENEFITS OF QML CLASS P

QML Class P offers multiple benefits to engineers working on space applications. The most obvious benefit is the reduction in package size. Plastic packages for QML Class P products are as much as 50 percent smaller while still having increased power density, translating to an area reduction at the power converter level.

For example, TI's TPS7H4001-SP is an 18 A buck converter offered in both QML Class V and QML Class P packages. One of this buck converter's functions is to power up high performance field-programmable gate arrays (FPGAs) in space applications. For both the QML Class V and QML Class P packages shown in ***Figure 1*** and ***Figure 2***, respectively, the design of the board using the TPS7H4001-SP has an input voltage of 5 V and an output voltage of 1 V with 18 A of current, at a switching frequency of 500 kHz. The actual converter area, shown inside the red lines of Figure 1 and Figure 2 for the QML Class V version, is 11 cm^2, while the converter area for the QML Class P version is 8.7 cm^2. Using QML Class P enables tighter placement of the passive components around the package. QML Class P also offers pin-to-pin compatibility between radiation-tolerant and radiation-hardened products, removing the need for

TABLE 1 TI SPACE PORTFOLIO DEVICE CLASSIFICATIONS						
	Rating	*Space*				
	Classification	*Space EP*	*SHP*	*QML-P*	*QML-Y*	*QML-V*
Production Testing and Documentation Provided	Vendor Item Drawing (VID)	✓	✓	✗	✗	✗
	Standard Microcircuit Drawing (SMD)	✗	✗	✓	✓	✓
	Process Conformance Report	✓	✓	✓	✓	✓
	Process Conformance Report Content	See Product Page		MIL-PRF-38535 Group A, B, C, D, E		
Manufacturing	Single Controlled Baseline	✓	✓	✓	✓	✓
	Multiple Wafer Lots Per Reel Possible	✗	✗	✗	✗	✗
	Life Test Per Wafer Lot	✗	✓	✓	✓	✓
Packaging	Package Construction	Plastic	Plastic	Plastic - Wirebond or Flip Chip With Overmold	Plastic - Flip Chip Without Overmold	Hermetic
	Bond Wires	Au	Au	Au	N/A	Al
	Pure Tin (Sn) Lead Finish Possible?	✗	✗	✗	✗	✗
	> 97% Tin (Sn) Inside Package Possible*	✓ For Flip Chip				✗
	Production Burn-In Required	✗	✓	✓	✓	✓
	Outgassing Tested Per ASTM E595	✓	✓	✓	✓	N/A
Radiation	TID Characterization Range (krad/Si)	30 to 50	50 to 300			
	TID Radiation Lot Acceptance Testing (RLAT) Range = RHA (krad/Si)	20, 30 or 50	50, 100 or 300			
	SEL Immunity (MeV*cm^2/mg)	≥ 43	≥ 60			
Typical Temperature Range		-55°C - 125°C				

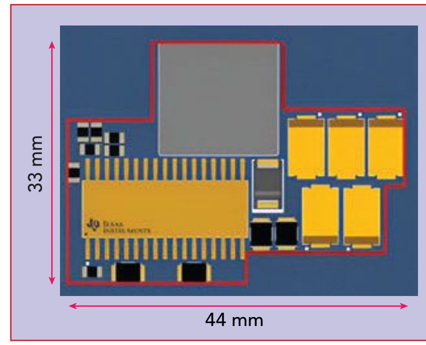
Table illustrates typical values for each Classification rating. For precise data or detailed information, please refer to the product-specific page.

* Bi unless Optimization aligned with DLA

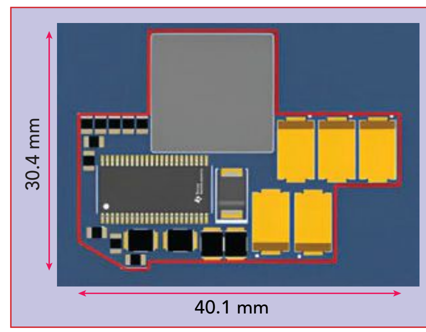
TID = Total Ionizing Dose
VID = Vendor Item Drawing
SEL = Single-Event Latch-up
RHA = Radiation Hardness Assured
QML = Qualified Manufacturers List
SMD = Standard Microcircuit Drawing

hardware changes when moving from one type of application to another.

Finally, because of the plastic materials and construction, QML Class P packages offer lower parasitic resistance, inductance and capacitance. The performance in these areas translates to improved electrical performance compared to ceramic QML Class V packages. The bond wires in plastic packages are smaller and shorter, resulting in lower resistance and inductance.



▲ Fig. 1 Board layout using the TPS7H4001-SP buck converter in the QML Class V package.



▲ Fig. 2 Board layout using the TPS7H4001-SP buck converter in the QML Class P package.

QML CLASS P PORTFOLIO

QML Class P expands TI's current portfolio of radiation-tolerant and radiation-hardened products in plastic and ceramic packages. TI has released these QML Class P products for use across spacecraft electrical power systems:

- TPS7H5001-SP is a pulse width modulator controller supporting advanced power topologies using silicon and GaN field-effect transistors
- TPS7H4001-SP is a 7 V, 18 A buck converter used to power up high performance FPGAs
- TPS7H1111-SP is a low dropout (LDO) linear regulator with low output noise and a high power supply rejection ratio
- TPS7H3302-SP is a 3 A sink-and-source double data rate termination LDO regulator
- TPS7H2201-SP is a 7 V, 6 A eFuse
- TPS7H2211-SP is a 14 V, 3.5 A eFuse.

Use cases range from high voltage applications in spacecraft solar panels to point-of-load payload applications.

CONCLUSION

The realization of the QML Class P plastic packaging standard is a step forward in solving some of the challenges engineers face in space applications. Leveraging the significant advances in semiconductor technology and applying them to space applications enables faster development to accelerate space exploration.

For more information, see ti.com/space.

Texas Instruments
Dallas, Texas
www.ti.com

240 GHz Silicon Transceiver for Automotive Radar Systems

indie Semiconductor
Aliso Viejo, Calif.

Driver and occupant monitoring will be a significant growth market for semiconductor manufacturers in the next five years. S&P Global Mobility forecasts that in-cabin monitoring leveraging cameras and radars will represent an opportunity of $908 million in 2029, up from $93 million in 2022[1], representing a 38 percent compound annual growth rate during this period. To support this growth, radar sensors are being deployed across a rapidly expanding range of automotive applications, tapping into new and emerging opportunities for automakers.

In the automotive market, radar is widely deployed in mid- and long-range sensing solutions for advanced driver assistance systems and automated safety features. These include automated emergency braking, adaptive cruise control and blind spot detection, leveraging frequencies between 76 to 81 GHz. As radar solution providers look to deploy frequencies in the terahertz spectrum, this will unlock higher resolution and greater precision in-cabin sensing to complement camera-based solutions for challenging driver and occupant monitoring systems (DMS/OMS) applications such as vital signs detection (VSD).

indie Semiconductor is a "pure-play" automotive system-on-chip (SoC) specialist. We offer the world's first commercial fully integrated 240 GHz radar front-end (RFE) SoC transceiver. Operating at 240 GHz, which is

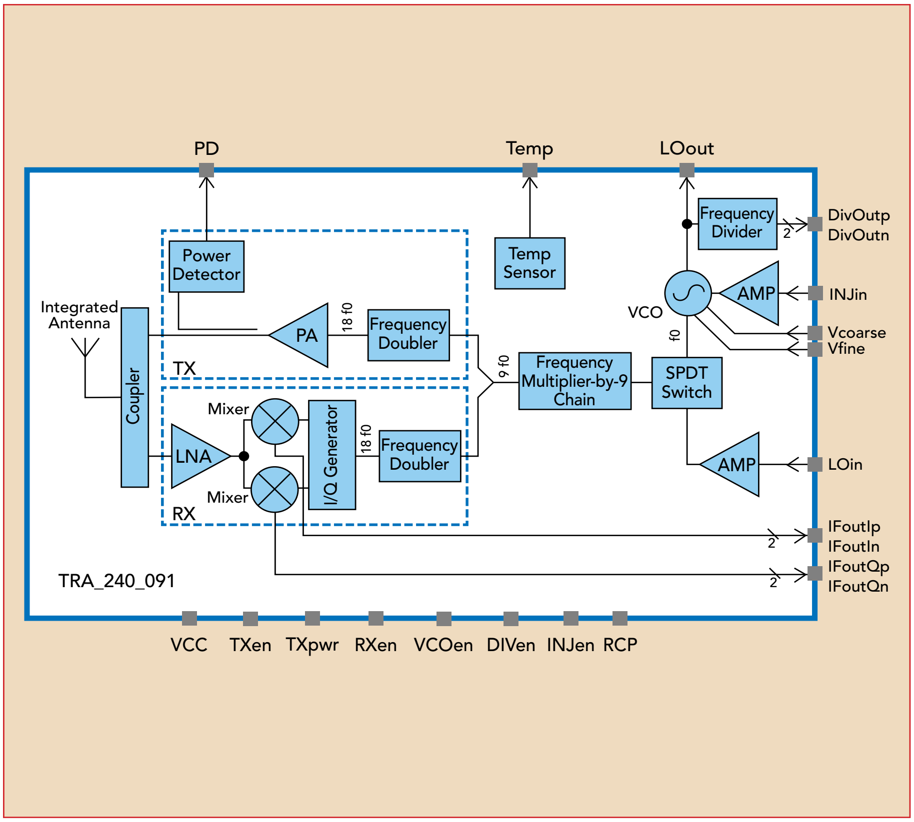


Fig. 1 TRA_240_091 functional block diagram.

significantly higher than traditional automotive radar systems, the TRA_240_091 offers automakers a radar solution with high resolution, enhanced detection and robust performance.

PRODUCT DESIGN

The cascadable RFE of the TRA_240_091 combines a 240 GHz operating frequency with a bandwidth of up to 45 GHz, assembled in a low-cost QFN package. Developed for applications within the license-free 244 to 246 GHz ISM band and beyond, the SoC can operate as a single-channel transceiver with an on-chip or off-chip voltage-controlled oscillator (VCO) or in an array with many devices synchronized. The maximum range can reach several meters, depending on the aperture of the lens placed on top of the chip.

The silicon-based solution includes a VCO, divide-by-8 frequency divider, SPDT switch, frequency multiplier-by-9 chain, frequency doublers, mixers, low noise amplifier, power amplifier, antenna/coupler and integrated antenna, as shown in ***Figure 1***. Theoretically, operation at 240 GHz equates to a measurement accuracy of 1.25 mm in free space; the 45 GHz of supported bandwidth gives a radar range resolution down to 6 mm in air and improves for materials with a refractive index higher than one. This is because the range resolution is inversely proportional to the material's refractive index.

EVOLVING AUTOMOTIVE RADAR APPLICATIONS

Leveraging higher frequencies (120 to 140 GHz), radar technology is quickly finding new use cases and opportunities for automotive applications, including DMS/OMS applications such as VSD. VSD offers a non-invasive and continuous method to monitor an occupant's physiological parameters, such as heart or respiration rates. With radar-based in-cabin sensing, the vehicle can monitor characteristics of driver alertness, like drowsiness or a dramatic increase in heart rate. It can also monitor passenger presence, such as a sleeping infant in the rear seat or distracted/drowsy driving and initiate critical safety responses and alerts that can reduce the chance of injury to occupants or accidents to other road users. The TRA_240_091 is also designed to support driver convenience features such as gesture control, providing carmakers with implementation, privacy and application capability options relative to camera-based solutions.

As an integrated transceiver circuit with an on-chip antenna, the TRA_240_091 eliminates the need for external antennas. This significantly simplifies application development, streamlines printed circuit board design and minimizes form factor size and cost. This is particularly important in applications where external antennas impose design limitations that are unacceptable to automotive manufacturers and consumers who want sleek vehicle interiors.

The superior precision of 240 GHz radar also supports new and rapidly emerging vehicle dynamics and monitoring applications. Initial use cases are expected to include assessing and controlling air spring-based suspension settings for trucks and other heavy vehicles, providing a lower-cost, higher-accuracy alternative to mechanical systems. Radar systems at 240 GHz can also support fine-grade monitoring of gas tank levels and real-time road surface quality and hazard assessments, leading to dynamically adapted ride quality.

INDUSTRIAL-SENSING APPLICATIONS

While automotive applications present a huge opportunity, indie's 240 GHz solution can also readily address adjacent industrial terahertz frequency applications, which Mordor Intelligence estimates will be a $1.8 billion opportunity by 2028.[2] The TRA_240_091 architecture means that it is also well suited to a wide array of industrial-sensing use cases, including thickness measurement of non-conductive material, non-destructive material analysis, imaging, in-line inspection and level metering. The exceptionally high resolution and bandwidth benefits of 240 GHz radar also support end-of-line product quality applications, tank-level monitoring, surface inspections and security scanners.

The analog RFE chip can be used as a standalone front-end in applications such as vibration measurement, which integrates easily with AI-based processing. This approach helps identify unexpected patterns and predict maintenance issues before they happen. This device also provides the flexibility to scale up to massive MIMO arrays for imaging and scanning applications, all using the same component.

CONCLUSION

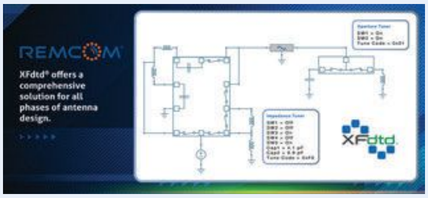
Radar technology for existing and emerging automotive- and industrial-sensing use cases brings unique versatility and robustness to the market. Through detection performance, high-resolution capabilities and the ability to operate in low-visibility weather conditions, radar enables enhanced safety features, vehicle efficiency and cost and miniaturization, creating affordable solutions for automakers.

The TRA_240_091 seamlessly integrates into indie Semiconductor's multi-modal portfolio, which includes LiDAR, ultrasonic sensors and camera systems. This multi-modal approach ensures that vehicles equipped with indie sensors have robust sensing capabilities, providing a more holistic view of the environment and enhancing overall safety and performance. indie Semiconductor has set a new standard for the industry to achieve greater heights in automotive and industrial safety and automation.

References

1. "Automotive Semiconductor Market Tracker – March 2024," S&P Global Mobility, April 1, 2024, Web: autotechinsight.ihsmarkit.com/shop/product/5003493/automotive-semiconductor-market-tracker-march-2024.
2. "Terahertz Technology Market Size & Share Analysis - Growth Trends & Forecasts (2024-2029)," Mordor Intelligence, Web: mordorintelligence.com/industry-reports/terahertz-technologies-market.

indie Semiconductor
Aliso Viejo, Calif.
www.indiesemi.com/



EM Simulation Software Includes Schematic Optimization

Remcom announces the latest release of XFdtd® 3D Electromagnetic Simulation Software, which contains schematic optimization to expedite determining an optimal matching network design solution. The release also adds tune codes supporting impedance and aperture tuner applications. These enhancements expand XFdtd's toolset for analyzing matching and corporate feed networks, providing a robust solution for all phases of an antenna design workflow.

XFdtd's schematic editor optimization capability calculates and reveals the ideal component property values and operating modes that fulfill user-defined matching network design goals, including antenna system efficiency. The variables in a goal definition may be configured in innumerable combinations to arrive at peak performance; optimization eliminates a potentially overwhelming task for very complex systems containing multiple switches and capacitors by providing a software-generated solution.

The release includes subcircuit analysis in the schematic editor and the ability to retrieve tune codes based on desired switch states. As switch states are manipulated, XFdtd updates the corresponding tune code. Alternatively, a known tune code may be entered and the software will adjust the switch states for that tune code. This autofill functionality eliminates transcribing data from external tables, removing a point of error when correlating a particular state to a given value.

For 30 years, Remcom has provided electromagnetic simulation and wireless propagation software for commercial users and U.S. government sponsors. Innovative software tools, combined with exceptional support, have enabled the world's most advanced engineering teams to deliver their devices to market by simplifying EM analysis for a wide variety of applications. Remcom is committed to its customers' unique needs, offering flexible licensing options for installations of all sizes and custom-engineered solutions.

VENDORVIEW

Remcom Inc.
State College, Pa.
www.remcom.com

1000 W GaN HEMT Amplifier for S-Band Radar

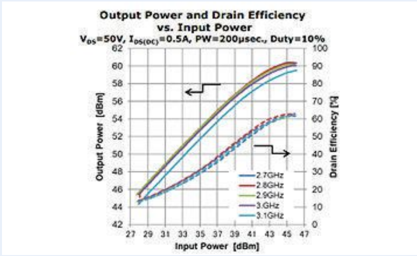


Fig. 1 **1000 W S-Band GaN HEMT performance.**

In recent years, semiconductor devices for air traffic control and meteorological applications have gone to higher transmit powers, and solid-state radars have been replacing conventional magnetron radars. Long service life is one of the advantages of solid-state devices. While magnetrons need to be replaced periodically, semiconductors do not require replacement and thus help reduce radar maintenance costs. Large frequency fluctuations make it difficult to see small objects with magnetron radars. In contrast, due to their high frequency stability, solid-state radars improve observation performance by detecting objects that were difficult to spot in the past.

In a solid-state amplifier-based radar, achieving a detection range equivalent to that of the magnetron-based radar requires several semiconductor devices. To minimize the number of solid-state devices needed to meet the requirements, the output power of each device must be increased. Sumitomo Electric Device Innovations (SEDI) has developed a family of GaN HEMTs for radar applications that operate in frequency ranges from L- to X-Band. SEDI's new S-Band GaN HEMT, the ES/SGN2731-800L-R, offers 1000 W (typical) output power, the highest in the industry. It has 60 percent (typical) efficiency with input and output prematched over the 2.7 to 3.1 GHz frequency band. The device is housed in SEDI's M2C small flangeless package. ***Figure 1*** shows the output power and drain efficiency for the 1000 W, S-Band ES/SGN2731-800L-R GaN HEMT. These characteristics were obtained by running the device at a drain voltage of 50 V with a 200 μsec pulse width and a 2 msec pulse period.

Sumitomo Electric Device Innovations USA Inc.
San Jose, Calif.
(408) 232-9500
www.sei-device.com
efavreau@sei-device.com

Ansys SimAI Overview: Train, Predict and Explore at the Speed of AI

Principal R&D Engineer of SimAI Camille Feghali showcases the seamless experience of using SimAI for engineers, designers and developers alike.

Ansys

www.youtube.com/watch?v=_giqjklqNHM

Showcasing Decades of Beamforming Experience

Decades of pioneering expertise in beamforming technology have resulted in delivering cutting-edge solutions for precise, high performance broadband communications across diverse industries and challenging environments.

ET Industries

https://etiworld.com

Understanding UDP Amplification DDoS Attacks

In today's interconnected world, the Distributed Denial-of-Service (DDoS) attack has become a persistent threat in the network security domain. Among various types of DDoS attacks, one popular attack is User Datagram Protocol (UDP) amplification attack which exploits the UDP for overwhelming target networks with a large volume of traffic.

Keysight Technologies

https://bit.ly/472RCXH

GaN Solid-State Microwave Generator

Check out this video highlighting the RIM251K6-20G, a 1600 W GaN on silicon carbide solid-state microwave generator operable from 2400 to 2500 MHz.

RFHIC

go.rfhic.com/l/1023161/2024-07-12/hbyxn

Intro to RF Power Measurements

Power is a vital parameter to measure across a wide range of modern commercial and defense applications. In this article, Mini-Circuits reviews the fundamentals of RF power measurement from the various measurement types for different waveforms.

Mini-Circuits

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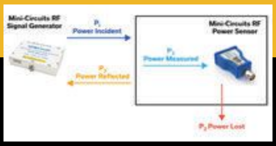

Beamformer ICs: Transforming Commercial and Defense Applications

Beamformer technology, particularly beamformer ICs, has seen remarkable advancements in recent years, driven by the demands of both commercial and defense applications.

RFMW

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DEVICES/ COMPONENTS/MODULES

Cavity Bandpass Filter

3H's CC35000-X2500-8KK is a high performance 35 GHz cavity bandpass filter offering a low insertion loss of 1.5 dB in a 2500 MHz passband. 3H's cavity filter offerings provide the lowest loss and highest Q in both military and commercial applications such as radar, weather monitoring, airborne navigation and military surveillance.
3H Communications Systems
www.3hcommunicationsystems.com

Wireline Couplers

Experience the future of RF technology with ETI's reimagined high-power 20 dB wireline coupler, operating within the 130 to 160 MHz range. Electromagnetic Technologies Industries is a U.S. manufacturer of 10 MHz to 67 GHz directional couplers, power dividers, 180-degree hybrid couplers, 90-degree hybrid couplers, phased array antennas and multi-beam antennas. All products are manufactured in their factory in New Jersey using locally sourced parts.
Electromagnetic Technologies Industries
www.etiworld.com

2-Way Wilkinson Power Divider

HYPERLABS has released the HL9677 2-way Wilkinson power divider, demonstrating industry-leading performance. The broadband HL9677 offers outstanding amplitude and in-phase power division/combining from 1 GHz to beyond 67 GHz. The design incorporates concatenated quarter-wavelength transformers that provide low loss outputs that are ideally attenuated to 3 dB, when all ports are impedance-matched to 50 Ω. Providing better than 15 dB of isolation between output ports, the HL9677 is an excellent choice for power combining applications.
HYPERLABS
www.hyperlabs.com

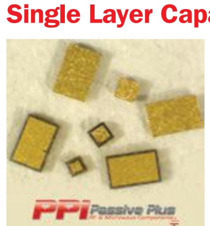
Directional Couplers

KRYTAR, Inc. announces two new directional couplers operating in the wideband frequency range of 0.4 to 18.5 GHz (L- through K-Bands) offering nominal coupling of 10 dB and 16 dB. These new couplers offer the ultimate solution for emerging designs and test and measurement applications, including wireless communications, radar and satellite communications. Both directional couplers offer input power rating of 20 W average and 3 kW peak. The directional couplers come with industry-standard N-type female connectors and optional SMA female connectors.
KRYTAR
www.krytar.com

0.6-6 GHz 50 W Surface-Mount 90-Degree Hybrid

MIcable just released the new 0.6 to 6 GHz high power surface-mount 90-degree hybrid. It has low insertion loss (1.2 dB maximum), excellent VSWR (1.40:1 maximum), extremely good amplitude unbalance (±0.8 dB maximum) and phase unbalance (±5 degrees maximum), high isolation (16 dB minimum) and 50 W power handling capability with excellent stability and heat dissipation ability in a small package. It is suitable for power amplifier, power combining network, antenna feed network, modulator and phase shifter applications.
MIcable
www.micable.cn

Single Layer Capacitor Line



Passive Plus offers a comprehensive range of single layer capacitors (SLC), designed to meet the diverse needs of the engineering community. PPI single layer capacitors come in four distinct varieties (standard edge-to-edge, border caps, twin caps and arrays), each customized to specific applications, offering precision, reliability and customization options. PPI SLCs deliver tight tolerances, precision and reliability according to the engineer's specifications, including capacitance, dissipation factor, insulation resistance, metallization, voltage, temperature coefficient and physical dimensions.
Passive Plus
www.passiveplus.com

Single Pole Two Throw Switch

Quantic PMI Model P2T-12G18G-45-R-SFF-10W is an independently controlled, high-power, reflective single pole two throw switch designed to operate between 12 to 18 GHz and handle input power levels up to 10 W CW and 30 W peak with a maximum pulse width of 1 μs and maximum PRF of 2 MHz. This switch offers low loss of 1.5 dB maximum and provides port-to-port isolation of 45 dB minimum. The rise/fall times are < 20 ns with delay on/off times of < 50 ns.
Quantic PMI
www.quanticpmi.com

Automotive-Grade Ultra-Wideband RF Switch

Now available from RFMW, PE423211 is designed for use in high performance ISM, WLAN 802.11 a/b/g/n/ac/ax, Bluetooth® Low Energy and ultra-wideband applications up to 10.6 GHz. The PE423211 features fast switching speed, high-power handling and robust ESD and temperature performance, all in a compact 6-lead 1.6 × 1.6 mm DFN package. Additionally, the PE423211's low power consumption of just 90 nA makes it ideal for use in battery-powered and power-sensitive devices.
RFMW
www.rfmw.com

1.0 mmW Phase Adjuster

WAKA Manufacturing has introduced a new coaxial adapter featuring an 11-picosecond phase adjuster with 1.0 mmW connectors. This phase adjuster ensures precise skew adjustment during final tuning. It supports frequencies up to 110 GHz and offers a compact form factor, ideal for use in narrow spaces. It provides an adjustable effective range of 3.4 mm (11 picoseconds), suitable for final skew adjustments in differential signal applications and other skew tuning needs.
WAKA Manufacturing
www.waka-manufacturing.com

New**Products**

CABLES & CONNECTORS

Connectors

A connector is a crucial component for transmitting RF signals and therefore enabling reliable connectivity. Smiths Interconnect's innovative new product, the 'Mini-Lock Connector,' enables extremely high frequency operation at a signal of up to 110 GHz – one of the highest frequency components on the market currently. This leads to more reliability, faster speed and lower downtime. The new technology has been developed to integrate into crucial applications such as satellites, space flight, radars, unmanned vehicles, military and other applications that require reliable communications with low-to-no downtime. This is important because advances made in these areas will ultimately translate into ever faster and more reliable global connectivity for society.

Smiths Interconnect
www.smithsinterconnect.com

Solderless Coaxial Sockets

VENDOR**VIEW**

Würth Elektronik expands its SMA connector family for high frequency applications to include WR-SMA PCB Solderless. The solderless approach allows quick and easy assembly without damage to the PCB. Besides simplifying the installation process, which requires no soldering equipment, the solderless SMA connectors can be reused multiple times, making them suitable for prototyping or temporary use. Because no solder is required on the signal pin, reproducible connection quality is achieved, and impedance variation due to the amount of solder paste is avoided.

Würth Elektronik
www.we-online.com

AMPLIFIERS

Medium Power Module SSPA

VENDOR**VIEW**

Exodus model MPA1115 operates from 10 to 6000 MHz, delivering over 2 W output power with 33 dB minimum gain. It features excellent gain flatness, low harmonics, spurious and noise figure. Powered by 28 VDC and consuming under 1 amp, it has SMA female connectors and is available in MIL-SPEC and sealed versions.

Exodus Advanced Communications
www.exoduscomm.com

Waveguide Amplifier

VENDOR**VIEW**

Mini-Circuits' model WVA-40603GX+ is a medium-power WR19 waveguide amplifier with +23 dBm output power at 1 dB

compression and +24 dBm saturated output power from 40 to 60 GHz. It provides 34 dB typical gain with ±1.5 dB gain flatness across the frequency range and operates from a single voltage supply of +10 to +15 VDC. Ideal for satcom and mmWave test applications, the amplifier features over-voltage and reverse-voltage protection and exhibits 13 dB typical input and output return loss.

Mini-Circuits
www.minicircuits.com

ANTENNAS

High-Gain Antenna

VENDOR**VIEW**

Designed for operation indoors or within a radome structure, model SAY-3433634310-28-S1-MP is a Cassegrain antenna with a monopulse feed network that spans 34 to 36 GHz. The linearly polarized antenna has WR-28 waveguide feeds that carry sum, elevation and azimuth signals. Nominal gain is 43 dBi for the sum port.

Eravant
www.eravant.com

Wi-Fi 6e/7 Omni and Flat-Panel Antennas

VENDOR**VIEW**

Fairview Microwave announced the launch of its Wi-Fi 6e/7 omni and flat-panel antennas. These MIMO multi-port antennas operate across the 2400-to-7000 MHz unlicensed bands, covering the latest Wi-Fi 6e and Wi-Fi 7 frequencies and delivering exceptional performance for high bandwidth, low latency, multi-user gigabit networking. These antennas are available in four-port, six-port and eight-port configurations, offering 4×4, 6×6 and 8×8 MIMO capabilities, respectively. Each configuration ensures optimal connectivity and network efficiency, making them ideal for a wide range of applications.

Fairview Microwave
www.fairviewmicrowave.com

Pre-Built Gain Horn Assemblies

VENDOR**VIEW**

Pasternack has announced the launch of its new in-house pre-built gain horn assemblies featuring coax adapters and antenna mounts. These assemblies provide enhanced usability and ease of mounting for a variety of applications. The new assemblies utilize Pasternack's high performance gain horns and gain horns with coax adapters, integrated with a robust cage-style mount. They have low signal interference and are available in WR-34, WR-51, WR-75 and WR-430 sizes and with dB values of 10, 15 and 20.

Pasternack
www.pasternack.com

TEST & MEASUREMENT

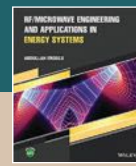
Vector Network Analyzer

The new SIGLENT SNA6000A Series vector network analyzer (VNA) simplifies complex microwave and RF measurements. The SNA6000A starts with a standard 4-port analyzer with two internal sources. The second internal source is especially useful for mixer and converter measurements. Combine that with up to 135 dB of dynamic range for precision measurements. Jumpers make it possible to extend the frequency even further. SNA6000A includes VNA, TDR, pulse, mixer and spectrum analysis up to 26.5 GHz.

SIGLENT
www.siglentna.com

MICRO-ADS

Reviewed by: Ajay Poddar



Microwave Engineering and Applications in Energy Systems

Abdullah Eroglu

Abdullah Eroglu's *Microwave Engineering and Applications in Energy Systems* comprehensively addresses RF and microwave communication technologies and the components that make up these systems. This book sheds light on the fundamentals of RF and microwave theory and design, along with emerging technologies expanding RF and microwave engineering technology for applications in energy systems focused on wireless power transfer, energy harvesting and HVAC systems. It consists of 13 chapters that provide fundamental theory, real-world engineering applications and examples, including design, simulation and prototype development.

These chapters address electromagnetic (EM) fundamentals, Maxwell's equations, the Smith chart, scattering parameters and impedance-matching techniques. After discussing the fundamentals, chapters go into passive and active circuits, looking at RF filters, waveguides, antenna and power amplifier designs. The final chapters of the book look at emerging RF and microwave engineering technologies and their applications in energy systems focused on energy harvesting, HVAC systems and future directions. The language in the book is easy to understand with designs explained in detail, enabling readers to have a better understanding of the theory through real-world engineering application examples.

Practical experimentation is validated by theory, simulation and measurements. The content and approach of the subject are dealt with very well. With a prerequisite calculus background and knowledge of Maxwell's equations, this book will be helpful for students and practical engineers who want to enhance their knowledge and technical design skills. Overall, the content of this book will enable readers to have a better understanding of the theory through real-world engineering application examples.

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FABS and LABS

MPG: Connecting & Protecting People®




With the slogan "Connecting & Protecting People®," Microwave Products Group (MPG) positions itself as one of the most trusted suppliers of electromagnetic spectrum purification, interference mitigation and monitoring solutions in RF and microwave applications. This vision reflects a commitment to providing reliable products and solutions to critical applications where safeguarding users depending on communications is of the utmost importance. Comprised of seven brands, beginning with K&L Microwave and Dow-Key Microwave® as the foundation, MPG was established within Dover Corporation's Engineered Products segment in 2005. Since then, MPG has expanded its capabilities by acquiring Pole/Zero®, BSC Filters, Espy and most recently, Criteria Labs, along with forming the MPG Solutions® brand.

The need for more highly integrated solutions is increasing as technologies and threats evolve. Pole/Zero supports mission-critical communications systems with tunable RF filters and cosite interference mitigation subsystems. BSC Filters augments the advanced filter capabilities that K&L Microwave provides. Espy's RF artificial intelligence/machine learning capabilities add to the signal intelligence/spectrum operations solutions as the demand for RF detection and spectrum analysis grows with the increased sophistication of radio communications. Criteria Labs brings comprehensive services to MPG's portfolio, including up-screening to Hi-Rel Space requirements, handling bare die, and providing advanced packaging solutions. Additionally, they deliver RF device and microelectronic engineering solutions tailored for high-reliability applications, which will enhance MPG's ability to meet stringent SWaP requirements in cutting-edge systems. To leverage opportunities, MPG Solutions® was created to integrate collaboration and blend the capabilities, products and technologies under the MPG brand banner.

Offering integrated solutions requires a heritage of performance and manufacturing reliability for the functional blocks. Most RF and microwave systems will include filtering on the transmit/receive signals, making filter capabilities critical. As system frequency and the number of channels increase, filters become standard building blocks for multiplexers addressing multiple frequency bands.

The breadth of MPG's portfolio reaches across four product lines: Filters, Switches, Spectrum Operations and Solutions, using several different technologies in a variety of configurations. MPG's latest advanced capabilities and innovations include HERCULES™, a 10 million cycle, DC to 27 GHz SPDT switch under the Dow-Key label, 1 to 2 GHz, 1 W stacked filter banks and miniaturized high performance fixed filters. These new capabilities target defense, electronic warfare, radar, communications, satcom, telecom, SIGINT, aerospace, space, automated test equipment, navigation/GPS and data link applications.

What started as separate and independent garage shop dreams has become one of the industry's most recognizable RF and microwave providers. Housing several of the industry's most recognizable names, MPG is backed by the strength and innovation of Dover Corporation while continuing to be a trusted leader. It helps safeguard the end operators and users who depend on its products and solutions when it matters most.

Dover is a diversified global manufacturer and solutions provider with over 25,000 employees and over $8 billion in annual revenue. They deliver equipment, components and services through five operating segments, each containing multiple brands.

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